Empir Econ (2009) 37:1–23
DOI 10.1007/s00181-008-0220-3

ORIGINAL PAPER

Addiction and interaction between alcohol and tobacco consumption

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Received: 15 May 2007 / Accepted: 15 February 2008 / Published online: 15 July 2008

Abstract This paper adopts a multi-commodity habit formation model to study whether unhealthy behaviors are related, i.e. whether there are contemporaneous and inter-temporal complementarities between alcohol and tobacco consumptions in Italy. To this aim time series data of per-capita expenditures and prices during the period 1960 to 2002 are used. Own price elasticities are negative and tobacco appears to be more responsive than alcohol demand, although both responses are less than unity. Cross price elasticities are also negative and asymmetric thus suggesting complementarity. A "double dividend" could then be exploited, because public policy needs to tackle the consumption of only one good to control the demand of both. These results show that the optimal strategy for maximizing public revenues would be to raise alcohol taxation more than tobacco taxation. Finally, past consumption of one addictive good does not significantly reinforce current consumption of the other.

Keywords Multiple addictions · Sin goods · GMM estimator

We thank participants to the Annual Conference of the European Society for Population Economics, Verona June 2006; the 61st European Meeting of the Econometric Society, Vienna August 2006, and participants of the conference "Individual and Collective Choices in Health Protection", Genoa November 2005 for helpful comments. We would also like to thank, without implicating, Pier Luigi Rizzi and two anonymous referees for helpful comments. Financial support from the University of Siena, PAR grant (Atheneum Research Grant), is gratefully acknowledged.

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JEL Classification D12 · C32

1 Introduction

Since 1992, the World Health Organization (WHO) has advocated a combined approach to reduce harm resulting from the use of alcohol, tobacco and illegal drugs. To this aim, the European Parliament has identified the main initiatives to be taken within the European Union (EU) to modify individual behaviors related to harmful consumptions. In Italy alcohol and tobacco demands have followed negative trends since 1985. However, a further reduction of both is required as a measure to alleviate the public health care costs implied by their adverse consequences and negative externalities, such as effects on crime, on injuries caused in motor vehicle accidents and on labor market performance. There are a large number of studies investigating the determinants of alcohol and tobacco demand separately, but only a few have dealt with their interaction explicitly recognizing their addictive nature (see for instance Goel and Morey 1995; Decker and Schwartz 2000; Bask and Melkersson 2004; Picone et al. 2004; Fanelli and Mazzocchi 2004). Moreover, except for Bask and Melkersson and Fanelli and Mazzocchi, empirical papers are usually not based on any formal theoretical framework.

When modeling addictive behaviors, one of the most popular frameworks is the rational addiction (RA) model proposed by Becker and Murphy (1988). The two key elements in their analysis are the interdependency of past, current and future consumption, which characterizes addictive goods, and the assumption of individual rationality, that is, of far-sighted consumers who can foresee the consequences of their current actions.

The purpose of this paper is to test an extension of the rational addiction model that includes two addictive goods: alcohol and tobacco. There are two main reasons for doing this: the first is to investigate their interaction. Public policies, in many countries, have focused on cigarettes and liquor as prime targets for excise taxation for at least two reasons: consumption reduction and revenue generation. Information on the way these "sin goods"[1] are related may allow a better coordination of such public policies. If they are complements, for instance, we could obtain a reduction in both consumptions by raising just one price. On the other hand, if they are substitutes, measures aimed at reducing one of them could produce undesired effects. Stated differently, it may not be sufficient to consider the use of addictive substances separately to design proper policy guidance, such as the optimal level of taxation, the effects of different forms of regulation and the impacts of legalization (Palacios-Huerta 2003, p. 18).

The second is to study whether there is an inter-temporal cross-reinforcement, i.e. whether past consumption of one of them affects current consumption of the other. This inter-temporal complementarity could be interpreted as evidence of a *quasi* gateway

[1] There is now a rather extensive literature focusing on "sin goods", defined as goods that are enjoyable to consume, but that create negative health consequences in the future. Besides O'Donoghue and Rabin (2006), additional recent contributions in this field are: Gruber and Köszegi (2001, 2004) and Gruber and Mullainathan (2005).

effect.[2] There now exists a body of empirical research (Kandel 1975; Pacula 1997, 1998; Kenkel et al. 2001) investigating the so called "gateway hypothesis": past consumption of alcohol or cigarettes (legal drugs) could reinforce current use of illicit addictive substances. The same effect can be thought to apply between alcohol and tobacco. An implication of the gateway hypothesis is that the conventional estimates of optimal taxation on alcohol or cigarettes may be biased downwards, because they ignore the inter-temporal cross-reinforcement between the two. Another implication is that if alcohol, say, is a gate to tobacco, effective measures against the former could mitigate initiation of the latter. If there is causal sequencing in the use of these two commodities, then public policy may be effective at reducing the demand of one of the two by raising the marginal cost of the initiation drug.

Our estimates refer to multi-commodity addiction with a non-common habit stock and are based on time series of alcohol and tobacco consumption in Italy from 1960 to 2002.

The remainder of the paper is structured as follows: Sect. 2 briefly reviews the existing literature on the relationship between alcohol and tobacco consumption; Sect. 3 explains the rationale for a common *versus* non-common habit stock in modeling the demand functions; in Sect. 4 we present the theoretical model; the empirical strategy and the estimation results are described in Sects. 5 and 6; conclusions are presented in Sect. 7.

2 Previous studies

There is an extensive literature investigating the demand for alcohol and cigarettes separately. More realistically these behaviors are jointly determined, but few empirical works have analyzed these coaddiction models. Jimenez and Labeaga (1994), Dee (1999) and Decker and Schwartz (2000) examine contemporaneous relationships, whereas contemporaneous and inter-temporal inter-dependences are studied by Jones (1989), Goel and Morey (1995), Bask and Melkersson (2004), Picone et al. (2004), Fanelli and Mazzocchi (2004), Jimenez-Martin et al. (2005) and Gohlmann and Tauchmann (2006). Moreover, most of these empirical papers are usually not based on any formal theoretical framework even though multiple habits and addictions seem to be the rule rather than the exception[3] and the relevance of the issue has been stressed in the literature (Palacios-Huerta 2003, p. 4).

[2] A true gateway effect occurs when consumption of one substance increases the subsequent likelihood of *initiation* of other substances by increasing their marginal utility of consumption. Let us consider alcohol and tobacco and suppose we want to test whether tobacco is a gate to alcohol. An individual will initiate consumption of alcohol if its marginal utility, evaluated at zero consumption, is greater than its marginal cost, i.e. its price. What makes, at zero consumption, the marginal utility of alcohol greater than its price is the existence of habit formation with respect to the gate good, i.e. past consumption of tobacco (see Pacula 1997, p. 522).

[3] The Italian Health Institute (Istituto Superiore di Sanità) reports that, over the last few years, the number of people treated for multiple addictions (poly-substance use) has steadily increased. See http://www.iss.it/ossfad/ for further details.

Jimenez and Labeaga (1994) estimate a static demand system using a cross-section of individual expenditures taken from the Spanish Family Expenditure Survey (SFES). The resulting elasticity of tobacco consumption with respect to alcohol price is, on average, −0.78, suggesting a rather strong complementarity.

Dee (1999) provides evidence of robust complementarity between drinking and smoking among teenagers using pooled cross-sections from the 1977–1992 Monitoring the Future (MTF) surveys of high school seniors. Complementarity is evaluated by exploiting the exogenous variation in the full prices of alcohol and tobacco generated by changes in cigarette taxes and state minimum legal drinking ages, but no elasticities are calculated.

Decker and Schwartz (2000) consider two separate static demand equations for alcohol and cigarettes which include, among others, the prices of both goods. They use individual level data from 45 states in the US from 1985 to 1993 taken from the Behavioral Risk Factor Surveillance System (BRFSS) and estimate a model which separates participation from consumption. Owing to their specification only impact elasticities are estimated. The overall cross-price elasticity of alcohol is +0.50, suggesting that the two addictive goods are substitutes, while that of cigarettes with respect to the price of alcohol is −0.14. This asymmetry, both in sign and in magnitude, is mainly due to differences in the price responsiveness of the participation decisions.[4]

Jones (1989) estimates budget share equations using an Almost Ideal Demand System (AIDS) which includes four categories of alcoholic beverages and tobacco, taking aggregate quarterly expenditures for the UK over the period 1964–1983. He finds tobacco to be a complement to all four categories of alcoholic drinks. The same data are used by Fanelli and Mazzocchi (2004) who, in addition, develop a dynamic version of AIDS which is consistent with the rational addiction theory and with the hypothesis of adjustment costs. A strong complementarity between alcohol and tobacco consumption is found in the data.

Goel and Morey (1995) use pooled data organized by year and state on US cigarette and liquor consumption for the period 1959–1982. The empirical specification includes habit persistence through lagged consumption of each good in both equations. They find evidence of substitutability, though cross-price effects vary from + 0.33 for liquor to +0.10 for cigarettes. This may be considered as potential evidence of differences in social norms regarding smoking and drinking. Namely, there may be some asymmetry in the number of people who smoke and drink liquor and those who only smoke or only drink liquor. The same idea is put forward in the paper by Picone et al. (2004), where increases in costs and smoking bans in the US are used to study the relationships between smoking and drinking through the first six waves of the Health and Retirement Survey (HRS). Their main findings can be summarized as follows: past consumption of cigarettes has a positive effect on current alcohol consumption;

[4] Decker and Schwartz distinguish between consumption and participation for both goods. The overall cross-price elasticity of alcohol, for instance, with respect to cigarettes is obtained by adding two components: the cross-price elasticity calculated for alcohol demand over all individuals (both drinkers and non-drinkers) and the cross-price elasticity calculated for alcohol demand among drinkers only. In the case of alcohol these two components have the same sign and add up to +0.50. In the case of cigarettes, on the other hand, the −0.19 cross-price elasticity of smoking participation contrasts with the +0.04 cross-price elasticity among smokers only, adding up to an overall elasticity of −0.14.

increasing the cost of smoking through the introduction of smoking bans reduces alcohol use; finally, higher cigarette prices increase alcohol consumption.

Bask and Melkersson (2004) model the demand for alcohol and cigarettes as two separate rational addiction equations and then as a simultaneous system. The dependence of current consumption on past consumption is modeled assuming a non-common habit stock, i.e. consumption is only a function of its own stock of past consumption and not of the joint stock of both goods. They use aggregate annual time series on sales volumes for the period 1955–1999 in Sweden. Both cross-price elasticities turn out to be negative, thus showing that alcohol and cigarettes are complements.

Finally, Gohlmann and Tauchmann (2006) propose a new approach for analyzing the interdependence in consumption of alcohol and tobacco using German survey data. Rather than relying on high quality price data, which may often not be available, they model both equations in terms of latent consumption which is assumed to depend on the latent quantity of the other good rather than the price. They find complementarity, although the result is statistically significant only for males. Table 1 summarizes the results from such previous studies.

3 Modeling the stock of alcohol and tobacco consumption

A growing body of medical evidence shows that alcohol and tobacco consumption are related (Decker and Schwartz 2000, p. 4), owing to a range of biological and psychological factors. Walton (1972), for instance, found that 97% of a sample of male alcoholics were smokers. Bobo et al. (1987) reported that practically the whole staff interviewed in an alcohol treatment facility estimated that 75 to 100% of their patients smoked. In general, it has been observed that individuals who declare currently using alcohol very often report current use of tobacco as well. More recently, Picone et al. (2004) stressed that the hypothesis according to which smoking and drinking behaviors are positively correlated is supported by a large epidemiological literature.

These stylized facts seem consistent with the conjecture that smoking and drinking reflect a "common addictive personality pattern". An interpretation for it is the so called "learning based explanation": smoking and drinking may serve as mutual cues in the sense that the use of one substance stimulates the consumption of the other. This may be due to situational factors or to pharmacological ones. While their contemporaneous relationship has been explored in the literature using different modeling approaches, the inter-temporal interaction, i.e. the hypothesis that their combined usage may also depend on past consumption of both, has yet to be taken into account. This is, however, quite important, because a positive effect of past consumption of one substance on current use of the other is necessary in order to have a so called "gateway effect": i.e. past consumption of a legal addictive substance may reinforce the current use of an illicit addictive drug[5] (Pacula 1997).

[5] In fact, we call this particular cross-reinforcement effect *quasi* gateway effect, because it suggests a reinforcement effect of one good on consumption of the other. As explained earlier in this paper, a true gateway effect arises when consumption of one substance increases the subsequent likelihood of initiation of the other substance by increasing its marginal utility of consumption.

Table 1 Findings on the interaction between alcohol and tobacco

Study	Data	Model	Dynamic specification	Contemporaneous interaction	
				$\varepsilon_{a,t}$	$\varepsilon_{t,a}$
Jones (1989)[1]	Quarterly aggregate time series	AID system	Habit formation	−0.46	−0.46
Jimenez and Labeaga (1994)	Cross-section, individual data	AID system	Static	–	−0.78
Goel and Morey (1995)	Pooled time series and cross-sections	Two separate linear equations	Habit formation	−0.33	+0.10
Dee (1999)	Pooled time series and cross-sections	Two separate linear equations	Static	–	–
Decker and Schwartz (2000)	Cross-section, individual data	Two separate linear equations	Static	+0.50	−0.14
Bask and Melkersson (2004)	Annual aggregate time series	Simultaneous linear equations	Rational addiction	+0.79	−0.31
Fanelli and Mazzocchi (2004)	Quarterly aggregate time series	Dynamic AIDS	Rational addiction	−0.50	+0.01
Picone et al. (2004)	Panel, individual data	Two separate linear equations	Habit formation	–	–
Gohlmann and Tauchmann (2006)	Cross-section, individual data	Two separate equations	Static	+0.5	+3.8

[1] The values of the cross-price elasticies are referred to spirits and tobacco. Symmetry is imposed in estimation

The empirical literature on the interaction between alcohol and tobacco has modeled the habit stock in two ways. A common habit stock is assumed when the following linear specification holds (Bask and Melkersson 2003): $H(t) = c(t-1) + s(t-1)$ (where c is cigarettes and s is Snus, a particular kind of smokeless tobacco). This formulation implies that past consumption of *any* of the two goods accumulates into a single stock and the two goods are perfect substitutes. This is, however, not a reasonable one for alcohol and tobacco.

A more general formulation is to assume that past consumption leads to the accumulation of two separate habit stocks. If each stock is equal to its own past consumption: $S_t = A_{t-1}$; $H_t = T_{t-1}$, where A_t is alcohol and T_t is tobacco. The justification for two separate habit stocks is that there are different social, psychological and physiological factors connected with each addictive good and one cannot freely substitute one addiction source for another. Although we feel that neither specification is satisfactory, in our case the second one is more viable and, in what follows, we use a non-common habit stock specification.

4 Theoretical framework

In the RA framework (Becker and Murphy 1988) the behaviour of an addict is characterized by reinforcement and tolerance. Tolerance means that the marginal utility of the stock of past consumption is negative; reinforcement, on the other hand, requires that an increase in past consumption raises the marginal utility of current consumption. An implication of reinforcement is that levels of consumption in adjacent time periods are complements. Moreover, consumers also take into account the future negative consequences of their behavior so that, for reinforcement to occur, the increase in the marginal utility of current consumption following an increase in past consumption must be greater than the reduction in the present value of future consumption due to the harmful consequences of addiction. Underlying the RA theory are several assumptions that have led to an extensive critical literature and to new classes of addiction models. In particular: (i) initiation in consumption is not explained: the individual consumes positive amounts of the addictive good; (ii) he/she can accurately predict future prices and other demand shifters; (iii) he/she is not only rational and forward looking, but also time consistent (O'Donoghue and Rabin 1999; Gruber and Köszegi 2001); he/she does not have self-control problems (Akerlof 1991; Elster and Skog 1999). The model fails to explain important aspects of addictive behavior, such as temptation (Gul and Pesendorfer 2007); projection biases (Loewenstein et al. 2003) and cue-triggered decision processes (Bernheim and Rangel 2004).

Nevertheless, the model is still very popular, because it leads to a simple linear specification with testable hypotheses.

Following Andersson et al. (2003) and Bask and Melkersson (2004), given two addictive goods, such as alcohol, A, and tobacco, T, the habit stock variables are:

$$\begin{aligned} S_t &= A_{t-1} + \delta T_{t-1} \\ H_t &= (1-\delta) T_{t-1} \end{aligned} \tag{1}$$

where $0 \leq \delta \leq 1$. When $\delta = 0$ we have non-common habit stocks, i.e. past consumption of each good leads to the accumulation of two different stocks, $\delta = 1$ is instead the case of joint habit stocks with perfect substitution between the two commodities.

The representative consumer's problem is to maximise the following function:

$$V = \max \sum_{t=1}^{T} \beta^{t-1} U\left(C_t, A_t, T_t, S_t, H_t, e_t\right) \tag{2}$$

where C_t is consumption at time t of a non-addictive good (used as numeraire), e_t reflects the impact of unmeasured demand shifters and β is the discount factor $1/(1+r)$, with r being the inter-temporal rate of time preference. The instantaneous utility function has the following properties: $U_A > 0$; $U_{AA} < 0$; $U_T > 0$; $U_{TT} < 0$; $U_C > 0$; $U_{CC} < 0$. Moreover, the standard properties of addiction—tolerance and reinforcement—are assumed to hold: $U_H < 0$; $U_{HH} < 0$; $U_S < 0$; $U_{SS} < 0$; $U_{AS} > 0$; $U_{TH} > 0$. Drinking and smoking are assumed to have no effect on the marginal utility derived from consuming the composite good C and vice versa: $U_{AC} = U_{TC} = U_{SC} = U_{HC} = 0$. Finally, the necessary condition for one good, say tobacco to facilitate the quitting of alcohol is that it affects the marginal utility of the latter negatively, i.e. $U_{AT} < 0$ and $U_{SH} < 0$. On the other hand, if smoking reinforces the craving for alcohol and vice versa $U_{AT} > 0$ and $U_{SH} > 0$. Thus, a necessary condition for tobacco to be a gate to alcohol is $U_{SH} > 0$ and for alcohol to be a gate to tobacco is $U_{HS} > 0$.

The inter-temporal budget constraint for the representative consumer is:

$$\sum_{t=1}^{T} \beta^{t-1} \left(C_t + p_{A_t} A_t + p_{T_t} T_t\right) = W \tag{3}$$

where W is the present value of wealth.

When the instantaneous utility function is quadratic and the inter-temporal rate of time preference is equal to the market interest rate, solving equation (2) generates the following structural equations:

$$\begin{aligned} A_t = \beta_{A0} + \beta_{A1} A_{t-1} + \beta_{A2} A_{t+1} + \beta_{A3} T_{t-1} + \beta_{A4} T_t + \beta_{A5} T_{t+1} \\ + \beta_{A6} p_{A_t} + \beta_{A7} e_t + \beta_{A8} e_{t+1} + \varepsilon_{At} \end{aligned} \tag{4}$$

$$\begin{aligned} T_t = \beta_{T0} + \beta_{T1} T_{t-1} + \beta_{T2} T_{t+1} + \beta_{T3} A_{t-1} + \beta_{T4} A_t + \beta_{T5} A_{t+1} \\ + \beta_{T6} p_{T_t} + \beta_{T7} e_t + \beta_{T8} e_{t+1} + \varepsilon_{Tt} \end{aligned} \tag{5}$$

where β_{i0}, β_{i1}, $\beta_{i2} > 0$, $\beta_{i6} < 0$ and $\beta_{i1} = (1+r)\beta_{i2}$ with $i = A, T$; that is: current consumption is positively related to past and future consumption and negatively related to own current price. Testing these parameter restrictions has in the literature been used as a validation of the rational addiction model. The signs of the remaining parameters depend on data. One implication of the coaddiction model and the gateway effect is that past cigarette consumption should reinforce current consumption of alcohol and conversely $\beta_{i3} > 0 (i = A, T)$. When a linear common habit stock is assumed ($\delta = 1$), there is an additional restriction imposed: $\beta_{i1} = \beta_{i3} (i = A, T)$, i.e. lagged consumptions have the same effect regardless of the equation. Finally, there is a cross equation constraint due to r which implies that $\frac{\beta_{A1}}{\beta_{A2}} = \frac{\beta_{T1}}{\beta_{T2}}$. The imposition of such a constraint requires a simultaneous estimation of the two behavioral equations and makes the two structural equations non-linear in the parameters. In estimation, we augment the basic specification with some exogenous variables representing the demand shifters subsumed in Eq. (2), i.e. disposable income as well as dichotomous variables which take into account the impact of government control measures and regulatory changes. For these structural equations long-run own price and income elasticities of demand, calculated at the sample mean, are given by:

$$\begin{aligned}\varepsilon_{AA} &= \frac{dA}{dp_A}\frac{\overline{p_A}}{\overline{A}} \\ &= \frac{(1-\beta_{T1}-\beta_{T2})\beta_{A6}}{(1-\beta_{A1}-\beta_{A2})(1-\beta_{T1}-\beta_{T2})-(\beta_{A3}+\beta_{A4}+\beta_{A5})(\beta_{T3}+\beta_{T4}+\beta_{T5})}\frac{\overline{p_A}}{\overline{A}} \quad (6)\\ \varepsilon_{TT} &= \frac{dT}{dp_T}\frac{\overline{p_T}}{\overline{T}} \\ &= \frac{(1-\beta_{A1}-\beta_{A2})\beta_{T6}}{(1-\beta_{A1}-\beta_{A2})(1-\beta_{T1}-\beta_{T2})-(\beta_{A3}+\beta_{A4}+\beta_{A5})(\beta_{T3}+\beta_{T4}+\beta_{T5})}\frac{\overline{p_T}}{\overline{T}}\end{aligned}$$

If the statistical model includes a proxy of disposable income, Y_t, we can also estimate the expenditure elasticities of demand:[6]

$$\begin{aligned}\varepsilon_{AY} &= \frac{dA}{dY}\frac{\overline{Y}}{\overline{A}} \\ &= \frac{(1-\beta_{T1}-\beta_{T2})\beta_{AY}+(\beta_{A3}+\beta_{A4}+\beta_{A5})\beta_{TY}}{(1-\beta_{A1}-\beta_{A2})(1-\beta_{T1}-\beta_{T2})-(\beta_{A3}+\beta_{A4}+\beta_{A5})(\beta_{T3}+\beta_{T4}+\beta_{T5})}\frac{\overline{Y}}{\overline{A}} \quad (7)\\ \varepsilon_{TY} &= \frac{dT}{dY}\frac{\overline{Y}}{\overline{T}} \\ &= \frac{(1-\beta_{A1}-\beta_{A2})\beta_{TY}+(\beta_{T3}+\beta_{T5}+\beta_{T4})\beta_{AY}}{(1-\beta_{A1}-\beta_{A2})(1-\beta_{T1}-\beta_{T2})-(\beta_{A3}+\beta_{A4}+\beta_{A5})(\beta_{T3}+\beta_{T4}+\beta_{T5})}\frac{\overline{Y}}{\overline{T}}\end{aligned}$$

The inter-temporal rate of time preference, r, can be derived from the structural parameters.

5 Data and empirical strategy

5.1 Alcohol and tobacco consumption in italy

Alcohol consumption has followed a decreasing trend since the early 1980s: aggregate per capita consumption of beer, wine and spirits decreased, between 1970 and 2001,

[6] $\beta_{iY} (i = A, T)$ is the parameter of expenditure (Y) when this variable is included among the regressors.

by 51.25%. In the year 2000 average per capita consumption of pure alcohol in Italy was about 7.5 l (Ministero della Salute 2003, p. 12), but according to the WHO for the European Region, the target of 6 l per capita per year should be reached by the year 2015.

The Italian Institute of Health (Scafato et al. 2004, p. 4) reports that the per capita decrease in alcohol consumption from 1981 to 2000 results from a 40.8% decrease in wine consumption, a 65.7% decrease in spirits consumption and a 57% increase in beer consumption.

At the same time, however, the following changes have occurred: (a) an increase in the number of female consumers; (b) an increase in the number of young consumers; (c) an increase in the number of people (and the increase is higher for females and the young) consuming alcohol outside the main meals. This may suggest a change in habits. Italy is a producer country where, traditionally, wine is consumed, on average, in moderate quantities and by all members of the household, to accompany meals. This changing pattern may suggest a transition from a Mediterranean model to a Northern European one characterized by binge drinking and the use of alcohol as a bridge to ease personal relationships and reduce social discomfort or as a means of female emancipation and cultural homologation. If this is the case, then the steady decrease in alcohol consumption could hide a rather different picture such as an increase in the number of people actually at risk, especially among the most vulnerable groups of society.

As to smoking, Italy is one of the industrialized countries with a very high percentage of daily smokers (OECD 2002). The Italian National Statistical Office (ISTAT 2002b) estimates that in the year 2000 the number of smokers in Italy was 12.330.000, about 24.9% of the population older than 14, and the highest share is registered in North-West and Central Italy (26.2%), followed by the Islands (24.5%), the South (23.8%) and the North-East (23.5%).

Household expenditure on tobacco, at constant 1995 prices, grew between 1982 and 1986 and decreased steadily between 1987 and 1995 (ISTAT 2002a). This decrease is likely to be due, at least partly, to the rapid increase in cigarette smuggling, estimated to have grown by about 800% between 1985 and 1993 and to account for about 13% of all cigarettes consumed.

5.2 Data

We use aggregate time series of alcoholic beverage and tobacco product expenditures (both in Billions of Euros) in Italy for the period 1960–2002 taken from ISTAT National Accounts. Per capita values are obtained by dividing aggregate expenditures of both commodities by population older than 14 (calculated in the middle of each year). Our dependent variables are per capita alcohol and tobacco consumption calculated as the ratio between per capita alcohol and tobacco expenditure at 1995 prices ($q_t p_{95}$) and per capita alcohol and tobacco expenditure in 1995 ($q_{95} p_{95}$). The real price is obtained by dividing the implicit deflator, calculated as the ratio between current expenditure and expenditure at 1995 prices, by the consumer price index (1995 = 1). The price of tobacco is set by the State Monopoly. It is thus a strictly exogenous price which can be used as a valid instrument in our estimation. Summary statistics and details of

Table 2 Variables definitions and summary statistics

Variable	Definition	Mean	SD
$CT_t = (TBQ_t/N14)100$	Per capita (age > 14) tobacco expenditure (1995 = 1)	0.968	0.256
$CA_t = (ALQ_t/N14)100$	Per capita (age > 14) alcohol expenditure (1995 = 1)	1.351	0.241
$PT_t = (TBV_t/TBQ_t)/CPI_t$	Real price of tobacco products (1995 = 1)	0.974	0.263
$PA_t = (ALV_t/ALQ_t)/CPI_t$	Real price of alcohol products (1995 = 1)	1.139	0.161
$Y_t = Y95_t/N14$	Real per capita expenditure per year (1995 = 1)	0.783	0.234
TBQ_t	Aggregate expenditure on tobacco products at constant 1995 prices (millions euro)	8252.438	2550.896
TBV_t	Aggregate expenditure on tobacco products at current prices (millions euro)	4198.528	4176.161
ALQ_t	Aggregate expenditure on alcoholic beverages, 1995 prices (millions Euro)	5417.678	837.055
ALV_t	Aggregate expenditure on alcoholic beverages, current prices (millions Euro)	2577.546	1882.417
CPI_t	Consumer Price Index (1995 = 1)	0.481	0.406
$Y95_t$	Households' final consumption expenditure per year, 1995 prices (millions Euro)	391066.923	145025.636
$N14$	Population > 14 (in millions units) calculated in the middle of each year	44.050	3.751

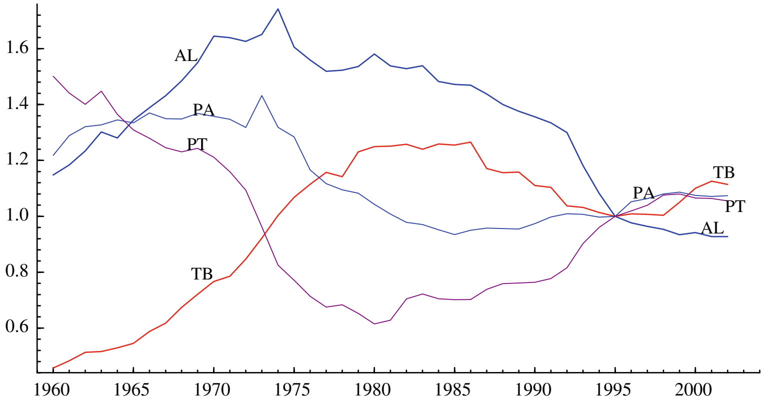

Fig. 1 Index (1995 = 1) of per capita (age > 14) alcohol (AL) and tobacco (TB) consumption and real alcohol (PA) and tobacco (PT) price

the data used are presented in Table 2. Figure 1 shows the indices (1995 = 1) of per capita consumption of both goods and their real prices.

The advantage of using this data set is that, in contrast to many studies on this topic, past and future consumptions used are actual consumption levels and not constructed from the data. Moreover a long and consistent time series is more appropriate to model dynamic behavior such as that depicted in this paper (Bentzen et al. 1999) as it also allows, given the time horizon, to take into account the impact of Government regulatory changes or of the disclosure of new information on the side effects of alcohol of tobacco consumption by way of dummy variables (Escario and Molina 2001; Fenn et al. 2001).

Of course, there are also disadvantages in using aggregate data. First, the total expenditure on alcohol aggregates the expenditure of all Italians. These data may be dominated by the behavior of light and moderate drinkers and a decrease in aggregate consumption of alcohol could hide a rather complicated picture. The fact that the information at hand does not allow participation to be separated from consumption seems to increase this problem. A second problem lies in the level of detail of the commodity structure in the National Accounts; beer, wine and spirits are mixed in this type of data[7] so that a decrease in the overall aggregate, for instance, could be the result of contrasting trends. In fact addictive behavior could be better captured by data on spirits consumption only, because the distribution of spirits is typically more bimodal than that of other alcoholic beverages.[8] Finally, Auld and Grootendorst (2004) dispute that aggregate data are appropriate to deal with rational addiction models under specific conditions. We do, however, test against the stated conditions before estimation.

A number of diagnostic tests have been performed in order to avoid biases towards finding rational addiction (Table 3). First we have tested for alcohol price exogeneity performing a Hausman–Wu (HW) test.[9] This is a Likelihood Ratio (LR) test distributed as a χ^2 with 2 degrees of freedom. We accept the null hypothesis of alcohol price exogeneity.

We have also checked for stationarity of the series using an Augmented Dickey-Fuller (ADF) test. First, we have assumed that the data generating process (DGP) is AR(1) with a constant added (random walk with drift) and we have considered the following as a DGP for all the series: $\Delta z_t = az_{t-1} + b_1 \Delta z_{t-1} + b_p \Delta z_{t-p} + c + u_t$ where z is the variable under consideration, u_t is white noise, c is the intercept and $t = p + 2, \ldots, n$. The null hypothesis is that z_t is a unit root process, i.e. $a = 0$, and the test statistic is the t-value of a.

The problem with the ADF is that it is an asymptotic test that may be biased when applied to small samples. For this reason we have also simulated the actual p-value of the ADF test using bootstrapping. Both tests reveal the presence of a unit root for all the variables but P_T.[10] Results of unit root tests are shown in Table 3.[11] All estimations

[7] This second problem may also apply to micro data.

[8] Bimodal distribution is an outcome of the Becker and Murphy theory of addiction and it implies that there are few consumers of small or moderate quantities of addictive goods and that a majority either do not consume at all or consume large quantities of the highly addictive good.

[9] The HW test compares the original demand equation (estimated with OLS) with the unrestricted model that includes, among the explanatory variables, the residuals of an auxiliary regression. In the auxiliary regression the real price is the dependent variable whereas the explanatory variables include all the exogenous variables in the model plus the instruments.

[10] P_T is a stationary series when the ADF is applied. However a Phillips-Perron test carried out on the same series accepts the null of a unit root in the DGP.

[11] Unit root tests have been performed using EasyReg by Prof. Bierens.

Table 3 Diagnostic tests on time series (p-values in parentheses)

	1. Price exogeneity	2. Unit Root				3. Autocorrelation (differenced model)	
	P_A	P_T	P_A	C_T	C_A	DC_T	DC_A
LR(HW)	0.137						
	(0.934)						
ADF		−3.473	−0.202	−0.193	−0.647		
		(0.010)	(0.240)	(0.080)	(0.860)		
Bootstrapping		(0.054)	(0.680)	(0.174)	(0.734)		
Durbin's h Alt.						−2.251	−2.327
						(0.024)	(0.020)
Breusch-Godfrey						5.065	5.416
						(0.024)	(0.020)

have therefore been carried out with the model in first differences. Finally, we have tested for autocorrelation of the differenced variables using two different tests: a Durbin's h alternative and a Breusch/Godfrey LM test. For all autocorrelation tests we reject the null of no autocorrelation[12] and accept the hypothesis of serial correlation of order 2 in the error terms of the differenced model.

5.3 Estimating the rational coaddiction model

Our empirical specification is based on Eq. (4) augmented with exogenous determinants to capture gradual as well as sudden changes in trends of both consumptions. To eliminate the problems of spurious regression all variables are transformed in first-differences:[13]

$$\begin{aligned}\Delta A_t = \beta_{A0} + \beta_{A1}\Delta A_{t-1} + \beta_{A2}\Delta A_{t+1} + \beta_{A3}\Delta T_{t-1} + \beta_{A4}\Delta T_t \\ +\beta_{A5}\Delta T_{t+1} + \beta_{A6}\Delta p_{A_t} + \beta_{AY}\Delta Y_t + \Delta\eta_{At}\end{aligned} \quad (8)$$

where $t = 3, \ldots, T-1$ and η_{At} is the error term; Y_t is real per capita expenditure used as a proxy of disposable income. The list of dummy variables has been dropped to save space.

There are two problems that prevent the linear expression (8) from being estimated by ordinary least squares. First, since we cannot claim to have exhausted the list of possible (social, institutional, regulatory) influences with one proxy, there is an omitted variable bias due to unaccounted demand shifters that may also be serially correlated

[12] The Durbin's h alternative follows a normal distribution and it is a valid test for autocorrelation when more than one lagged dependent variable is included in the regressors.

The Breusch–Godfrey LM test for autocorrelation of order x follows a χ^2 distribution with $DF = x + k - 1$, where x is the number of lags and k is the number of identified coefficients in the model, including the intercept.

[13] Without loss of generality, we sketch estimation of Eq. (4). The same methods are used for the other behavioral Eq. (5).

(Becker et al. 1991, 1994; Baltagi and Griffin 2001). If unobserved effects (e_t and e_{t+1}) are positively correlated, this will give rise to past and future consumption having a positive effect on current consumption even in the absence of addictive behavior. Due to concerns about serial correlation on the disturbances, researchers have avoided using lagged values of consumption as instruments. Second, there is measurement error when we use actual values of future consumption, which do not fully anticipate planned future consumptions of both addictive goods, leading to an error-in-variable model (Picone 2005).[14]

In an attempt to correct for such endogeneity bias the strategy is to find a set of instruments Z_{At} that are uncorrelated with $\Delta\eta_{At}$ and correlated with the regressors and apply a generalized method of moments [15] (GMM).

The question is what are the relevant instruments in this instance. If we assume that actual values of consumption in period $t+1$ are error ridden variables, it can be shown that the disturbance in Eq. (4) is given by:

$$\eta_{At} = \beta_{A7}e_{At} + \beta_{A8}e_{At+1} + \beta_{A2}m_{At+1} + \beta_{A5}m_{Tt+1} + \varepsilon_{AT} \tag{9}$$

where e_A is a comprehensive demand shifter, m_A and m_T are measurement errors in the planned future consumptions of alcohol and tobacco, respectively, and $\beta's$ are structural parameters. By definition, e_{At+1} and A_{t+1} are correlated; in addition, we expect measurement errors to be zero mean, uncorrelated with planned future consumptions as well as with each other, and correlated with actual values of addictive goods in period $t+1$, which in turn implies that both measured future consumptions become endogenous in Eq. (4):

$$E\left(A_{t+1}\eta_{At}\right) = \beta_{A8}E\left(A_{t+1}e_{At+1}\right) - \beta_{A2}\sigma^2_{m_A} \tag{10}$$

and

$$E\left(T_{t+1}\varepsilon_{At}\right) = -\beta_{A5}\sigma^2_{m_T} \tag{11}$$

Whether or not A_{t-1} is predetermined depends upon the potential serial correlation of the disturbance η_{At} and the first difference transformation (8) used in estimation, which makes the error term $\Delta\eta_{At}$ follow a MA(2) process. After some diagnostic tests on the time series properties of the explanatory variables (see Table 3), we confidently

[14] Among the assumption of the Becker and Murphy (1988) model are perfect foresight on prices and on other demand shifters (such as Y and e). Thus A_{t+1} and T_{t+1} in Eq. (8) should be interpreted as planned future consumption at time $t+1$ using the information available at time t. If at time $t+1$ prices or the other demand shifters are different from their expected value at time t, then the decision maker will revise his consumption at $t+1$. Since actual and not planned consumption is observed at time $t+1$ there is a measurement error (Picone 2005, p. 12).

[15] A comprehensive discussion on the generalized method of moments can be found in Davidson and MacKinnon (1993, Chap. 17), Hall (2005), Hansen (2005, Chap. 5), Hayashi (2000, Chaps. 3 and 4), and Matyàs (1999), to cite a few.

assume that prices of alcohol and tobacco and the expenditure variable are strictly exogenous and use the following mixed matrix of instruments both in levels and in first differences:

$$Z = [1, D, \Delta Y, Y, \Delta p_A, p_A, \Delta p_T, p_T] \tag{12}$$

where 1 is a vector of ones, D is the set of dummy variables when present and the remaining terms represent sub-matrices containing two lags and two leads of each instrument.

6 Results

Table 4 reports GMM estimates using the matrix of instruments (12). For each type of addictive good five different sets of estimates are reported, which can be seen as a means of checking the sensitivity of the estimates to the maintained assumptions, conditional upon the instrument set.

The rational coaddiction model is estimated both as two separate equations and as system, allowing for the possibility of joint determination of alcohol and tobacco consumption unaccounted for by the basic specification (i.e. beyond cross-price and quantity effects). The simultaneous estimation proves useful in that we can impose the cross-equation restriction implied by theory, namely that the structural parameters for past and future consumption of the two sin goods should differ by the same discount factor. Whether the degree of forward-looking behavior of the representative consumer is the same when making decisions about drinking and smoking is of some concern. Failure to account for this unobserved characteristic may bias the parameter estimates. While heterogeneity among individuals has been explored by the literature in a proper setting (Arcidiacono et al. 2005), apparently the existence of homogeneity between goods has not been investigated, yet.

GMM estimates of the two separate equations (first column in Table 4) show that accounting for addictive behavior by past consumption gives highly significant and positive estimates and the contemporaneous own-price is negative and significant for the pair of goods. Apparently both equations are consistent with the rational addiction conjecture since future consumption variables too enter with positive signs and are statistically significant. Moreover, the (unconstrained) estimates of past consumption parameters are greater than future consumption parameters implying that the derived inter-temporal rate of time preference is positive in both equations. Looking at the inter-temporal cross-reinforcement of addiction, evidence of the quasi-gateway effect is mixed: i.e., alcohol is a gate to tobacco, whereas the effect of lagged consumption of tobacco on alcohol is not significant. Finally, the estimates of the income parameter are both positive but differ markedly and only the coefficient of the alcohol equation is statistically significant.

An additional set of results refers to the structural demand equations with the linear common habit stock (CHS) (second column in Table 4). Pacula (1998, p. 9) stresses that in order to test for a gateway effect one should have a unique stock representing

Table 4 Alcohol and tobacco consumption (p-values in parentheses)

Alcohol	Structural model				Semi-reduced model
	Independent equations		System		
	Non-common stock	Common stock	Heterogenous	Homogenous	
Constant	−0.031(0.000)	−0.030(0.000)	−0.026(0.013)	−0.030(0.014)	−0.031(0.000)
ΔA_{t-1}	0.271(0.002)	0.222(0.000)	0.361(0.026)	0.330(0.052)	0.226(0.006)
ΔA_{t+1}	0.264(0.052)	0.174(0.218)	0.324(0.069)	0.302(0.024)	0.144(0.323)
ΔT_{t-1}	0.083(0.515)	–	0.358(0.287)	0.394(0.157)	0.045(0.764)
ΔT_t	−0.194(0.250)	−0.134(0.457)	−0.960(0.000)	−0.904(0.001)	–
ΔT_{t+1}	0.315(0.069)	0.276(0.088)	0.698(0.037)	0.660(0.018)	0.295(0.052)
Δp_{A_t}	−0.130(0.022)	−0.021(0.785)	−0.109(0.533)	−0.070(0.695)	−0.028(0.733)
Δp_{T_t}	–	–	–	–	0.014(0.870)
ΔY_t	1.227(0.000)	1.184(0.000)	1.126(0.022)	1.233(0.013)	1.220(0.000)
D_{91}	–	−0.000(0.185)		−0.000(0.994)	−0.011(0.143)
Wald test (CHS)		0.275(0.600)			
R^2	0.407	0.427			0.434
n	37	37	38	38	38

Tobacco	Independent equations		System		Independent equations
	Non-common stock	Common stock	Heterogenous	Homogenous	
Constant	0.011(0.117)	0.009(0.161)	–	−0.013(0.126)	0.004(0.346)
ΔT_{t-1}	0.236(0.009)	0.106(0.003)	0.417(0.052)	0.475(0.002)	0.164(0.017)
ΔT_{t+1}	0.227(0.034)	0.314(0.002)	0.338(0.126)	0.435(0.013)	0.213(0.076)
ΔA_{t-1}	0.092(0.068)	–	0.235(0.041)	0.222(0.068)	0.107(0.008)
ΔA_t	−0.055(0.281)	−0.083(0.054)	−0.467(0.000)	−0.481(0.000)	–
ΔA_{t+1}	−0.015(0.747)	−0.056(0.095)	0.123(0.420)	0.172(0.085)	0.251(0.000)
Δp_{T_t}	−0.249(0.000)	−0.264(0.000)	−0.085(0.417)	−0.133(0.192)	−0.337(0.000)
Δp_{A_t}	–	–	–	–	−0.270(0.000)
ΔY_t	0.064(0.768)	0.229(0.150)	0.488(0.145)	0.521(0.136)	−0.155(0.463)
D_{80}	−0.016(0.005)	−0.018(0.002)	−0.016(0.106)	–	–
D_{91}	0.015(0.022)	0.013(0.042)	0.010(0.291)	0.009(0.418)	0.027(0.000)
Wald Test (CHS)/(r)		0.264(0.607)		0.839(0.359)	
R^2	0.462	0.450	0.234	0.254	0.552
n	37	37	38	38	38

the cumulative influence of past consumption of *both* substances. When a linear CHS is assumed, the following parameter restrictions are predicted by the RA theory:

$$\beta_{A1} = \beta_{A3} \tag{13}$$

$$\beta_{T1} = \beta_{T3} \tag{14}$$

In this case the lagged values of alcohol and tobacco have the same impact on current demand of each equation. Testing whether this restriction holds can be considered a test of the hypothesis of a linear CHS. We have performed a Wald test (Davidson and MacKinnon 2004) on each of the two equations. The null hypothesis is given by the restricted model and the test statistic follows a χ^2 distribution with 1 DF. For the alcohol equation, the test statistic with 1 DF is 0.275, whereas the χ^2 distribution value at the 90% of significance is 3.841. In the tobacco equation the test statistic is 0.264. For both equations we thus accept the null hypothesis of a linear CHS. However, specifying the common stock as a linear additive function implies: (i) that alcohol and tobacco are perfect substitutes in consumption; (ii) that, if the coefficients β_{i1} $(i = A, T)$ turn out to be positive and statistically significant, there is a symmetric gateway effect between the two goods, i.e. past consumption of alcohol and tobacco has an equal effect on current consumption of each good. Both implications are unreasonable when the goods involved are alcohol and tobacco[16] and a reasonable specification of the joint stock would require an in depth analysis of the relevant medical literature. While we find that this is an interesting topic to be explored in future research, in absence of a through understanding of such relationship, the current literature on alcohol and tobacco consumption has mainly relied on non-common stock specifications for empirical purposes.

Moving to the third column containing the joint estimation of the structural parameters without restriction on the discount rate imposed, we can see that p-values are smaller and mostly significant, so that allowing for the possibility that unspecified common factors influence the disturbance covariances from the two equations results in an efficiency gain. A marked similarity between parameters of the two goods is found, too, with few exceptions. One of them is the positive sign of the coefficient of lagged consumption of tobacco in the alcohol equation, which is still not significant, but in principle renders the hypothesis of a gateway effect in both directions numerically viable.

We have also tested for the hypothesis of a unique discount rate for the two demand equations (see discussion in Sect. 4). Results of the simultaneous estimation of the two demand functions with this additional restriction imposed are shown in the fourth column of Table 4. A Wald test for the hypothesis of unicity of r reveals that this is a valid hypothesis, as the test statistic, following a χ^2 distribution with 1 DF, is 0.839 with a p-value of 0.359. Discussion of the last column of results in Table 4 is postponed to Sect. 6.1.

Long-run elasticities and interest rates implied by the GMM estimation of the two separate equations are shown in Table 5. Own-price elasticities have the expected negative signs with tobacco demand twice as responsive as alcohol demand. As for expenditure elasticities, alcohol is a luxury while tobacco is a normal good, though the latter response is negligible and statistically not significant.

[16] Bask and Melkersson (2000) model the common stock as a linear additive function when tobacco and smuggling tobacco are the goods involved. In this case it makes sense to assume perfect substitution between the two goods, because they are the same good and only the institutional setting is different.

Table 5 Alcohol and tobacco elasticities (p-values in parentheses)

Elasticity	Structural model			Semi-reduced model
	Independent equations	System Heterogenous	System Homogenous	
ε_{AA}	−0.240(0.068)	−0.257(0.592)	−0.115(0.723)	−0.606(0.464)
ε_{TT}	−0.474(0.000)	−0.307(0.360)	−1.068(0.592)	−0.737(0.027)
ε_{AT}	–	–	–	−0.240(0.454)
ε_{TA}	–	–	–	−1.154(0.185)
ε_{AY}	1.590(0.000)	2.135(0.084)	2.386(0.153)	2.114(0.121)
ε_{TY}	0.188(0.507)	0.284(0.795)	1.515(0.762)	1.560(0.269)
Discount rate				
r_A	2.76%	11.54%	–	–
r_T	3.80%	23.58%	–	–
r	–	–	9.30%	–

The implied discount rates are obtained comparing the parameter estimates of own lagged and lead consumption, which measure the degree of reinforcement of addiction. They are all positive and take a plausible value.

As to cross-price elasticities of demand, the cross-price response of tobacco consumption to changes in the price of alcohol is much higher than the response of alcohol demand to tobacco price changes. This contrasts with previous findings where the cross-price elasticity of alcohol with respect to tobacco price is greater, in absolute value, than the cross-price elasticity of tobacco with respect to alcohol. Both elasticities are negative, implying that the two goods are complements,[17] but they are asymmetric in magnitude.[18]

The statistical significance of cross-price effects bears important implications for taxation and health policies as explained in the next section. This finding suggests that increases in the price of alcohol would be effective also in reducing tobacco consumption. It also seems consistent with the intuition by Goel and Morey (1995), who stress a presumed asymmetry in the proportion of people who drink and also smoke: drinkers seem to get more easily hooked on smoking behavior than smokers do on drinking behavior. Lastly, the income elasticity of alcohol consumption is greater than one implying that alcoholic beverages are luxuries. These results are consistent with

[17] Alcohol and tobacco turn out to be gross complements, since we estimate Marshallian cross-price elasticities. However, net complementarity is also verified through calculation of the Hicksian cross-price elasticites:
$\varepsilon^*_{AT} = \varepsilon_{AT} + \varepsilon_{AY}\omega_A$, where ω_A is the mean annual per capita budget share of alcohol. Hicksian cross-price elasticities thus calculated are −0.1796 for alcohol and −0.394 for tobacco, so that both commodities are net complements.

[18] Goel and Morey (1995, p. 456), who found a similar result, view this as potential evidence of differences in social norms regarding smoking and drinking, i.e. it may be that the intersection of smokers and liquor drinkers constitutes a much larger proportion in the population of alcohol consumers than it does in the population of smokers.

those found in other studies using aggregate data in the context of demand systems estimation (Duffy 1983, 2003; Fanelli and Mazzocchi 2004; Jones 1989) although we do not know of similar estimates for Italy. If the income elasticity of alcohol consumption is also growing across income classes, then alcohol taxation would have a progressive impact, contrary to the conventional wisdom considering taxation of "sin goods" as regressive.

6.1 Policy implications

Our findings elicit a number of interesting policy implications and guidance for the appropriate design of "sin taxes", i.e. for taxation of unhealthy items that people may consume too much of (O'Donoghue and Rabin 2006).

First, since alcohol and tobacco are complements, a reduction in the demand of both goods could be achieved by raising the price of just one of them. Such a reduction is a desirable policy outcome in order to alleviate the related public health care costs and negative externalities, as stated in the introduction. In this case public revenues from alcohol/tobacco taxation could be used to bear the social costs generated by the consumption of unhealthy goods.

The estimated asymmetry in cross-price responses coupled with the magnitude of own-price elasticities (of both goods) offers further appropriate policy guidance. More precisely it suggests that alcoholic beverages are the most suitable for price increases in order to maximize public revenues. Alcohol demand is more rigid than tobacco and, at the same time, the cross-price elasticity of tobacco with respect to alcohol price is higher than the cross-price elasticity of alcohol with respect to the price of tobacco. Therefore an increase in alcohol taxation, on one hand, could reduce alcohol demand by less than an equivalent increase in tobacco taxation would cause for tobacco demand. On the other hand, given the asymmetry in the values of cross-price elasticities, the complementary reduction in tobacco demand, caused by an increase in the price of alcohol would be higher than that in alcohol demand caused by an increase in the price of tobacco. Thus, the desired effect on the demand for both goods would be achieved, maximizing public revenues.

Such effects are illustrated in the following simulation exercise. We combine Eqs. (4) and (5) to obtain a semi-reduced system, estimated with all the variables in first differences as follows:

$$\begin{aligned}\Delta A_t &= \alpha_{A0} + \alpha_{A1}\Delta A_{t-1} + \alpha_{A2}\Delta A_{t+1} + \alpha_{A3}\Delta T_{t-1} + \alpha_{A4}\Delta T_{t+1} \\ &\quad + \alpha_{A5}\Delta p_{A_t} + \alpha_{A6}\Delta p_{T_t} + \alpha_{AY}\Delta Y_t \qquad (15)\\ \Delta T_t &= \alpha_{T0} + \alpha_{T1}\Delta T_{t-1} + \alpha_{T2}\Delta T_{t+1} + \alpha_{T3}\Delta A_{t-1} + \alpha_{T4}\Delta A_{t+1} \\ &\quad + \alpha_{T5}\Delta p_{T_t} + \alpha_{T6}\Delta p_{A_t} + \alpha_{TY}\Delta Y_t \qquad (16)\end{aligned}$$

where, the $\alpha's$ are non-linear combinations of the $\beta's$.[19] Here α_{i0}, $i = A, T$, is an intercept term and Y is real per capita final consumption expenditure used as a proxy of

[19] See Bask and Melkersson (2003) for explicit expressions for these parameters. As for the elasticities of the semi-reduced form they are available upon request.

disposable income. If the model is correctly specified one should have $\alpha_{A0} = \alpha_{T0} = 0$. However, we allow for a non-zero intercept in all estimations in order to avoid mis-specification bias in the other parameters. We have used the GMM estimates (see last column of results in Table 4) of Eqs. (15) and (16) to evaluate the effects, on consumption of both commodities, of a change in alcohol price only from the year 2003. In this simulation real prices are actual ones up until 2002, but we assume a 3% per year growth rate in the real price of alcohol over the period 2003–2016. The real price of tobacco and the proxy of disposable income are instead assumed to grow at their historical trends. To simulate the system beyond the estimation period (i.e. after 2002) we need to know A_{t+1} and T_{t+1}. They are obtained as fitted values of two auxiliary regressions whose explanatory variables are the instruments described in Eq. (12).

Equation (8) and the corresponding tobacco equation are then estimated from 2003 to 2020 using as prices those generated as described above. Given this exogenous information on A_{t+1}, T_{t+1}, p_{At}, p_{Tt} and Y_t, Eqs. (15) and (16) are dynamically simulated from 1962 to 2016. Results of this exercise are shown in Table 6 where the percent variation in consumption of both goods is reported following a 3% per year increase in alcohol price. Consumption of both commodities decreases as a consequence of complementarity. Therefore, raising only the price of alcohol seems to be enough to affect both demands.

Secondly, according to our findings, the inter-temporal cross-reinforcement is rather low, so that evidence of a *quasi* gateway effect between the two goods is weak. The implication is that, in calculating the optimal level of alcohol or tobacco taxation, only the contemporaneous interaction is relevant, so that neglecting inter-temporal cross-reinforcement does not result in downward biases in the estimated level of optimal taxation.

Thirdly, one of the advocated reasons for low taxation of alcohol or tobacco is its assumed regressivity. We find, however, an income elasticity of alcoholic beverages

Table 6 Variation (%) in Alcohol (DCA) and Tobacco (DCT) expenditure when Alcohol price grows at 3% per year

Year	DCA	DCT
2003	−0.140	−0.904
2004	−0.390	−1.152
2005	0.145	−1.008
2006	−1.398	−1.436
2007	−1.052	−1.380
2008	−1.087	−1.395
2009	−1.123	−1.412
2010	−1.161	−1.430
2011	−1.200	−1.449
2012	−1.240	−1.470
2013	−1.283	−1.492
2014	−1.327	−1.515
2015	−1.373	−1.540
2016	−1.421	−1.567

higher than one throughout the investigation period, suggesting that alcohol is a luxury. This is an interesting point which calls for further investigation. Should the income elasticity of demand be increasing across income classes, alcohol taxation would have a progressive (rather than regressive) impact, thus producing a positive distributional effect.

Finally, a further reason for advocating alcohol rather than tobacco price increases is grounded in the work of Viscusi (1992). If we exclude the role of second-hand smoke, smoking can be characterized as an individual risk taking activity, thus weakening the role for "paternalistic" approaches to public policy. Alcohol consumption, however, owing to its detrimental effect on traffic injuries and labor market performance can be more characterized as a social risk-taking activity, identifying a greater role for public intervention.

7 Conclusions

This paper investigates the contemporaneous and inter-temporal relationship between alcohol and tobacco consumption. A range of empirical evidence emphasizes that these goods are often jointly consumed, thus it is likely that they are related in consumption. An understanding of their interdependence is important for a number of reasons. It may help in designing appropriate policy measures aimed at reducing the negative externalities associated with their consumption. It may reveal whether past use of one of the two reinforces current consumption of the other.

We model the demand for the two addictive goods as an extension of the RA model that allows for multi-commodity addiction. We find a strong habit persistence effect in both alcohol and tobacco use and also both demands reflect a forward looking behavior, since the lead consumption terms, in each equation, are positive and significant.

Our analysis also reveals that the two goods are complements in consumption since both cross-price elasticities are negative. Thus, a policy measure effective in reducing the demand in one of the two would also produce the additional result of curbing the other. More specifically, the cross-price elasticity of tobacco with respect to alcohol price is greater in absolute value than the response of alcohol consumption to a change in the price of tobacco.

The asymmetry in the values of cross-price elasticities coupled with the relative magnitude of own-price elasticities seems to suggest that the optimal strategy for maximizing public revenues through increases in "sin taxes" would be to raise alcohol taxation more than tobacco taxation. This policy measure would also produce the additional dividend of curbing tobacco demand, given the absolute values of the cross-price elasticities. Moreover, alcohol turns out to be a luxury across the whole sample 1960–2002. This is an interesting point for the research agenda. Should the income elasticity of alcohol consumption also be growing across income classes[20] then, contrary to the conventional wisdom that views taxation of "sin goods" as regressive, alcohol taxation could have a progressive impact, making such policy measure more acceptable on distributional grounds as well as on more obvious efficiency viewpoints.

[20] However, the distribution of income is not taken into account here. Thus, alcohol could be a luxury at low levels of income, but a necessary or inferior good at high levels of income.

Such conclusions should be viewed with some caution given the structure of the data used. Our results point out that assuming separability in consumption of two addictive goods may be inadequate for appropriate policy design aimed at reducing their demand.

Finally, an interesting topic that has not been extensively explored in the literature is the possibility of a *common habit stock* between alcohol and tobacco products. The hypothesis of a joint habit stock seems to be important in order to test for the existence of a gateway effect (Pacula 1997). However, we do not know of specifications of the joint habit stock other than the linear additive one, which implies perfect substitution between the two commodities. A more appropriate specification of the common stock is thus needed to properly test for the presence of a gateway effect.

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