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**Pseudo Panel Data Estimation Technique and Rational Addiction Model:
An Analysis of Tobacco, Alcohol and Coffee Demands**

Aycan Koksak

Cleveland State University
Department of Economics
aycankoksak@gmail.com

Michael Wohlgenant

North Carolina State University
Department of Agricultural and Resource Economics
michael_wohlgenant@ncsu.edu

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In this paper, we generalize the rational addiction model to include three addictive goods: cigarettes, alcohol and coffee. We use a pseudo-panel data approach which has many advantages compared to aggregate and panel data. While cigarette and coffee demands fit well with the rational addiction model, alcohol demand does not. This result might be due to possible inventory effects. Our results suggest that although cigarettes and alcohol reinforce each other in consumption, consumers substitute them when there are permanent changes in relative prices. In the semi-reduced system, the cross-price elasticity of coffee demand with respect to cigarette price is positive and significant. Long-run cross-price elasticities derived from the semi-reduced system and the Morishima elasticities show that when relative prices increase, consumers substitute addictive goods with other addictive goods. This is likely due to compensation and income effects. When there is a permanent increase in relative prices, addicts cut the consumption of a harmful addictive substance, and substitute it with another addictive substance to compensate for the resulting stress. Moreover, when the consumption of an addictive substance decreases after a price increase, relative consumption of other substances increase due to the positive income effect.

Key words: *cigarette, alcohol, coffee, rational addiction, pseudo panel*

The rational addiction model (Becker and Murphy, 1988) is the most popular framework used to estimate the demand for addictive goods. In myopic demand models of addictive behavior, past consumption increases current consumption, but consumers do not take into account the future consequences of their actions when they make current consumption decisions. In the rational addiction model, the consumer is aware of the future consequences of addiction and accounts for them when making consumption choices. In the rational addiction model, both past and anticipated future consumption affect current consumption positively.

Bask and Melkersson (2004) extended the rational addiction model to allow for commodity addictions in two addictive goods: alcohol and cigarettes. This paper extends their model by analyzing the interdependence among three addictive goods in a rational addiction framework: cigarettes, alcohol and coffee.

The rational addiction model has been previously applied to cigarette consumption (e.g., Becker et al., 1994), alcohol consumption (e.g., Grossman et al., 1998) and coffee consumption (e.g., Olekalns and Bardsley, 1996), separately. Many papers claim interdependence between cigarette and alcohol consumption using the myopic or rational addiction models. On the other hand, to the best of our knowledge, there is no paper that analyzes the relationship between the consumption of coffee and other addictive goods like cigarettes and alcohol using a theoretical framework.

Zavela et al. (1990) examined the relation between cigarettes, alcohol, and coffee consumption among army personnel. They found that, for women, cigarette and alcohol consumption are positively correlated; but, for men, cigarette and coffee consumption are

positively correlated. In addition, they found a pattern of abstention from alcohol and coffee among nonsmokers.

In this paper, we analyze the relationship between cigarettes, alcohol and coffee consumption in a rational addiction framework using a pseudo-panel data approach. The objectives of this study are twofold: First, to gain more insight into behavioral processes concerning cigarettes, alcohol and coffee consumption; second, to generalize the rational addiction model to include three addictive goods to provide a framework for future research in the related literature (e.g., interdependence among cigarettes, alcohol and marijuana or interdependence among cigarettes and different types of alcoholic beverages such as beer and wine).

Theoretical Model

Following Bask and Melkersson (2004), we assume:

$$U_{it} = U(C_{it}, A_{it}, K_{it}, S_{it}, D_{it}, L_{it}, N_{it}) \quad (1)$$

where C_{it} , A_{it} and K_{it} are the quantities of cigarettes, alcohol and coffee consumed; S_{it} , D_{it} and L_{it} are the habit stocks of cigarettes, alcohol and coffee respectively; N_{it} is the consumption of a non-addictive composite good.

We assume a strictly concave utility function. The marginal utility derived from each good is assumed to be positive (i.e., $U_C > 0$, $U_A > 0$, $U_K > 0$ and $U_N > 0$; concavity implies $U_{CC} < 0$, $U_{AA} < 0$, $U_{KK} < 0$ and $U_{NN} < 0$). Following the rational addiction literature, we assume that habit stocks of cigarettes and alcohol affect current utility negatively due to their adverse health effects (i.e., $U_S < 0$ and $U_D < 0$; concavity implies $U_{SS} < 0$ and $U_{DD} < 0$). Since coffee use is

not associated with adverse health effects, we don't impose any assumptions on the marginal utility of habit stocks of coffee.

Reinforcement implies $U_{CS} > 0$, $U_{AD} > 0$ and $U_{KL} > 0$. Cigarette, alcohol and coffee consumption are assumed to have no effect on the marginal utility derived from the consumption of the composite good (i.e., $U_{CN} = U_{AN} = U_{KN} = U_{SN} = U_{DN} = U_{LN} = 0$).

If alcohol (cigarette) consumption decreases the marginal utility derived from cigarette (alcohol) consumption, $U_{CA} < 0$ and $U_{SD} < 0$; if alcohol consumption reinforces cigarette consumption and vice versa, $U_{CA} > 0$ and $U_{SD} > 0$.

If past alcohol consumption increases the marginal utility from current cigarette consumption, $U_{CD} > 0$; if past cigarette consumption increases the marginal utility from current alcohol consumption, $U_{AS} > 0$. Pierani and Tiezzi (2009) name this intertemporal cross-reinforcement effect the quasi-gateway effect.¹ When cigarette consumption does not affect the marginal utility from alcohol consumption and vice versa $U_{CA} = U_{SD} = U_{AS} = U_{CD} = 0$

If coffee consumption reinforces cigarette consumption, $U_{CK} > 0$ and $U_{SL} > 0$; and if coffee consumption decreases the marginal utility from alcohol consumption, $U_{AK} < 0$ and $U_{DL} < 0$. When consumption of coffee does not affect the marginal utility from cigarette consumption, $U_{CK} = U_{SL} = U_{CL} = U_{KS} = 0$. When consumption of coffee does not affect the marginal utility from alcohol consumption, $U_{AK} = U_{DL} = U_{AL} = U_{KD} = 0$.

¹ A true gateway effect refers to the condition that consumption of one addictive substance leads to later *initiation* of another addictive substance (Pacula,1997).

The intertemporal budget constraint is

$$\sum_{t=1}^{\infty} \beta^{t-1} (P_{Ct}C_{it} + P_{At}A_{it} + P_{Kt}K_{it} + N_{it}) = W_i \quad (2)$$

where $\beta = 1/(1+r)$ with r being the discount rate, P_{Ct} , P_{At} and P_{Kt} are prices of cigarettes, alcohol and coffee, respectively, and W_i is the present value of wealth. The composite good, N , is taken as the numeraire good.

Then the consumer's problem is:

$$\begin{aligned} \max \quad & \sum_{t=1}^{\infty} \beta^{t-1} U(C_{it}, A_{it}, K_{it}, S_{it}, D_{it}, L_{it}, N_{it}) \\ \text{s. t.} \quad & \sum_{t=1}^{\infty} \beta^{t-1} (P_{Ct}C_{it} + P_{At}A_{it} + P_{Kt}K_{it} + N_{it}) = W_i \end{aligned} \quad (3)$$

As in previous studies, we assume that $S_{it} = C_{it-1}$, $D_{it} = A_{it-1}$ and $L_{it} = K_{it-1}$. When the utility function is quadratic, the solution to problem (3) generates the following demand equations²:

$$\begin{aligned} C_{it} = & \alpha_{1i} + \beta_{10} + \beta_{11} C_{it-1} + \beta_{12} C_{it+1} + \beta_{13} A_{it-1} + \beta_{14} A_{it} + \beta_{15} A_{it+1} + \beta_{16} K_{it-1} \\ & + \beta_{17} K_{it} + \beta_{18} K_{it+1} + \beta_{19} P_{Ct} + \gamma_1 X_{it} + u_{1it} \end{aligned} \quad (4)$$

$$\begin{aligned} A_{it} = & \alpha_{2i} + \beta_{20} + \beta_{21} A_{it-1} + \beta_{22} A_{it+1} + \beta_{23} C_{it-1} + \beta_{24} C_{it} + \beta_{25} C_{it+1} + \beta_{26} K_{it-1} \\ & + \beta_{27} K_{it} + \beta_{28} K_{it+1} + \beta_{29} P_{At} + \gamma_2 X_{it} + u_{2it} \end{aligned} \quad (5)$$

$$\begin{aligned} K_{it} = & \alpha_{3i} + \beta_{30} + \beta_{31} K_{it-1} + \beta_{32} K_{it+1} + \beta_{33} C_{it-1} + \beta_{34} C_{it} + \beta_{35} C_{it+1} + \beta_{36} A_{it-1} \\ & + \beta_{37} A_{it} + \beta_{38} A_{it+1} + \beta_{39} P_{Kt} + \gamma_3 X_{it} + u_{3it} \end{aligned} \quad (6)$$

² See Appendix A for derivation of Equations (4)-(6).

As pointed out by Bask and Melkersson (2004), the rational addiction model nests many different behaviors: “A non-addicted consumer responds only to information in the current period, which means that the parameters for those variables which correspond to the past and the future are zero. An addicted but myopic consumer also responds to past information. Finally, an addicted consumer who is also rational responds to past, current, and future information” (p.375). The specification also allows for quasi-gateway effects across different addictive goods. The nested structure is convenient for testing certain parameter restrictions to evaluate the merits of a generalization.

In the empirical model, in addition to the variables that directly come from the theoretical model, for each equation we add an error term (u_{it}), some consumer demographics (X_{it}) and an individual fixed effect (α_i) to account for unobserved individual heterogeneity, such as attitudes towards health risks.

For $k=1,2,3$ economic theory implies $\beta_{k9} < 0$. Rational addiction implies $\beta_{k1} > \beta_{k2} > 0$ with $\beta_{k1} = (1 + r)\beta_{k2}$. From the structural parameters, the rate of time preference can be derived for each good³. In the applied literature, these parametric restrictions have been tested to check the validity of the rational addiction model.

For $k=1,2$, $\beta_{k4} > 0$ if smoking and drinking reinforce each other; and $\beta_{k4} < 0$ if drinking makes it easier to abstain from smoking, and vice versa. If $\beta_{13} > 0$ alcohol consumption is a quasi-gateway for cigarette consumption, if $\beta_{23} > 0$ cigarette consumption is a quasi-gateway for alcohol consumption.

³ In empirical applications it is possible to find different rate of time preference, r , for different addictive goods.

If $\beta_{34} > 0$ then coffee and cigarette consumption reinforce each other. If $\beta_{37} < 0$ then coffee consumption makes it easier to abstain from alcohol consumption.

Data

Consumer Expenditure Survey(CEX) Diary data by Bureau of Labor Statistics(BLS) are used in this study. Cigarette, alcohol and coffee expenditures, together with price variables, are used to calculate (average weekly) consumptions (i.e., cigarette consumption= cigarette expenditure/ cigarette price).

The observations with missing state variables are dropped. To avoid any inconsistency, we also dropped the very few households that report different household head demographics (i.e., race, education) for each week that the Diary data are collected.

Because price data are not collected by CEX, price variables used in the analysis are gathered from other data sources. All price variables are deflated by the CPI for all items reported on the BLS webpage. Annual state level cigarette prices are gathered from the website of Department of Health and Human Services, Centers for Disease Control and Prevention (CDC). To obtain alcoholic beverages prices, we construct Lewbel (1989) price indices that have household specific price variation⁴. Regional coffee prices reported monthly on the BLS webpage are used to obtain quarterly coffee prices⁵.

⁴ See Appendix B for derivation of Lewbel price indices.

⁵ Regional coffee prices are not reported for the most recent years, we derived those using monthly coffee price index and the previous month's coffee price.

Methodology

Although individual level panel data have many advantages compared to aggregate data, they generally span short time periods, suffer from measurement error and are subject to attrition bias. In order to avoid these problems, Deaton (1985) suggested using pseudo-panel data approach as an alternative method for estimating individual behavior models.

In the literature, for estimating dynamic models of demand, the pseudo-panel method is a relatively new econometric method. It is an instrumental variables approach in which cohort dummies are used as instruments in the first-stage (i.e., the first stage predicted values are equivalent to cohort averages). The pseudo-panel approach enables one to follow cohorts of people through repeated cross-sectional surveys. Because repeated cross-sectional surveys are often over longer time-periods than true panels, with pseudo panel method models can be estimated over longer time periods. Moreover, averaging within cohorts removes individual-level measurement error (see Antman and McKenzie, 2007).

In pseudo-panel analysis, because cohorts are followed over time, they are constructed based on characteristics that are time invariant, such as geographic region or the birth year of the reference person. When we construct cohorts, we face a trade-off between the number of cohorts and the number of individuals within cohorts. If individuals are allocated into a large number of cohorts, there will be few observations in the cohorts which might cause biased estimators. On the other hand, if only a few cohorts are chosen to have a large number of observations per cohort, individuals within a cohort might be heterogeneous, which would cause inefficiency. Thus, the challenge when we construct a pseudo-panel is finding a balance between the number of cohorts and the number of individuals within cohorts. The optimal choice would be the one that

minimizes the heterogeneity within each cohort but maximizes the heterogeneity among them. In that case, pseudo-panel method results in consistent and efficient estimators.

In most of the applied pseudo-panel studies, the sample is divided into a small number of cohorts with a large number of observations in each (e.g., Browning et al., 1985; Blundell, Browning and Meghir 1994; Propper, Rees and Green 2001). Verbeek and Nijman (1992) showed that if cohorts contain at least 100 individuals and there is sufficient time variation in the cohort means, the bias due to measurement error would be small and can be ignored⁶.

In the pseudo-panel approach, cohorts can be constructed based on a single characteristic (i.e., birth cohort) or multiple characteristics (i.e., birth and region; birth and education, birth and gender, etc). In this study, we form pseudo-panels based on household head's year of birth and the geographic region. Cohorts are defined by the interaction of three generations (born before 1950, born between 1950-1964, born in 1965 or later) and four geographic regions (northeast, midwest, south, west). For example, all household heads born before 1950 that reside in the northeast would form one cohort and all households born before 1950 that reside in the midwest would form another cohort. The resulting pseudo-panel consists of a total of 336 observations over 12 cohorts and 28 quarters. This allocation results in around 100 households per cohort.

Because pseudo-panel approach is an instrumental variables (IV) method, standard IV conditions should be satisfied for identification (Verbeek and Vella, 2005). The time-invariant instruments should have correlation not only with the lagged and lead consumption variables but also with the exogenous variables in the model (i.e., sufficient cohort-specific variation should be present in the exogenous variables). When we construct our cohorts, we take into account

⁶ They also state that the cohort sizes may be smaller than 100 observations if the individuals grouped in each cohort are sufficiently homogeneous.

standard instrumental variables (IV) conditions. To have (time-variant) correlation between the model variables and the time invariant instruments (i.e., cohort dummies), we construct our cohorts based on household head's year of birth and the geographic region. The three generations (born before 1950, born between 1950-1964, born in 1965 or later) are likely to have different consumption patterns which are subject to change over time as the generations age. Different generations are likely to differ also in terms of consumer demographics (e.g., preference for small versus large families) which can change as generations age (e.g., family size changes as children leave the house to start their own family). There are also differences across regions in terms of prices, consumer demographics, and consumption patterns which would change over time because of migration, local policy changes, etc.

Figure 1 shows cigarette consumption by birth cohorts over the sample period. The youngest birth cohort has an increasing cigarette consumption on average, while the average cigarette consumption of older cohorts are decreasing from 2002 to 2008. The oldest cohort (i.e., people born before 1950) has the lowest cigarette consumption. Their low (and decreasing) consumption can be attributed to age related health problems which force older consumers to cut back cigarette consumption. The highest cigarette consumption is observed among the people born between 1950-1964, which slightly decreases over the sample period. The people born after 1964 have a lower cigarette consumption compared to people born in 1950-1964. This can be explained by the 1964 surgeon general's report on smoking. The 1964 surgeon general's report caused awareness about the health consequences of smoking and changed public attitudes towards smoking.

Figure 2 shows alcohol consumption by birth cohorts over the sample period. From 2002 to 2008, the average alcohol consumption slightly increases for all birth cohorts. The oldest birth cohort (i.e., born before 1950) has the lowest alcohol consumption on average.

Figure 3 shows coffee consumption by birth cohorts over the sample period. From 2002 to 2008, the average coffee consumption increases for all birth cohorts. The youngest birth cohort (i.e., born after 1964) has the lowest coffee consumption on average.

Figure 4, Figure 5 and Figure 6 show average consumptions by region. The midwest has the highest cigarette consumption, while west has the lowest. Cigarette consumption decreases in the midwest and west, while it increases in the south and northeast. Over the sample period alcohol consumption slightly increases across all regions, and among all regions the south has the lowest alcohol consumption. Coffee consumption increases across all regions, and the most significant increase in consumption is observed in the west.

In section 2, we derived the structural equations of the following form:

$$C_{it} = \alpha_{1i} + \beta_{10} + \beta_{11} C_{it-1} + \beta_{12} C_{it+1} + \beta_{13} A_{it-1} + \beta_{14} A_{it} + \beta_{15} A_{it+1} + \beta_{16} K_{it-1} \\ + \beta_{17} K_{it} + \beta_{18} K_{it+1} + \beta_{19} P_{Ct} + \gamma_1 X_{it} + u_{1it} \quad (4)$$

$$A_{it} = \alpha_{2i} + \beta_{20} + \beta_{21} A_{it-1} + \beta_{22} A_{it+1} + \beta_{23} C_{it-1} + \beta_{24} C_{it} + \beta_{25} C_{it+1} + \beta_{26} K_{it-1} \\ + \beta_{27} K_{it} + \beta_{28} K_{it+1} + \beta_{29} P_{At} + \gamma_2 X_{it} + u_{2it} \quad (5)$$

$$K_{it} = \alpha_{3i} + \beta_{30} + \beta_{31} K_{it-1} + \beta_{32} K_{it+1} + \beta_{33} C_{it-1} + \beta_{34} C_{it} + \beta_{35} C_{it+1} + \beta_{36} A_{it-1} \\ + \beta_{37} A_{it} + \beta_{38} A_{it+1} + \beta_{39} P_{Kt} + \gamma_3 X_{it} + u_{3it} \quad (6)$$

In order to estimate the individual level structural equations (4) - (6), we use cohort dummies as instruments in the first-stage. Taking cohort averages of (4) - (6), over n_c individuals observed in cohort c at time t results in:

$$\begin{aligned}
\bar{C}_{c(t),t} &= \bar{\alpha}_{1c,t} + \beta_{10} + \beta_{11} \bar{C}_{c(t),t-1} + \beta_{12} \bar{C}_{c(t),t+1} + \beta_{13} \bar{A}_{c(t),t-1} + \beta_{14} \bar{A}_{c(t),t} \\
&+ \beta_{15} \bar{A}_{c(t),t+1} + \beta_{16} \bar{K}_{c(t),t-1} + \beta_{17} \bar{K}_{c(t),t} + \beta_{18} \bar{K}_{c(t),t+1} + \beta_{19} P_{Ct} \\
&+ \gamma_1 \bar{X}_{c(t),t} + \bar{u}_{1c(t),t}
\end{aligned} \tag{7}$$

$$\begin{aligned}
\bar{A}_{c(t),t} &= \bar{\alpha}_{2c,t} + \beta_{20} + \beta_{21} \bar{A}_{c(t),t-1} + \beta_{22} \bar{A}_{c(t),t+1} + \beta_{23} \bar{C}_{c(t),t-1} + \beta_{24} \bar{C}_{c(t),t} \\
&+ \beta_{25} \bar{C}_{c(t),t+1} + \beta_{26} \bar{K}_{c(t),t-1} + \beta_{27} \bar{K}_{c(t),t} + \beta_{28} \bar{K}_{c(t),t+1} + \beta_{29} P_{At} \\
&+ \gamma_2 \bar{X}_{c(t),t} + \bar{u}_{2c(t),t}
\end{aligned} \tag{8}$$

$$\begin{aligned}
\bar{K}_{c(t),t} &= \bar{\alpha}_{3c,t} + \beta_{30} + \beta_{31} \bar{K}_{c(t),t-1} + \beta_{32} \bar{K}_{c(t),t+1} + \beta_{33} \bar{C}_{c(t),t-1} + \beta_{34} \bar{C}_{c(t),t} \\
&+ \beta_{35} \bar{C}_{c(t),t+1} + \beta_{36} \bar{A}_{c(t),t-1} + \beta_{37} \bar{A}_{c(t),t} + \beta_{38} \bar{A}_{c(t),t+1} + \beta_{39} P_{Kt} \\
&+ \gamma_3 \bar{X}_{c(t),t} + \bar{u}_{3c(t),t}
\end{aligned} \tag{9}$$

where $\bar{\alpha}_{c,t}$ is the average of the fixed effects for those individuals in cohort c at time t .

In repeated cross-sectional surveys, different individuals are observed at each time period. Thus, the lagged and lead variables are not observed for the same individuals in cohort c at time t . Therefore, following the previous literature, we replace these sample means of the unobserved variables with the sample means of the individuals at time $t-1$, and $t+1$, respectively, which leads to the following equations⁷:

$$\begin{aligned}
\bar{C}_{c(t),t} &= \bar{\alpha}_{1c,t} + \beta_{10} + \beta_{11} \bar{C}_{c(t-1),t-1} + \beta_{12} \bar{C}_{c(t+1),t+1} + \beta_{13} \bar{A}_{c(t-1),t-1} + \beta_{14} \bar{A}_{c(t),t} \\
&+ \beta_{15} \bar{A}_{c(t+1),t+1} + \beta_{16} \bar{K}_{c(t-1),t-1} + \beta_{17} \bar{K}_{c(t),t} + \beta_{18} \bar{K}_{c(t+1),t+1} + \beta_{19} P_{Ct} \\
&+ \gamma_1 \bar{X}_{c(t),t} + \bar{u}_{1c(t),t}
\end{aligned} \tag{10}$$

⁷ As the number of individuals in each cohort becomes large, the measurement error introduced by the use of pseudo-panel analysis, i.e. $\bar{C}_{c(t),t-1} - \bar{C}_{c(t-1),t-1}$ converges to zero (McKenzie, 2004).

$$\begin{aligned}
\bar{A}_{c(t),t} &= \bar{\alpha}_{2c,t} + \beta_{20} + \beta_{21} \bar{A}_{c(t-1),t-1} + \beta_{22} \bar{A}_{c(t+1),t+1} + \beta_{23} \bar{C}_{c(t-1),t-1} + \beta_{24} \bar{C}_{c(t),t} \\
&+ \beta_{25} \bar{C}_{c(t+1),t+1} + \beta_{26} \bar{K}_{c(t-1),t-1} + \beta_{27} \bar{K}_{c(t),t} + \beta_{28} \bar{K}_{c(t+1),t+1} + \beta_{29} P_{At} \\
&+ \gamma_2 \bar{X}_{c(t),t} + \bar{u}_{2c(t),t}
\end{aligned} \tag{11}$$

$$\begin{aligned}
\bar{K}_{c(t),t} &= \bar{\alpha}_{3c,t} + \beta_{30} + \beta_{31} \bar{K}_{c(t-1),t-1} + \beta_{32} \bar{K}_{c(t+1),t+1} + \beta_{33} \bar{C}_{c(t-1),t-1} + \beta_{34} \bar{C}_{c(t),t} \\
&+ \beta_{35} \bar{C}_{c(t+1),t+1} + \beta_{36} \bar{A}_{c(t-1),t-1} + \beta_{37} \bar{A}_{c(t),t} + \beta_{38} \bar{A}_{c(t+1),t+1} + \beta_{39} P_{Kt} \\
&+ \gamma_3 \bar{X}_{c(t),t} + \bar{u}_{3c(t),t}
\end{aligned} \tag{12}$$

Because the sample is collected separately for different time periods, $\bar{\alpha}_{c,t}$ is not constant over time. $\bar{\alpha}_{c,t}$ can be treated as unobserved cohort fixed effect (α_c) if there is sufficient number of observations per cohort (see Verbeek and Nijman, 1992). In that case, we can estimate the structural equations at the cohort level by using cohort dummies or cohort fixed effects. In the dynamic pseudo-panel data model, the fixed effects estimator on cohort averages is consistent when T is small and $n_c \rightarrow \infty$ provided that there are no cohort and time effects in the individual error terms once controlled by cohort fixed effects (McKenzie, 2004). The number of observations in each cohort is sufficiently large in our sample to ensure consistency (i.e., around 100 observations). Thus the fixed effects estimator on cohort averages is used.

In the sample, the number of households in each cohort and time period is not the same which might induce heteroskedasticity. Following Dargay (2007), to correct for heteroskedasticity, all cohort variables are weighted by the square root of the number of households in each cohort. To obtain consistent standard errors, bootstrapped standard errors are calculated (1000 replications).

Empirical Results

First, each equation in (10) - (12) is estimated as a separate equation. The results are shown in Table 1. Both cigarette and coffee demands are consistent with rational addiction (i.e., lag and lead consumption coefficients are positive and significant). In both equations the coefficient on lag consumption is higher than the lead consumption coefficient, implying the rate of intertemporal preference is positive. In alcohol demand, lag and lead consumptions have negative coefficients. This result might be due to inventory effects. In the alcohol demand equation, current cigarette consumption has a positive and significant coefficient suggesting that current cigarette consumption reinforces current alcohol consumption. We have not found any proof of quasi-gateway effects across cigarette and alcohol consumptions.⁸ Lag alcohol (cigarette) consumption in the cigarette (alcohol) demand equation is not significant. In coffee demand, the coefficients on current cigarette and current alcohol consumptions are positive, but not statistically significant.

The implied discount rates, r , are derived from the parameter estimates of own lagged and lead consumption (*i. e.* $\beta_1 = (1 + r)\beta_2$). They are positive and plausible for cigarette and coffee consumption. It is 4.57% for cigarette consumption and 1.91% for coffee consumption. Because cigarettes are more addictive than coffee, consumers of cigarettes are likely to be more myopic than consumers of coffee.

Regarding demographics, as family size increases cigarette and alcohol consumptions increase. Whites have a higher consumption of cigarettes and alcohol compared to other races.

⁸ Failure to find evidence for quasi-gateway effects does not mean that there are no true gateway effects. Our results do not rule out the possibility that consumption of one substance leads to *initiation* of use of another substance. Unfortunately, the way the model is formulated does not make it possible to test for these true gateway effects.

The consumer units whose household head has at least an associate's degree smoke less cigarettes, but drink more alcohol and coffee compared to other consumer units. However the effect of education on consumption is not statistically significant. Overall, consumer demographics do not seem to affect coffee consumption significantly. On the other hand, cohort fixed effects are jointly significant in all three equations. The p-value for the F-test is smaller than 1% suggesting one should account for unobserved cohort fixed effects (F-values are 7.02, 3.53 and 3.45 for cigarettes, alcohol and coffee, respectively).

Bask&Melkersson (2004) and Pierani&Tiezzi (2009) point out that decisions regarding cigarette and alcohol consumptions are often made jointly. Thus following Bask and Melkersson (2004), we combine equations (10) - (12) to estimate a semi-reduced system.

$$\begin{aligned}\bar{C}_{ct} = & \alpha_{4c} + \beta_{40} + \beta_{41} \bar{C}_{ct-1} + \beta_{42} \bar{C}_{ct+1} + \beta_{43} \bar{A}_{ct-1} + \beta_{44} \bar{A}_{ct+1} + \beta_{45} \bar{K}_{ct-1} \\ & + \beta_{46} \bar{K}_{ct+1} + \beta_{47} P_{Ct} + \beta_{48} P_{At} + \beta_{49} P_{Kt} + \bar{u}_{4ct}\end{aligned}\quad (13)$$

$$\begin{aligned}\bar{A}_{ct} = & \alpha_{5c} + \beta_{50} + \beta_{51} \bar{A}_{ct-1} + \beta_{52} \bar{A}_{ct+1} + \beta_{53} \bar{C}_{ct-1} + \beta_{54} \bar{C}_{ct+1} + \beta_{55} \bar{K}_{ct-1} \\ & + \beta_{56} \bar{K}_{ct+1} + \beta_{57} P_{At} + \beta_{58} P_{Ct} + \beta_{59} P_{Kt} + \bar{u}_{5ct}\end{aligned}\quad (14)$$

$$\begin{aligned}\bar{K}_{ct} = & \alpha_{6c} + \beta_{60} + \beta_{61} \bar{K}_{ct-1} + \beta_{62} \bar{K}_{ct+1} + \beta_{63} \bar{C}_{ct-1} + \beta_{64} \bar{C}_{ct+1} + \beta_{65} \bar{A}_{ct-1} \\ & + \beta_{66} \bar{A}_{ct+1} + \beta_{67} P_{Kt} + \beta_{68} P_{Ct} + \beta_{69} P_{At} + \bar{u}_{6ct}\end{aligned}\quad (15)$$

Because the parameters in these equations are non-linear functions of the parameters in equations (10) - (12), we don't have prior expectations for their signs. Instead, we focus on the long-run demand elasticities.

The semi-reduced system is estimated by using iterated seemingly unrelated regression (ITSUR) method. The model coefficients are reported on Table 3. The long-run price and income

elasticities calculated at the sample mean are shown on Table 4. The long-run own price elasticities are negative for all three goods. Cigarette and coffee have inelastic demands while alcohol demand is elastic. Bask and Melkersson (2004) also found that alcohol demand is elastic in the long-run. An explanation for this might be that most alcoholic beverage drinkers are just social drinkers. The income elasticity is positive and less than one for all three goods.

Regarding cross-price elasticities, only the cross-price elasticity of alcohol with respect to cigarette price, and the cross-price elasticity of coffee with respect to cigarette price are significant. The positive cross-price elasticities with respect to the cigarette price suggests that as the cigarette price increases people compensate reduced cigarette consumption with increased alcohol and coffee consumption.

Because the cross-price elasticity does not take into account the price sensitivity of the good whose price has been changed, Morishima elasticities of substitution are also calculated for the long-run. The elasticity of substitution measures how the relative consumption of two goods changes along the indifference curve when the relative prices change. Morishima elasticity of substitution is calculated using the formula:

$$\sigma_{ij}^M = \frac{\partial \ln(x_i^h/x_j^h)}{\partial \ln(p_j^h/p_i^h)} = \varepsilon_{ij}^h - \varepsilon_{jj}^h \quad (13)$$

where ε_{ij}^h and ε_{jj}^h are Hicksian own and cross price elasticities.

Hicksian price elasticities are derived as $\varepsilon_{ij}^h = \varepsilon_{ij}^m + s_j \varepsilon_{iy}$ where ε_{jj}^m is Marshallian cross-price elasticity, ε_{iy} is income elasticity and s_j is budget share of good j.

Morishima elasticities of substitution point to significant compensating behavior. All the Morishima elasticities of substitution are positive and significant. Except σ_{AK} , all the Morishima

elasticities of substitution are greater than one. This suggests that cigarette, alcohol and coffee substitute each other along the indifference curve when the relative prices change. As the relative price of alcohol increases, the share of both cigarette and coffee consumptions relative to alcohol consumption increase suggesting that the consumer compensates reduced alcohol consumption with other addictive goods. Similar compensating behaviors apply to coffee and cigarette consumptions too.

Concluding Remarks

This study uses a pseudo-panel data approach to analyze the relationship between cigarettes, alcohol and coffee consumption within the rational addiction framework. The specification that we use is very general and nests several different behaviors and accounts for possible relationships among the three addictive goods.

We found that cigarette and coffee consumptions are consistent with rational addiction whereas alcohol consumption is not (i.e., in the alcohol demand equation lag and lead consumptions have negative coefficients). If there are inventory effects, this might be the reason why alcohol demand does not fit the theoretical model so well. In a different study (Koksal and Wohlgenant, 2011) when we replaced “overall alcohol expenditures” with “restaurant alcohol expenditures”, (restaurant) alcohol demand became consistent with rational addiction which reinforces our belief that in the current study the inconsistency of alcohol demand with the rational addiction model is due to inventory effects observed in quarterly alcohol expenditures.

The structural model does not suggest any significant reinforcement effect between coffee and cigarette consumption. However this does not rule out the possibility that coffee and cigarette

consumption might reinforce each other for some subpopulations. On the other hand, in the semi-reduced system, the cross-price elasticity of coffee demand with respect to cigarette price is positive and significant suggesting that coffee substitutes for cigarettes when cigarette prices increase.

Morishima elasticities of substitution point to significant compensating behavior (i.e., cigarette, alcohol and coffee substitute each other along the indifference curve when the relative prices change). As the relative price of alcohol increases, the share of both cigarette and coffee consumptions relative to alcohol consumption increase suggesting that the consumer compensates reduced alcohol consumption with other addictive goods. Coffee and cigarette consumptions provide similar compensating behaviors. When relative price of cigarettes (alcohol) increase, consumers substitute cigarettes (alcohol) with alcohol (cigarettes). Our findings are consistent with Picone et al.(2004) who claim that alcohol and cigarettes are gross substitutes in price although they are complements in consumption for social drinkers. They explain positive cross-price responses with compensation and income effects. When there is a permanent increase in relative prices, addicts cut the consumption of a harmful addictive substance, and substitute it with another addictive substance to compensate for the resulting stress. Moreover, when consumption of an addictive substance decreases due to a price increase, consumption of other addictive substances are likely to increase due to a positive income effect.

Although cigarette taxation has been cited as one of the most effective public health tools for cigarette control, the empirical results suggest that increasing cigarette prices might increase alcohol consumption (i.e., the cross-price elasticity of alcohol with respect to cigarette price is

positive and significant in the semi-reduced system). Because of compensating behaviors of addicts, taxes might result in increases in the consumption of other addictive goods.

There are other studies that find evidence of addiction displacement. Using both qualitative and quantitative data, Skog (2006) examines if the decline in the Norwegian alcohol consumption during the nineteenth century is related to the growth of coffee culture as a substitute. He claims that coffee filled a cultural ‘niche’ created by the restrictive Norwegian alcohol policy (i.e., decreased availability and increased taxes) in the nineteenth century. He concludes that the decline in alcohol consumption was, in part, as a result of coffee substituting alcohol as an alternative ‘new’ beverage for all social classes.

Reich et al. (2008) investigate coffee and cigarette use among recovering alcoholics that participate in Alcoholics Anonymous (AA) meetings in 2007 in Nashville. They find that cigarette and coffee consumption among AA members is higher compared to the general U.S. population. Most recovering alcoholics explain that they consume coffee for its stimulatory effects (i.e., feeling better, higher concentration, more alertness), and they consume cigarettes for its reduction of negative feelings (i.e., depression, anxiety and irritability).

Many studies support that kicking a habit becomes much easier when addicts form a new replacement habit. Our results suggest that if compensating behaviors can be channeled toward harmless addictive substances such as caffeine or smokeless tobacco (e.g., Rodu and Cole, 2009 on smokeless tobacco consumption versus cigarette consumption), the unintended consequences of increasing cigarette prices in the form of increased alcohol consumption can be avoided.

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Figure 1: 2002-2008 Cigarette Consumption by Birth Cohorts

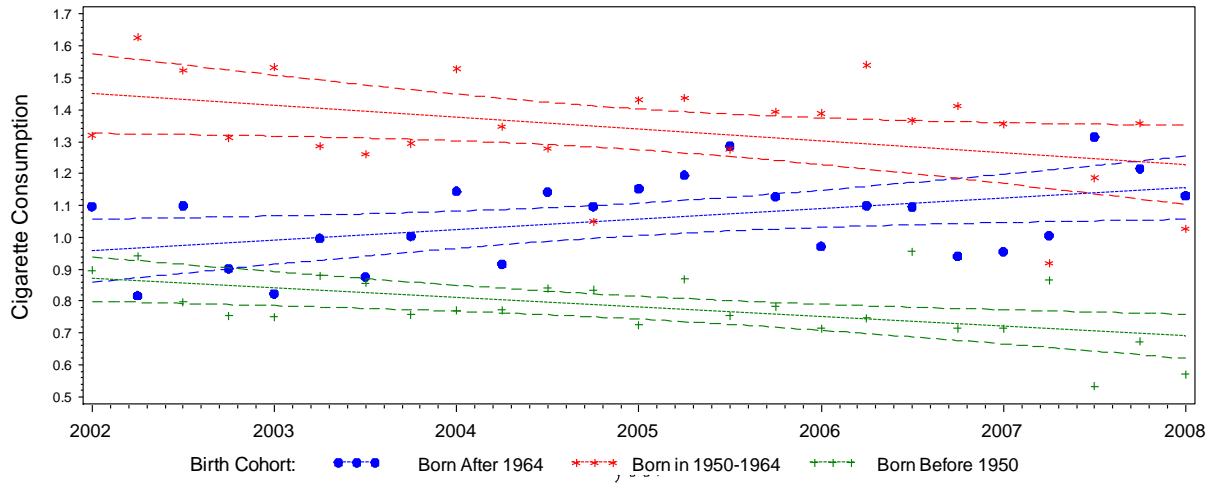


Figure 2: 2002-2008 Alcohol Consumption by Birth Cohorts

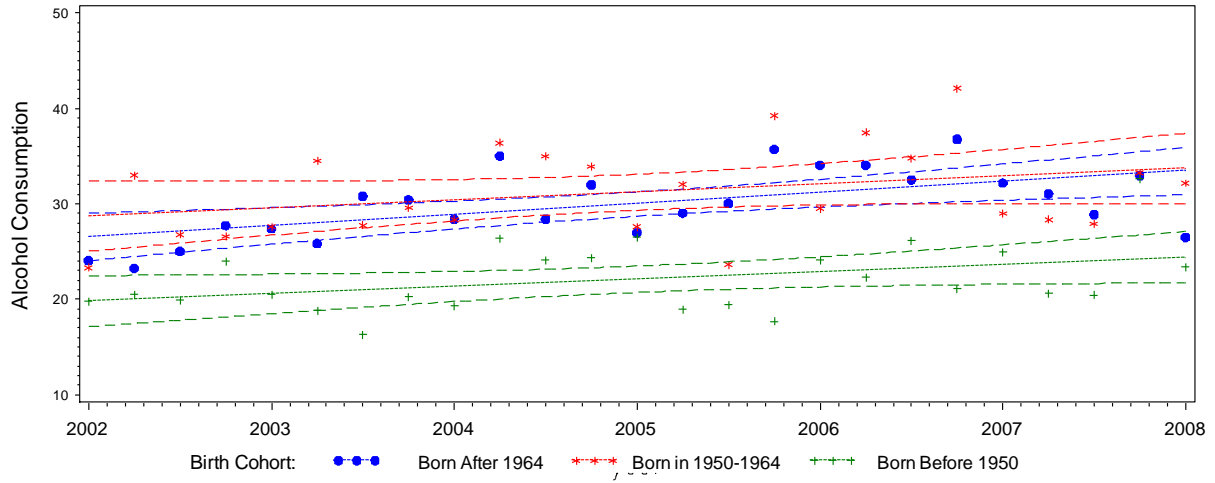


Figure 3: 2002-2008 Coffee Consumption by Birth Cohorts

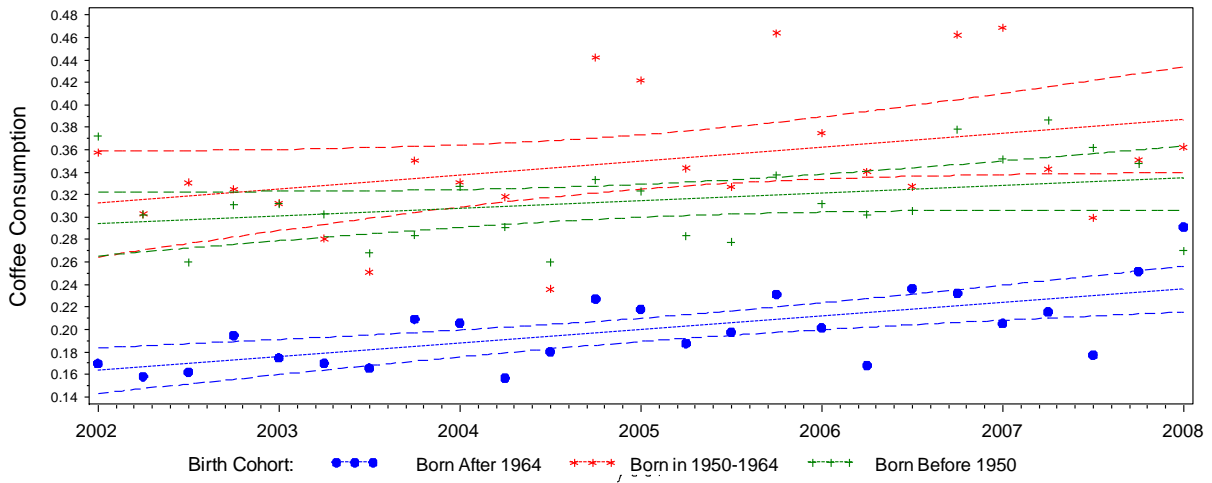


Figure 4: 2002-2008 Cigarette Consumption by Region

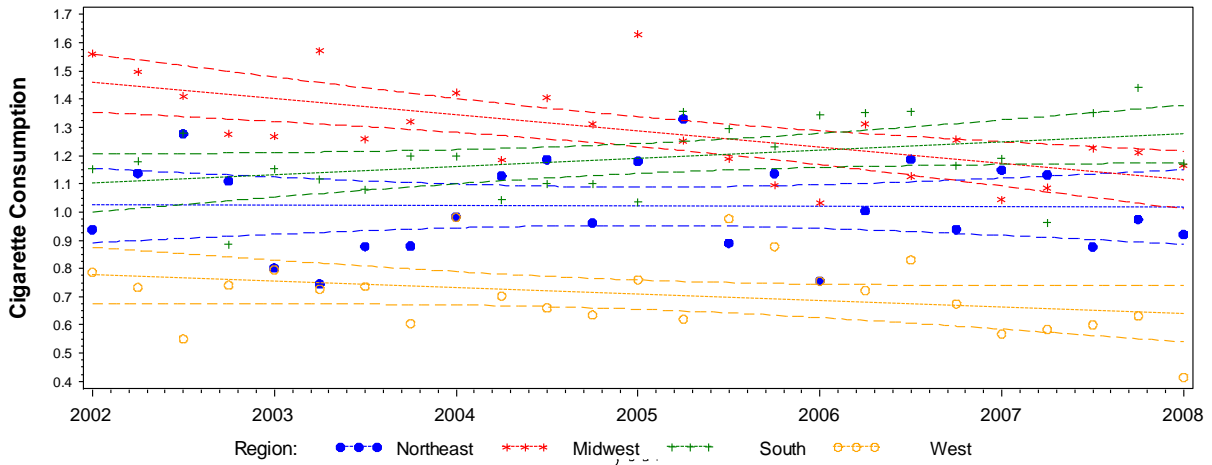


Figure 5: 2002-2008 Alcohol Consumption by Region

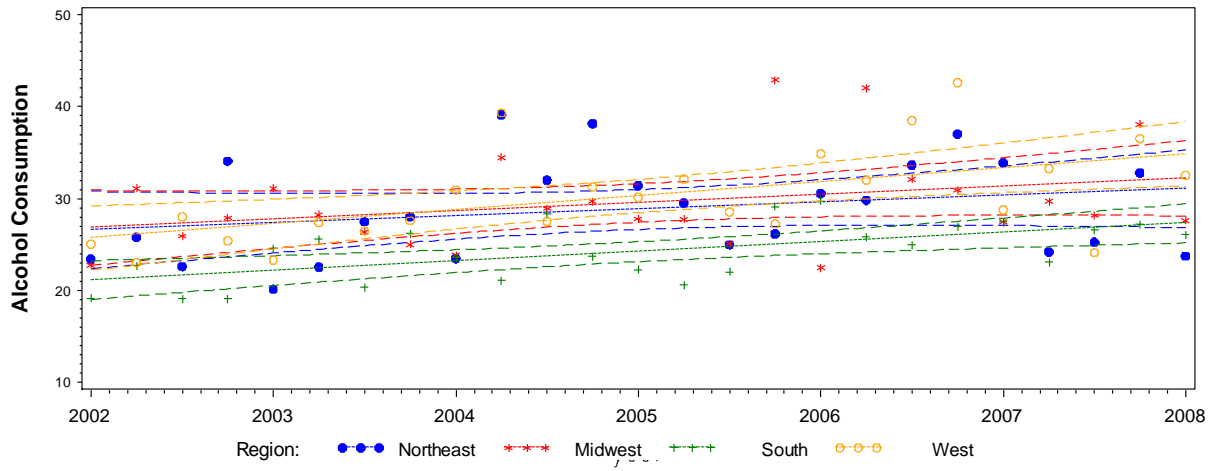


Figure 6: 2002-2008 Coffee Consumption by Region

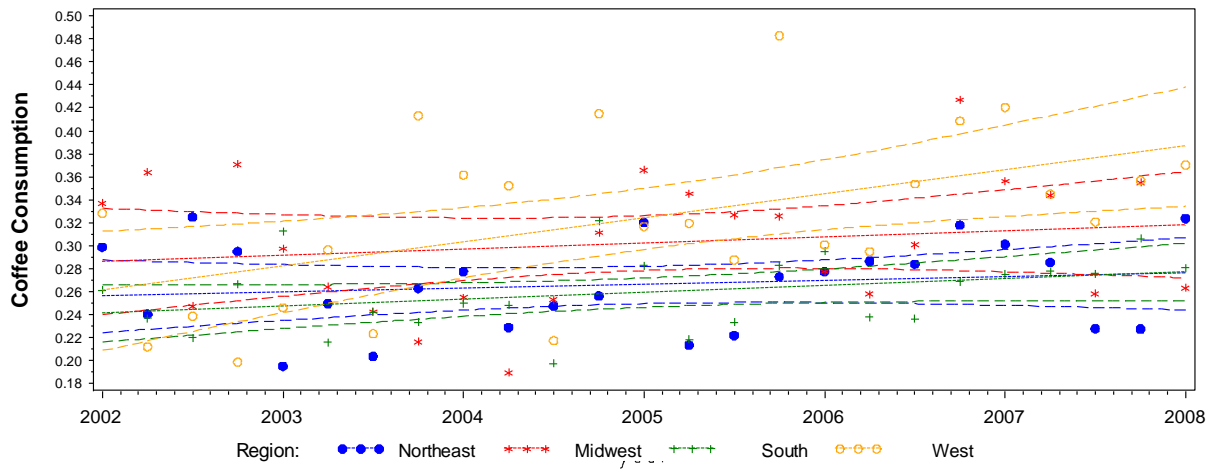


Table 1. Cigarette, Alcohol and Coffee Demands Estimated Separately

| <i>Cigarettes</i> | | | <i>Alcohol</i> | | | <i>Coffee</i> | | |
|----------------------------|-----------|---------|----------------------------|------------|----------|----------------------------|----------|----------|
| Constant | -7.416*** | (2.269) | Constant | 148.287** | (60.688) | Constant | 1.533** | (0.603) |
| C _{t-1} | 0.109** | (0.049) | A _{t-1} | -0.085** | (0.043) | K _{t-1} | 0.105** | (0.053) |
| C _{t+1} | 0.104** | (0.051) | A _{t+1} | -0.104*** | (0.039) | K _{t+1} | 0.103* | (0.054) |
| A _{t-1} | 0.001 | (0.002) | C _{t-1} | 0.051 | (1.130) | C _{t-1} | 0.014 | (0.013) |
| A _t | 0.004 | (0.002) | C _t | 2.392** | (1.163) | C _t | 0.003 | (0.014) |
| A _{t+1} | 0.002 | (0.002) | C _{t+1} | 0.274 | (1.010) | C _{t+1} | -0.005 | (0.013) |
| K _{t-1} | 0.083 | (0.195) | K _{t-1} | 0.804 | (4.313) | A _{t-1} | -0.0001 | (0.001) |
| K _t | 0.022 | (0.203) | K _t | 6.955 | (4.578) | A _t | 0.001 | (0.001) |
| K _{t+1} | 0.058 | (0.190) | K _{t+1} | -0.955 | (4.353) | A _{t+1} | -0.0001 | (0.001) |
| P _{Ct} | -0.062 | (0.089) | P _{At} | -61.551*** | (7.113) | P _{Kt} | -0.038** | (0.019) |
| I | -0.0002 | (0.002) | I | 0.254*** | (0.043) | I | 0.001*** | (0.0005) |
| fam. size | 0.328*** | (0.087) | fam. size | 6.726*** | (1.872) | fam. size | 0.021 | (0.020) |
| white | 0.778** | (0.355) | white | 37.363*** | (7.411) | white | 0.117 | (0.086) |
| college | -0.326 | (0.327) | college | 7.640 | (7.469) | college | 0.073 | (0.086) |
| <i>adj. R</i> ² | 0.67 | | <i>adj. R</i> ² | 0.52 | | <i>adj. R</i> ² | 0.43 | |

Notes: Bootstrapped standard errors (1000 reps.) are reported in parenthesis. *** denotes significance at 1%, ** denotes significance at 5%, * denotes significance at 10%. The coefficients on cohort dummies are not reported to save space.

**Table 2. Long-run Elasticities:
Separate Demand Equations**

| | | |
|---|-----------|---------|
| ϵ_{CC} | -0.297 | (0.376) |
| ϵ_{AA} | -1.341*** | (0.204) |
| ϵ_{KK} | -0.494** | (0.219) |
| ϵ_{CA} | -0.313** | (0.158) |
| ϵ_{CK} | -0.035 | (0.045) |
| ϵ_{AC} | -0.026 | (0.043) |
| ϵ_{AK} | -0.032 | (0.034) |
| ϵ_{KC} | -0.017 | (0.041) |
| ϵ_{KA} | -0.103 | (0.155) |
| ϵ_{CI} | 0.096 | (0.080) |
| ϵ_{AI} | 0.409*** | (0.057) |
| ϵ_{KI} | 0.350*** | (0.078) |
| <i>Morishima elasticities of substitution</i> | | |
| σ_{CA} | 1.027*** | (0.218) |
| σ_{CK} | 0.459** | (0.205) |
| σ_{AC} | 0.271 | (0.341) |
| σ_{AK} | 0.463** | (0.211) |
| σ_{KC} | 0.280 | (0.357) |
| σ_{KA} | 1.238*** | (0.242) |

Notes: Elasticities calculated at sample means. Bootstrapped standard errors (1000 reps.) are reported in parenthesis. *** denotes significance at 1%, **denotes significance at 5%, * denotes significance at 10%.

Table 3. Semi-reduced System of Cigarette, Alcohol and Coffee Demands Estimated Using ITSUR

| <i>Cigarettes</i> | | | <i>Alcohol</i> | | | <i>Coffee</i> | | |
|---------------------|-----------|---------|---------------------|-----------|-----------|---------------------|-----------|----------|
| Constant | -6.870*** | (2.294) | Constant | 80.518 | (61.996) | Constant | 0.972 | (0.622) |
| C _{t-1} | 0.107** | (0.049) | A _{t-1} | -0.086** | (0.043) | K _{t-1} | 0.101* | (0.053) |
| C _{t+1} | 0.105** | (0.051) | A _{t+1} | -0.098** | (0.039) | K _{t+1} | 0.100* | (0.054) |
| A _{t-1} | 0.0004 | (0.002) | C _{t-1} | 1.027 | (1.122) | C _{t-1} | 0.023* | (0.013) |
| A _{t+1} | 0.002 | (0.002) | C _{t+1} | 0.735 | (1.005) | C _{t+1} | -0.002 | (0.013) |
| K _{t-1} | 0.084 | (0.196) | K _{t-1} | 1.175 | (4.274) | A _{t-1} | -0.0002 | (0.001) |
| K _{t+1} | 0.094 | (0.190) | K _{t+1} | -0.437 | (4.319) | A _{t+1} | -0.0002 | (0.0005) |
| P _{Ct} | -0.149 | (0.108) | P _{At} | -72.41*** | (8.556) | P _{Kt} | -0.070*** | (0.022) |
| P _{At} | -0.054 | (0.377) | P _{Ct} | 7.494*** | (2.458) | P _{Ct} | 0.073*** | (0.027) |
| P _{Kt} | 0.153 | (0.093) | P _{Kt} | -1.597 | (2.291) | P _{At} | -0.042 | (0.095) |
| rincome | 0.0004 | (0.002) | rincome | 0.267*** | (0.040) | rincome | 0.002*** | (0.0005) |
| fam. size | 0.357*** | (0.088) | fam. size | 5.532*** | (1.923) | fam. size | 0.003 | (0.022) |
| white | 0.657* | (0.370) | white | 31.046*** | (8.176) | white | 0.047 | (0.092) |
| college | -0.341 | (0.326) | college | 6.647 | (7.267) | college | 0.074 | (0.086) |
| adj. R ² | 0.67 | | adj. R ² | 0.53 | | adj. R ² | 0.44 | |

Notes: Bootstrapped standard errors (1000 reps.) are reported in parenthesis. *** denotes significance at 1%, ** denotes significance at 5%, * denotes significance at 10%. The coefficients on cohort dummies are not reported to save space.

**Table 4. Long-run Elasticities:
Semi-reduced System**

| | | |
|---|-----------|---------|
| ϵ_{CC} | -0.552 | (0.455) |
| ϵ_{AA} | -1.557*** | (0.246) |
| ϵ_{KK} | -0.830*** | (0.237) |
| ϵ_{CA} | -0.180 | (0.335) |
| ϵ_{CK} | 0.474 | (0.289) |
| ϵ_{AC} | 0.839*** | (0.314) |
| ϵ_{AK} | -0.117 | (0.206) |
| ϵ_{KC} | 1.136*** | (0.402) |
| ϵ_{KA} | -0.050 | (0.315) |
| ϵ_{CI} | 0.083 | (0.080) |
| ϵ_{AI} | 0.409*** | (0.056) |
| ϵ_{KI} | 0.348*** | (0.078) |
| <i>Morishima elasticities of substitution</i> | | |
| σ_{CA} | 1.377*** | (0.366) |
| σ_{CK} | 1.304*** | (0.360) |
| σ_{AC} | 1.391*** | (0.494) |
| σ_{AK} | 0.713** | (0.300) |
| σ_{KC} | 1.688*** | (0.565) |
| σ_{KA} | 1.508*** | (0.394) |

Notes: Elasticities calculated at sample means. Bootstrapped standard errors (1000 reps.) are reported in parenthesis. *** denotes significance at 1%, **denotes significance at 5%, * denotes significance at 10%.

Appendix A: Derivation of Equations (4) - (6)

The quadratic utility function is:

$$\begin{aligned}
 U = & \frac{1}{2}u_{CC}C_t^2 + \frac{1}{2}u_{AA}A_t^2 + \frac{1}{2}u_{KK}K_t^2 + \frac{1}{2}u_{NN}N_t^2 + \frac{1}{2}u_{SS}S_t^2 + \frac{1}{2}u_{DD}D_t^2 + \frac{1}{2}u_{LL}L_t^2 \\
 & + u_{CA}C_tA_t + u_{CK}C_tK_t + u_{CS}C_tS_t + u_{CD}C_tD_t + u_{CL}C_tL_t + u_{AK}A_tK_t + u_{AS}A_tS_t \\
 & + u_{AD}A_tD_t + u_{AL}A_tL_t + u_{KS}K_tS_t + u_{KD}K_tD_t + u_{KL}K_tL_t + u_{SD}S_tD_t + u_{SL}S_tL_t \\
 & + u_{DL}D_tL_t + u_C C_t + u_A A_t + u_K K_t + u_N N_t + u_S S_t + u_D D_t + u_L L_t
 \end{aligned}$$

u_{ij} are parameters carrying the sign of their respective derivatives (e.g., $u_{CC} < 0$ because $U_{CC} < 0$). We assume that $S_t = C_{t-1}$, $D_t = A_{t-1}$ and $L_t = K_{t-1}$.

$$\begin{aligned}
 \max L = & \sum_{t=1}^{\infty} \beta^{t-1} U(C_t, A_t, K_t, C_{t-1}, A_{t-1}, K_{t-1}, N_t) \\
 & - \lambda (W - \sum_{t=1}^{\infty} \beta^{t-1} (P_{Ct}C_t + P_{At}A_t + P_{Kt}K_t + N_t))
 \end{aligned}$$

Derive the first order condition(FOC) with respect to C_t :

$$\begin{aligned}
 \frac{\partial L}{\partial C_t} = & \frac{\partial U(C_t, A_t, K_t, C_{t-1}, A_{t-1}, K_{t-1}, N_t)}{\partial C_t} + \beta \frac{\partial U(C_{t+1}, A_{t+1}, K_{t+1}, C_t, A_t, K_t, N_{t+1})}{\partial C_t} \\
 & - \lambda P_{Ct} \\
 = & u_{CC}C_t + u_{CA}A_t + u_{CK}K_t + u_{CS}C_{t-1} + u_{CD}A_{t-1} + u_{CL}K_{t-1} + u_C + \beta(u_{SS}C_t \\
 & + u_{CS}C_{t+1} + u_{AS}A_{t+1} + u_{KS}K_{t+1} + u_{SD}A_t + u_{SL}K_t + u_S) - \lambda P_{Ct} = 0
 \end{aligned}$$

Solving FOC for C_t :

$$C_t = \beta_{10} + \beta_{11} C_{t-1} + \beta_{12} C_{t+1} + \beta_{13} A_{t-1} + \beta_{14} A_t + \beta_{15} A_{t+1} + \beta_{16} K_{t-1} + \beta_{17} K_t \\ + \beta_{18} K_{t+1} + \beta_{19} P_{Ct}$$

where

$$\begin{aligned} \beta_{10} &= -\frac{u_c + \beta u_s}{(u_{CC} + \beta u_{SS})} & \beta_{14} &= -\frac{u_{CA} + \beta u_{SD}}{(u_{CC} + \beta u_{SS})} & \beta_{18} &= -\frac{\beta u_{KS}}{(u_{CC} + \beta u_{SS})} \\ \beta_{11} &= -\frac{u_{CS}}{(u_{CC} + \beta u_{SS})} > 0 & \beta_{15} &= -\frac{\beta u_{AS}}{(u_{CC} + \beta u_{SS})} & \beta_{19} &= \frac{\lambda}{(u_{CC} + \beta u_{SS})} < 0 \\ \beta_{12} &= -\frac{\beta u_{CS}}{(u_{CC} + \beta u_{SS})} > 0 & \beta_{16} &= -\frac{u_{CL}}{(u_{CC} + \beta u_{SS})} \\ \beta_{13} &= -\frac{u_{CD}}{(u_{CC} + \beta u_{SS})} & \beta_{17} &= -\frac{u_{CK} + \beta u_{SL}}{(u_{CC} + \beta u_{SS})} \end{aligned}$$

Solving FOC , $\frac{\partial L}{\partial A_t} = 0$, for A_t :

$$A_t = \beta_{20} + \beta_{21} A_{t-1} + \beta_{22} A_{t+1} + \beta_{23} C_{t-1} + \beta_{24} C_t + \beta_{25} C_{t+1} + \beta_{26} K_{t-1} + \beta_{27} K_t \\ + \beta_{28} K_{t+1} + \beta_{29} P_{At}$$

where

$$\begin{aligned} \beta_{20} &= -\frac{u_A + \beta u_D}{(u_{AA} + \beta u_{DD})} & \beta_{24} &= -\frac{u_{CA} + \beta u_{SD}}{(u_{AA} + \beta u_{DD})} & \beta_{27} &= -\frac{u_{AK} + \beta u_{DL}}{(u_{AA} + \beta u_{DD})} \\ \beta_{21} &= -\frac{u_{AD}}{(u_{AA} + \beta u_{DD})} > 0 & \beta_{25} &= -\frac{\beta u_{CD}}{(u_{AA} + \beta u_{DD})} & \beta_{28} &= -\frac{\beta u_{KD}}{(u_{AA} + \beta u_{DD})} \\ \beta_{22} &= -\frac{\beta u_{AD}}{(u_{AA} + \beta u_{DD})} > 0 & \beta_{26} &= -\frac{u_{AL}}{(u_{AA} + \beta u_{DD})} & \beta_{29} &= \frac{\lambda}{(u_{AA} + \beta u_{DD})} < 0 \\ \beta_{23} &= -\frac{u_{AS}}{(u_{AA} + \beta u_{DD})} \end{aligned}$$

Solving FOC , $\frac{\partial L}{\partial K_t} = 0$, for K_t :

$$K_t = \beta_{30} + \beta_{31} K_{t-1} + \beta_{32} K_{t+1} + \beta_{33} C_{t-1} + \beta_{34} C_t + \beta_{35} C_{t+1} + \beta_{36} A_{t-1} + \beta_{37} A_t \\ + \beta_{38} A_{t+1} + \beta_{39} P_{Kt}$$

where

$$\beta_{30} = -\frac{u_K + \beta u_L}{(u_{KK} + \beta u_{LL})} \quad \beta_{34} = -\frac{u_{CK} + \beta u_{SL}}{(u_{KK} + \beta u_{LL})} \quad \beta_{38} = -\frac{\beta u_{AL}}{(u_{KK} + \beta u_{LL})} \\ \beta_{31} = -\frac{u_{KL}}{(u_{KK} + \beta u_{LL})} > 0 \quad \beta_{35} = -\frac{\beta u_{CL}}{(u_{KK} + \beta u_{LL})} \quad \beta_{39} = \frac{\lambda}{(u_{KK} + \beta u_{LL})} < 0 \\ \beta_{32} = -\frac{\beta u_{KL}}{(u_{KK} + \beta u_{LL})} > 0 \quad \beta_{36} = -\frac{u_{KD}}{(u_{KK} + \beta u_{LL})} \\ \beta_{33} = -\frac{u_{KS}}{(u_{KK} + \beta u_{LL})} \quad \beta_{37} = -\frac{u_{AK} + \beta u_{DL}}{(u_{KK} + \beta u_{LL})}$$

For $k=1,2,3$: $\beta_{k2} = \beta * \beta_{k1}$ or $\beta_{k1} = (1+r)\beta_{k2}$ since $\beta = \frac{1}{(1+r)}$ with r being

discount rate.

Appendix B: Calculation of Lewbel Price Indices for Alcoholic Beverages

Lewbel price indices allow heterogeneity in preferences within a given bundle of goods. Within bundle Cobb Douglas preferences are assumed, while among different bundles any specification is allowed. See Lewbel(1989) for details. Following Lewbel (1989) and Hoderlein and Mihaleva (2008), we construct Lewbel price indices as:

$$v_i = \frac{1}{k_i} \prod_{j=1}^{n_i} \left(\frac{p_{ij}}{w_{ij}} \right)^{w_{ij}}$$

where w_{ij} is the household's budget share of good j in group i . k_i is a scaling factor with $k_i = \prod_{j=1}^{n_i} \bar{w}_{ij}^{-\bar{w}_{ij}}$ and \bar{w}_{ij} is the budget share of the reference household.

Let $p_{ij} = P_i$ where P_i is the price index for group i which is set to 1 in the first time period. Because there are zero expenditures for some subcategories, Lewbel price index cannot be used in levels (i.e., a number divided by zero is undefined). In the empirical analysis, Hoderlein and Mihaleva(2008) used log prices instead of prices in levels using the result that $\lim_{x \rightarrow 0} x \log(x) = 0$. In our economic model, prices are in levels, so we first took the log of the Lewbel price index and then took the anti-log of it to obtain price indices.

In the current study, zero alcohol consumption might be due to so many different reasons such as quitting, abstention, corner solution and infrequency of purchase. For non-consumers, the Lewbel price index is assigned to be equal to 1 which means if the consumption took place, the expenditure shares would have been identical to that of reference household. To determine the expenditure shares of the reference household, we took the average of the expenditure shares for each consumer unit in the whole sample in the whole sample period.