PRICING POLICIES AND CONTROL OF TOBACCO IN EUROPE

Toolkit for Econometric Analysis of Demand for Tobacco

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The report is largely based on Nguyen, Rosenqvist, Pekurinen (2012). Rosenqvist wrote the first version of this toolkit except for section 5 on Data and variable specifications, for which Nguyen wrote the first version. All three authors commented upon and contributed to the whole report and are jointly responsible for it.

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1 Introduction

Health and economic consequences of smoking are described for example in the PPACTE Policy Report (Currie et al 2012). It is noted for example that within the European Union (EU), smoking continues to be the largest single cause of death and disease, accounting for over 650 000 premature deaths each year. Although Europe has only 15% of the world population, it faces nearly one third of the worldwide burden of tobacco-related diseases. In addition to the harmful health effects, there are considerable economic consequences of smoking for the EU economy, which have been estimated to be between 98 and 130 billion euro, or between 1.04% and 1.39% of the EU's GDP for 2000, quoted in Currie et al (2012).

In fact, tobacco smoking is a world wide epidemic. Whithin the EU, smoking continues to be a problem. Under such cicumstances, consumers' behavior, such as how smokers respond to higher tobacco prices and more toughen adopted tobacco control policies, should be assessed. Hence, it is naturally advised that empirical analysis of demand for tobacco should be undertaken in various countries. A large body of empirical studies exist that use aggregate data over several time periods, utilizing a variety of econometric techniques. These studies are e.g. Cox and Smith 1984, Laugesen and Meads 1991, Stewart 1993, Saffer and Chaloupka 2000, Escario and Molina 2001, Nelson 2003, and Gallus et al. 2006. These studies used to be performed mainly in high income countries although there has been a growing degree of undertaking such demand studies in low and middle income countries. The IARC (2011) handbook gives an account.

The PPACTE project set out to perform such an econometric analysis of demand for tobacco for possibly many European countries. However, finding appropriate data turned out to be a challenge as Nguyen, Rosenqvist and Pekurinen, here after *NRP* (2012) noted when reporting econometric results for only 11 EU Member States. These study states tend to be rather high income countries. Thus, further econometric studies for a larger scale of

countries are called for. This toolkit describes the methodology applied by NRP (2012) and is intended to assist further such demand studies. This report hopes to be a complement to the World Bank's Toolkit for economic analysis of tobacco demand (Wilkins, Yurekli and Hu 2003).

2 Purpose

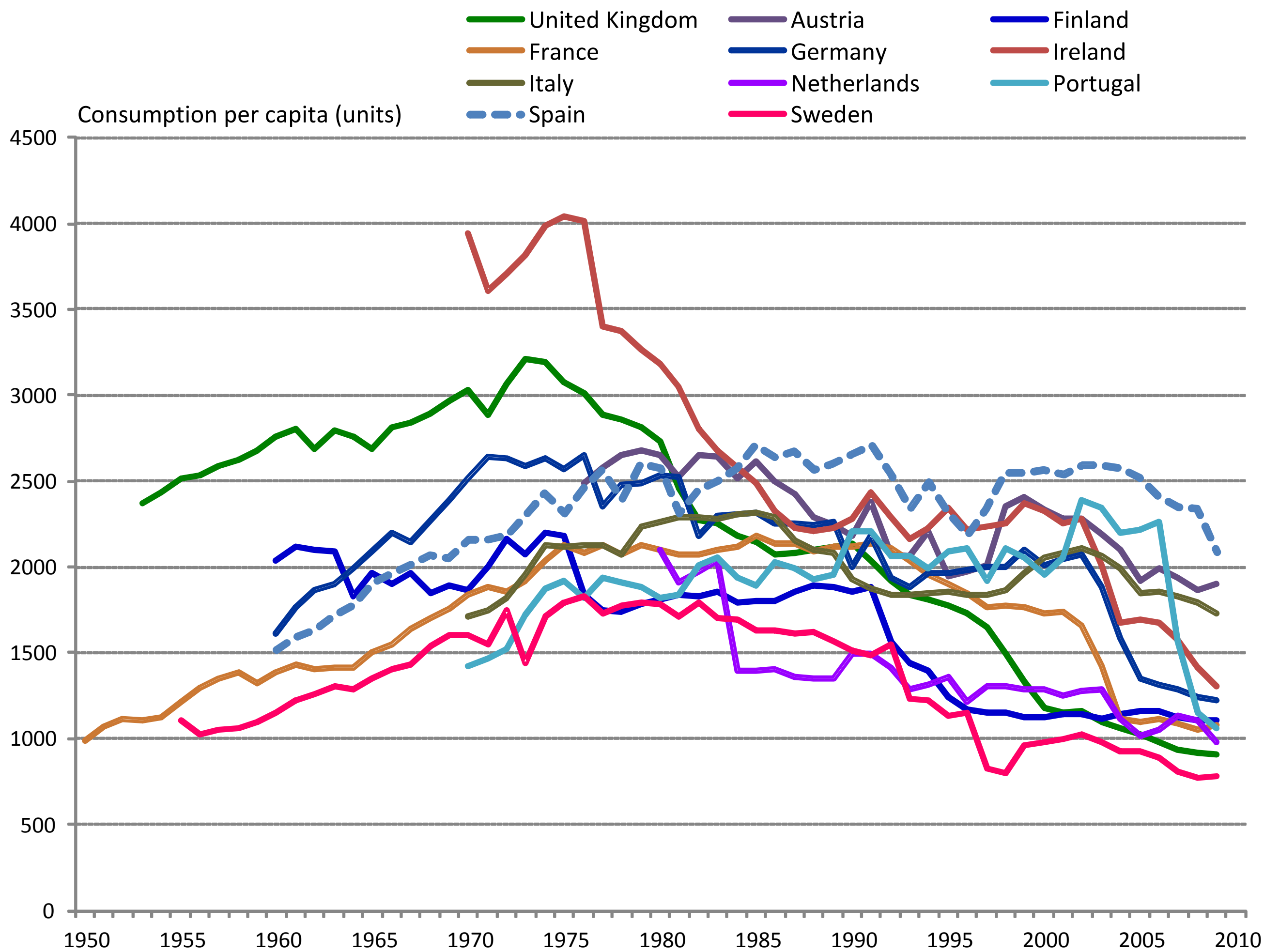
The purpose of this toolkit is to describe how econometric analysis of demand for tobacco is performed with aggregate time series data on national or corresponding level. It is an account of the methodology used by NRP (2012). As noted, this toolkit should be utilized in conjunction with the World Bank's toolkit (Wilkins et al 2003) that in a very useful way described many aspects of empirical economic analysis of demand for tobacco. Hopefully, it will be useful for researchers intending to do this type of econometric analyses in the first place. The toolkit itself also hopes to be a contribution to such demand analyses being performed for a larger scale of countries in the future.

The intended reader is assumed to have a basic research education including a basic or intermediate knowledge of statistics, econometrics, and general economics or health economics. There is of course a large set of econometric textbooks available which describes these econometric procedures, such as Enders (2010), Wooldridge (2009), Maddala and Lahiri (2009); as well as various useful review articles and handbooks like Hendry and Juselius (2000, 2001), Mills and Patterson (2007 and 2009). Doornik and Hendry (2009), in addition to describing one of the software options, also provide a good econometric tutorial.

Empirical studies of the type described in this toolkit makes it possible to explore the key factors that affect the aggregate demand for significant tobacco products (such as cigarettes, pipe and hand-rolling tobacco, and snus) on national level. They enable researchers to estimate price elasticities of demand for significant tobacco products and

investigate whether for example cigarettes and pipe and hand-rolling tobacco or/and snus are substitutes. Hence, studying price elasticities of demand and the effect of control policies on tobacco consumption will assist researchers to evaluate to what extent demand for tobacco products can be controlled by price measures and/or by other tobacco control policies. Throughout in this toolkit, we will use the case of Finland as an illustrative example.

Figures 1 and 2 giving consumption of cigarettes and real prices of cigarettes in 11 EU Member States (NRP, 2012) illustrate the kind of data the analysis of which is discussed in this toolkit.



Figur 1. Number of cigarettes consumed annually per capita in 11 EU Member States.

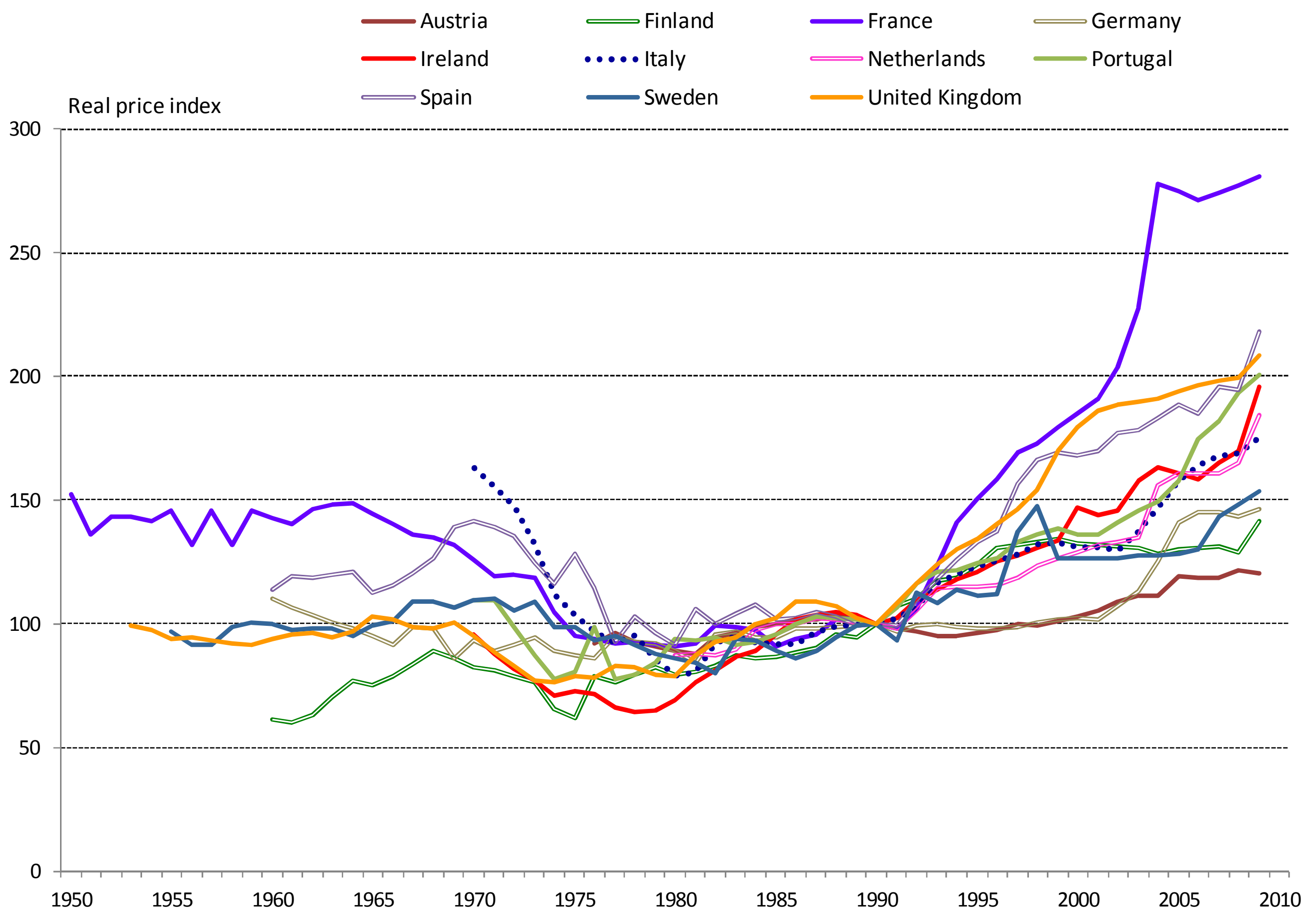


Figure 2. Real price indices of cigarettes (1990=100) for 11 EU Member States.

3 Steps in empirical economic analysis

In various econometric textbooks, you can find slightly different versions of the steps in the econometric process, for example in Wooldridge (2009). Also Wilkins et al (2003) give a list of the steps or components of a study of demand for tobacco. Based o these sources as well as on our own experiences, in particular on NRP (2012), we can define the following steps in empirical economic analysis of demand for tobacco.

(i) A *design phase* to design the study and develop structures and management procedures.

(ii) *Economic model*. Formulation of a formal economic model is a basis for economic analysis and data modeling, especially in cases that involve testing of economic theory.

(iii) *Econometric model*. The economic theoretical model needs to be turned into an econometric model, which is available for empirical analyses. This means that the form of the function relating say tobacco consumption to tobacco price needs to be specified and variables that appear in the theoretical model need to be observed. An econometric model is typically characterized by an error term because not everything of relevance can be observed and the error term is assumed to capture unobserved effects. We will see examples of econometric models in section 4.

(iv) *Formulating hypotheses* of interest in terms of the unknown parameters. Examples are given in section 4.

(v) *Obtaining and preparing data*. This may be surprisingly challenging when analyzing tobacco demand. For example NRP (2012) succeeded to obtain data from only 11 EU Member States. This stage involves following necessary steps, such as

- gathering background information and the data to be used for detailed analysis;
- evaluating and cleaning the data, and
- transforming the data

These steps will be further labored in section 5.

(vi) *Estimating* the parameters of the model.

(vii) *Testing* of the *model specification*. If the specified model is rejected, it implies that the model has to be respecified. With time series data, it is of special importance to test for autocorrelation in residuals. Autocorrelation in the residuals is a signal implying that the estimated model is not dynamically complete and thus should be augmented with further lags of the dependent variable and/or (further) lags of explanatory variables for describing better the dependent variable. This is described in section 6.

(viii) Formally *testing* of the *hypotheses* of interest.

(ix) Predictions, policy *conclusions*.

(x) *Dissemination* in order to communicate the results and findings.

Since time series data very often exhibit non-stationarity, they imply a risk for spurious relations in regression analysis. At the stage of evaluating and transforming the data,

before finally specifying and choosing the appropriate model, it is important to evaluate the stationarity of the time series to be used. Testing for stationarity is dealt with in section 6.

4 Theoretical basis

The starting point for the econometric endeavour to study the demand for tobacco products is based on economic theory. The economics of smoking with a focus on the demand for tobacco products and tobacco control policies, particularly the effect of pricing policy, as well as on alternative approaches to economic modelling of the demand for tobacco have been comprehensively reviewed previously (see e.g. Grossman et al. 1998; Chaloupka and Warner 2000; Chaloupka et al. 2000). Here, we describe only the essential economic concepts and the main economic approaches following NRP (2012).

One fundamental concept in economics is the law of demand. That is, there is a negative relationship between the price of a given commodity (or product or service) and the quantity demanded. This law of demand is derived from a constrained utility maximizing framework. Given an individual’s preferences presented by a utility function and taking into account prices, income (a budget constraint) and other factors, a demand function for a given product can be derived where the quantity in demand negatively relates to the price of that product. An issue of interest in empirical studies is typically how the quantity demanded of the product will respond to changes in the prices. This responsiveness is captured by the price elasticity of demand, representing a percentage change in quantity demanded in response to a percent change in price, with all other factors being held constant.

The quantity of tobacco demanded theoretically responds to changes in monetary prices, and other costs as well as being influenced by income and factors describing tastes. It is assumed that the demand for a tobacco product is a function of its price, the prices of other products, and consumers’ disposable income. In practice, the price variables are often

restricted to close substitutes and complements. The conventional demand model is a static model specified as

$$(1) \qquad Q_{it} = f_i(P_{it}, P_{jt}, Y_t, \mathbf{Z_t})$$

where i and j stand for two single tobacco products, and t stands for period. Q_{it} and P_{it} denote the per capita consumption of product i and its real price respectively; while P_{jt} is the real price of product j, and Y_t is the real disposable income per capita. Vector $\mathbf{Z_t}$ accounts for other factors that are thought to affect the consumption of tobacco product i, in particular tobacco control policies, such as bans and restrictions on smoking in public and work places, increased information on the health risks of smoking, public information campaigns, bans on advertising and promotion of tobacco products, warning labels on cigarette boxes and other tobacco products and treatment to help dependent smokers quit.

With a contemporaneous specification (1), the current demand specified by the conventional model is a function of current prices and income as well as other relevant explanatory variables. Addictive behaviour in consumption of a tobacco product has been modelled through backward-looking myopic addiction models, also called partial adjustment models, as well as through forward-looking rational addiction models (Becker et al. 1994; Becker and Murphy 1988). In the partial adjustment models, past consumption influences current consumption, while in the rational addiction models, not only past consumption but also future consumption affects current consumption.

The addiction approach attempts to model three dimensions of addiction—tolerance, reinforcement and withdrawal—which are associated with the consumption of addictive goods (see Ashton and Stepney 1982; Chaloupka 1988). Tolerance suggests that a given level of current consumption is less satisfying (lower utility) as cumulative past consumption is higher. Reinforcement reflects consumers' learned responses to consumption and rewards related to it. Withdrawal indicates the negative physical and mental reactions to quitting smoking and reducing or interrupting consumption. Addiction

implies that current consumption decisions are dependent upon past consumption choices and past consumption increases the marginal utility of current consumption.

In addition to reflecting the dependence of current consumption decisions on past consumption behaviour, the rational addiction model of consumption of an addictive good also considers the future consumption implications when making current consumption decisions (Becker and Murphy 1988). The consumption of an addictive good is assumed to display 'adjacent complementarity' (Becker et al. 1991; Becker and Murphy 1988). Due to reinforcement, the quantities of the addictive good demanded in different time periods are complements. In turn, this implies that current consumption of the addictive good will be inversely related to all the current, past and future prices of the good. Past consumption will have a larger impact on current consumption than future consumption, and the long-run effect of a permanent change in the price of the addictive product will exceed the short-run effect. In addition, the effect of an anticipated change in the price of that product will be higher than the effect of an unanticipated change in the price.

5 Econometric models

To estimate price and income elasticities of demand for tobacco, the typical starting point is to specify a demand equation.

We shall describe the conventional (static) model, addiction models (partial adjustment and rational addiction models) as well as error correction models.

Writing the **conventional (static) demand model** (1) as a linear equation,

$$(2) \qquad Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_{jt} + \alpha_3 Y_t + others_t + \varepsilon_t$$

where the dependent variable Q_t is per capita consumption of a given tobacco product, while P_t is the real price of the tobacco product, and P_{jt} is the real price of other tobacco products, Y_t is the real disposable income per capita, and ε_t is the error term. Parameters α_1, α_2, and α_3, which are associated with variables P_t, P_{jt}, and Y_t, are coefficients to be estimated. 'Others$_t$' stands for those factors that are thought to affect the consumption of the tobacco product described by vector $\mathbf{Z_t}$ in equation (1).[1] The static model is typically too simple to fit the data well but is often used as a starting point and a kind of elementary benchmark. As we shall see, it also appears as a long run relation in error correction models.

The **partial adjustment model** or the **myopic addiction model** can be specified as

$$(3) \qquad Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_{jt} + \alpha_3 Y_t + \alpha_4 Q_{t-1} + others_t + \varepsilon_t$$

where $0 < \alpha_4 < 1$, the lagged consumption variable Q_{t-1} is the per capita consumption of the tobacco product in the period previous to t, with the other variables being the same as in

[1] As 'others$_t$' is written in simple form here, it implicitly means that there are coefficients to be estimated that are associated with factors included in 'others$_t$'.

model (2). Tobacco use is addictive if $\alpha_4 > 0$, and the degree of addiction is greater when α_4 is larger.

The coefficient on past consumption Q_{t-1}, α_4, can be also interpreted as the speed of adjustment to the steady state level or desired level of consumption (Baltagi and Lewin 1986). The smaller is α_4, the greater is the partial adjustment factor $(1 - \alpha_4)$ and the faster actual demand will reach the steady state or desired level. In a case where a log-log specification is used, i.e., both dependent and explanatory continuous variables are log-transformed, then constant elasticity estimates of demand for a given tobacco product can be easily derived from the estimated model. For example, specified as (3), the estimated coefficient α_1 is the short-run price elasticity, while the long-run price elasticity is equal to $\alpha_1 / (1 - \alpha_4)$. The long-run price elasticity is assumed to be greater, in absolute terms, than the short-run price elasticity, indicating that a change in the current price will have a larger impact on consumption in the long run than in the short run.

The partial adjustment model (3) takes into account the addictiveness of tobacco by including the lagged dependent variable in the estimation equation. This econometric method is a standard technique that is based on the concept of persistence habit (Houthakker and Taylor 1970; Fujii 1980; Baltagi and Lewin 1986).

In the **rational addiction model** proposed by Becker and Murphy (1988), the focus is on future consumption (or future prices) in explaining current consumption. A simple version of the rational addiction model can be written as

(4) $$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_{jt} + \alpha_3 Y_t + \alpha_4 Q_{t-1} + \alpha_5 Q_{t+1} + others_t + \varepsilon_t$$

where $0 < \alpha_5 < \alpha_4 < 1$ and $\alpha_4 + \alpha_5 < 1$, the lead consumption variable Q_{t+1} is the per capita consumption of the tobacco product in the period following t, with the other variables being the same as in model (3).[2] In a case where a log-log functional form is used for

[2] In less restrictive versions of the rational addiction model, lagged and lead prices are also included in the right-hand side of the equation, e.g. $Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_{t-1} + \alpha_3 P_{t+1} + \alpha_4 Q_{t-1} + \alpha_5 Q_{t+1} + \varepsilon_t$.

model (4), the estimated coefficient α_1 is the short-run price elasticity and the long-run price elasticity is equal to $\{\alpha_1 / [1 - (\alpha_4 + \alpha_5)]\}$ where $[1 - (\alpha_4 + \alpha_5)]$ is the partial adjustment factor.

The rational addiction model (4) assumes that current consumption does not only depend on consumption that occurred in the previous period but also on future anticipated consumption that would occur in the following period. If tobacco is an addictive good, current tobacco consumption Q_t is expected to be positively associated with past consumption Q_{t-1} and future consumption Q_{t+1}. The coefficients on past consumption Q_{t-1}, α_4, and on future consumption Q_{t+1}, α_5, can be used to test for whether consumers are addicted or not, and whether they are myopically or rationally addicted. Myopic addiction or partial adjustment would imply that only the parameter α_4 is statistically significant, whereas rational addiction would also suggest that the parameter α_5 is statistically significant. If tobacco consumption is rationally addictive, the long-run price elasticity obtained will be greater than the corresponding long-run price elasticity obtained when tobacco consumption is partially adjusted (or myopically addictive).

Given that past and future consumption Q_{t-1} and Q_{t+1} are endogenous in equation (4) and past consumption Q_{t-1} in equation (3), using ordinary least squares to estimate equations (3) and (4) would lead to inconsistent estimates of the parameters of interest (e.g. Becker et al. 1994). To address this issue, assuming that the unobserved errors are not correlated with prices in periods t–1 and t+1, past and future prices can be used as instruments for past and future consumption (see further the Estimation strategies).

The fourth demand model we have applied is the **error correction model**, which in a simple version is specified as

(5) $$\Delta Q_t = \beta_0 + \beta_1 \Delta P_t + \beta_2 \Delta P_{jt} + \beta_3 \Delta Y_t + others_t + \pi \varepsilon_{t-1} + \nu_t$$

where Δ is the difference operator, for example, $\Delta Q_t = Q_t - Q_{t-1}$, and ν_t is the error term. ε_t is the equilibrium equation, which is defined by means of equation (2) as

$\varepsilon_t = Q_t - \alpha_0 - \alpha_1 P_t - \alpha_2 P_{jt} - \alpha_3 Y_t - others_t$.[3] To revert to equilibrium, the adjustment coefficient π is expected to have a negative sign ($\pi < 0$). In this case, the conventional model (2) describes the equilibrium relationship between consumption and the explanatory variables, whereas the error correction model (5) explains the short-run relationship between those variables. If a log-log specification is used for both models (2) and (5), the estimated coefficient β_1 in model (5) is the short-run price elasticity, while the estimated coefficient α_1 in model (2) is the price elasticity for the equilibrium equation ε_t. General versions of the error correction model of demand may have more consumption lags such as $\Delta Q_{t-1}, \Delta Q_{t-2}, \Delta Q_{t-3}, \ldots$ appearing as explanatory variables on the right-hand side of equation (5).

Results from a meta-analysis of demand elasticities showed that the conventional, partial adjustment and rational addiction models introduced have mostly been estimated by OLS and 2SLS methods (56.4% and 33.1%) (Gallet and List 2003). In addition, the log-log (double log) and linear-linear specifications have mostly been employed—the former being more frequently applied than the latter (54.3% and 44.2%)—and the semi-log specification is very rarely used (1.5%) (Gallet and List 2003). NRP (2012) used the log-log specification for all estimated models. Using this functional form, the coefficients of the log-transformed continuous explanatory variables obtained from the estimated models can be directly interpreted as elasticities, with the elasticities being constant.

When interpreting regression coefficients one at the time one needs to remember the *ceteris paribus* assumption, i.e., assuming everything else remains constant. In many cases this is clearly not realistic. For example, as we will argue for example in section 6 (Table 3), an increase in the real price of a tobacco product is expected to cut down individual consumption, while growth in real household disposable income is expected to increase individual consumption. The effects of these two simultaneous changes on tobacco consumption will then partly mitigate each other, and thus the effectiveness of price policies in tobacco control may be reduced. Hence, the conclusion is reached that when

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[3] The explanatory variables included in vector 'others$_t$' are also in form of 1st difference in equation (5).

evaluating and planning of tobacco price policy and other tobacco control policies the effect of real income development on tobacco consumption has to be taken into account.

6 Data and variable specifications

According to demand theory introduced above, the explanatory variables to be collected are information on price of a given product, price of the other product (if there are two main tobacco products used in a certain country), and household disposable income as well as information on tobacco control policies adopted in each country. In addition, to get real terms of economic variables (price and income), we need information on consumer price index (CPI). Since consumption and income are measured as the quantity of tobacco used and the income obtained by an adult, that is, a capita which is typically defined as a person aged at least 15 years old, the number of population aged 15 or older is also required.

There is available a general guide tool highlighting research techniques that can be adapted to the tobacco data collection process (Ciecierski and Chaloupka). This tool for example outlines the concept of aggregate data and identifies potential sources of such data. In general, econometric analysis of the type performed in a typical study of demand for tobacco using aggregate data requires sufficiently long time series. For example, while selection of countries in NRP (2012) was steered by availability of aggregate data, annual time series covering 30–60 years were used. We suppose that at minimum with annual data approximately 25 years should be required for the number of observations to be in a reasonable relation to the number of parameters to be estimated. Instrumental variables may reduce the number of observations when estimating dynamic models (e.g. Becker, Grossman and Murphy, 1994) and the effects of different tobacco control policies on tobacco consumption by means of dummy variables imply further loss of degrees of freedom. Moreover, the length of the time series for each time series variable should be exactly the same. That is, judging by the number of observations, all the selected time series should be balanced. Hence, in practice, depending on sources, availability of information on variables that are concurrently needed can limit very much the length of the

time series, narrowing down the number of observations. Different sources need to be found to collect data for a desirable long period.

For each country or market to be analyzed, the most popular types of tobacco products should be identified. Cigarettes are the tobacco product most used in all countries as cigarette consumption and smoking are very apparent in every day. Information on cigarette consumption and prices is rather easy to obtain. For finding products much used besides cigarettes, judgement can be based on background or research information, but practically on collected consumption data. If consumption figures are quite small or end at some year although consumption did exist during several previous years, that product cannot be selected and analyzed. Per capita cigarette consumption (in 11 countries), per capita consumption of pipe and hand-rolling tobacco (in Finland, Germany and the Netherlands), and per capita consumption of snus (in Sweden) were dependent consumption variables in NRP (2012). A capita was defined as a person aged at least 15 years old, who is generally assumed to be an adult in this typical demand study.

Where to collect data?

It is generally less expensive and easier to collect information on aggregate data than on individual data. There exists a large body of useful sources where aggregate data are available for tobacco demand analysis. By the experience of NRP (2012), five groups of sources of aggregate data can be distinguished:

i) National Statistical Offices
ii) Ministries of Finance
iii) Other departments of government (e.g. Revenue – Irish Tax and Custom)
iv) Private data agencies, e.g. Tobacco Market Commission (CMT), and the Tobacco Manufacturers' Association (TMA)
v) International organizations: Annual macro-economic (AMECO)[4], Statistical Office of the European Communities (EuroStat)[5], and Organization for Economic Co-operation and Development (OECD)[6]

[4] See http://ec.europa.eu/economy_finance/ameco/user/serie/SelectSerie.cfm.
[5] See http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home.

vi) Publications (e.g. Hill and Laplanche 2003) (see also Ciecierski and Chaloupka).

The primary data sources used in NRP (2012)'s study are introduced in Table 1. As seen, national statistical offices were the first sources where most information collected and used was obtained.

Table 1. Data sources used in the study by NRP (2012).

Country	Availability	Source				
		Tobacco products' consumption	Consumer price index	Price	Disposable income	Population
Austria	1976–2000	USDA FAS				
	2001–2000	Ministry of Finance	Austria Statistics			
Finland	1960–2009	Statistics Finland (Tilastokeskus)				
France	1950–2003	Hill & Laplanche (2003)	OECD	Hill & Laplanche (2003)	National Institute of Statistics and Economic Studies (INSEE)	
	2004–2009	Altadis/DGDDI	OECD	INSEE	INSEE	INSEE
Germany	1960–1989					
	1991–2009	German Federal Statistical Office				
Ireland	1970–2009	Revenue - Irish Tax & Customs	Central Statistics Office of Ireland (CSO)			
Italy	1970–1990	National Institute of Statistics (ISTAT)	OECD	ISTAT	OECD	EuroStat
	1990–2009	ISTAT	OECD	ISTAT	OECD	EuroStat
Netherlands	1980–2009	Statitistics Netherlands (CBS)				
Portugal	1970–2009	Statistics Portugal (INE)			OECD	EuroStat
Spain	1960–1975	Tobacco Market Commision (CMT)	OECD	CMT	AMECO	EuroStat
	1975–2009	CMT	OECD	National Statistics Institute (INE)	AMECO	EuroStat
Sweden	1955–2009	Statistics Sweden (SCB)				
United Kingdom	1953–2009	Tobacco Manufacters' Association (TMA)	Office for National Statistics (ONS)			

Note.
AMECO database = Annual macro-economic database

[6] See http://stats.oecd.org/.

EuroStat = Statistical Office of the European Communities
OECD = Organization for Economic Cooperation and Development
DGDDI = Direction générale des douanes et droits indirects (Directorate General for customs and excise)
USDA FAS = United States Department of Agriculture, Foreign Agricultural Service

Information on used variables can be obtained from international organizations' online databases in addition to national statistical offices' online databases. In general, time-series data on price and income variables for 15–25 years were obtained directly online from the national statistics offices' websites, while longer expanded time-series data were provided by statistical advisors from several national statistics offices by contacting them directly or by exploring manually, for example, old published national statistical yearbooks.

Checking the quality of data

In this kind of study, in which time series data are used, trends and relative changes are more important than absolute values. Hence, when short series that are collected from different sources (e.g., a national statistical office, the EuroStat, and the OECD) are combined and chained, they should be checked and justified. For example, by plotting the data, relative changes in the number over time can be looked at. Furthermore, by comparing the profiles of the curves drawn by time series, the time series obtained from different sources for the same variable can be assessed whether they have similar trends and profiles or not.

NRP (2012) used disposable household income collected directly from the national statistics offices for eight countries including Austria, Finland, France, Germany, Ireland, the Netherlands, Sweden, and the United Kingdom. However, they had to use net national disposable income collected from the OECD online databases for Italy and Portugal and from the AMECO databases for Spain. Indeed, the detailed profiles of the curves depicted by different short income series were compared before deciding to use data from sources other than their national statistical offices.

Tax paid annual sales data or industry data of actual release into the domestic market are generally used as proxies for each tobacco product's annual consumption in estimated demand models. Per capita tobacco consumption in the country-specific data is assumed to

reflect the behaviour of a representative consumer in that country. For a given country x at time t, per capita consumption of a tobacco product, let's say cigarettes, is obtained by dividing total annual cigarette sales/consumption at time t by the mean adult population at time t. Similarly, dividing total country-level disposable income by the mean adult population will lead to per capita disposable income. That is,

$$Per\ capita\ cigarette\ consumption_{x,t} = \frac{Total\ annual\ cigarette\ consumption_{x,t}}{Total\ adult\ population_{x,t}} \text{ and}$$

$$Per\ capita\ disposable\ income_{x,t} = \frac{Total\ disposable\ income_{x,t}}{Total\ adult\ population_{x,t}}.$$

In order to obtain elasticity estimates of demand, it does not matter whether prices of tobacco products and income are monetary values or indices because elasticity estimates are the same.[7] As such, NRP (2012) used tobacco products' retail prices and retail price indices but also information on the prices of cigarette packs for the period 1960–1975 in Spain's statistical analysis to get a longer price series 1960–2009 instead of the shorter price series 1976–2009. The idea here is to first compute price indices based on monetary prices and then to chain indices by combining two price series.

To get the real terms, the per capita disposable income and the retail price index are deflated by the consumer price index. For country x at time t, real price index of cigarettes and real disposable income are calculated as:

$$Real\ cigarette\ price\ index_{x,t} = \frac{Cigarette\ price\ index\ at\ current\ price_{x,t}}{Consumer\ price\ index_{x,t}} \text{ and}$$

$$Real\ disposable\ income_{x,t} = \frac{Disposable\ income\ at\ current\ price_{x,t}}{Consumer\ price\ index_{x,t}}.$$

[7] This applies for log-log situations, i.e. for models with both the dependent and explanatory variable being in logarithmic form. For log-level, level-log and level-level situation, the interpretation of the slope parameter changes by such a transformation. However, things are still under control as long as one is aware of the change in interpretation. A good account of this is given e.g. by Wooldridge (2009).

Official information can be disjoint and insufficient, inconsistent or inadequate due to external reasons such as measurement unit was changed from lbs to kg and changes in data collection methods. NRP (2012) had to correct and adjust consumption figures for Germany, Ireland, and Italy. For example, due to the reunification of Germany in 1990, the consumption figure for 1990 that did not exist was computed as the mean of the total consumption in 1989 and 1991. In Ireland, manufactured cigarettes consumed in 1970–1976 were counted in lbs. However, if each cigarette was counted as weighing a nominal 1 g of tobacco, the consumption figures for that period seemed to be very small compared to the following years. Historical tobacco consumption and excise duties were checked. It appeared that there was no increase in excise duty in 1978. Accordingly, the number of cigarettes in 1978 was pro rata to the excise, which gave a formula to check the number of cigarettes in 1977 in relation to the number of cigarettes in 1978. The ratio of the former to the latter was used to convert the cigarette consumption in lbs in 1977 to the number of cigarettes in 1978. Then, this factor was used as a basis to convert the consumption in lbs to the number of cigarette for 1970–1976. For Italy, the consumption data were based on the sum of both consumptions of foreign and national cigarettes. The total number of cigarettes consumed in 1981 was used as the base line to chain the consumption figures backwards since 1981 in order to obtain consumption for domestic use. For Portugal, the consumption data were based on apparent consumption that is production plus imports and minus exports. There was a sharp drop in the consumption figures from 2006 to 2007, which appeared to be correct and could not be explained yet.

Table 2 introduces explanatory economic variables used in the empirical models of demand for tobacco products by NRP (2012). As noted, they had to combine different time series in order to get long series for some variables. For example, price index of tobacco was use as price index of cigarettes for 1970–1975 for Ireland and for 1953–1973 for the United Kingdom. For Spain, price of a 20-cigarette pack was used for 1960–1975 and price index of tobacco for 1976–2009.

Table 2. Price and income variables used in the study by NRP (2012).

Country	Explanatory variable					
	Real price index				Real disposable income	
	Cigarettes	Pipe and HRT	Snus	Tobacco	Household	Net national
Austria	x				x	
Finland	x	x			x	
France	x				x	
Germany	x	x			x	
Ireland[a]	x				x	
Italy				x		x
Netherlands	x	x			x	
Portugal				x		x
Spain[b]				x		x
Sweden	x		x		x	
United Kingdom[c]	x				x	

Note. HRT = Hand-rolling tobacco
[a] For Ireland, we used price index of tobacco for the period 1970–1975 and price index of cigarettes for 1976–2009.
[b] For Spain, we used price of a 20-cigarette pack for 1960–1975 and price index of tobacco for 1976–2009.
[c] For United Kingdom, we used price index of tobacco for 1953–1973 and price of cigarettes for 1974–2009.

The total consumers' expenditure series for tobacco products (all tobacco, cigarettes) can be also used to derive implicit price deflators for those tobacco products. For example, for the United Kingdom, NRP (2012) used the total consumers' expenditures for tobacco at current and constant prices taken from the National Accounts to derive retail price indices of tobacco for some years before 1970.

For deriving price elasticity estimates, the most vital economic variable is the price of a tobacco product, which should be included in all empirical models for tobacco demand as an explanatory variable. In addition to price and income, various population-level tobacco control interventions also affect tobacco use. To economize on the degrees of freedom of models, while picking up the whole of the effects of diverse tobacco control policies in a single variable consistently among different countries, the so-called tobacco control policy (TCP) index (Currie 2012) can be used as an explanatory variable in the empirical models. This control index was constructed and modified following Joossens and Raw's (2006) original TCS, which is seen as an attempt to systematically measure the overall magnitude of the implemented tobacco control policies at country level (Joossens and Raw 2006). The TCP index excludes price policy but includes the four following policy areas: (1) smoke-

free workplace and other public places (total 22 points), (2) comprehensive bans on advertising and promotion, (3) large direct health warning labels, and (4) treatment to help dependent smokers quit. Currie (2012) gives a detailed description of the construction of TCP indices for 11 countries.

Since the original TCS score is based on what was deemed 'best practice' in 2005 and thus allocates points only for comprehensive bans, the constructed TCP index can be useful for most recent years but may become less relevant the further back we go. Furthermore, due to that many European countries started to implement smoke-free policies and tobacco control interventions mostly since the beginning of 1970s (IARC 2009), the TCP index had a zero value before 1970.

As an alternative traditional approach to describing the impacts of tobacco control policies on tobacco consumption, dummy variables have been used as explanatory variables in the empirical demand models. In addition, dummy variables can be used to describe the impacts of those policies and interventions that were implemented earlier than 1970, as well as those interventions not included in the TCP index variable.

The literature suggests three types of dummy variables. The first indicate limited duration effects, which have a value of one in the year of a policy measure (health education, health scare, health campaigns etc.) and for a specified number of years after the particular event (see Witt and Pass 1981). This dummy variable captures the immediate though short-lived effect that the measure has had on consumption. The second type of dummy variable describes permanent effects: the specified dummy variable has a value of one in the year of the measure and all subsequent years. This practice suggests that a particular measure results in an effect that extends beyond the immediate effect on consumption during the year in which it occurs and is permanent. This generally reflects the view that the resulting effects are not just fleeting but irreversible. The third type of dummy variable combines a permanent effect with a time trend (to capture a relapse or a growth rate), which is defined by $R = 1, 2, 3, \ldots$ for the years following the measure. This dummy variable accounts for the erosion (or intensification) of the initial effect of the measure on consumption, i.e., it

allows for the initial impact of the health measure to change (fade or grow) in subsequence years. These three types of dummy variables were used as explanatory variables in the tobacco demand equations of several studies (e.g. Jones 1989; Pekurinen 1989, 1992; Duffy 1996).

In NRP (2012), the TCP index variable was assumed to substitute all dummy variables describing tobacco control policies from 1970 onwards. However, for six countries (Finland, France, Germany, Spain, Sweden, and the United Kingdom) that had time series began before 1970, several dummy variables were included in the models after going through country-specific tobacco control policies. In addition, two one-year limited duration variables (D1960 and D1964) that were assumed to capture the effects of 'health scares' (or health education) were added in the models for Sweden, and a similar one-year dummy variable (D1964) in the models for Finland.

To the demand models of the United Kingdom, NRP (2012) included four dummy variables D1962, D1971, D1977, and D1983, and four time-trend variables R1963, R1972, R1978, and R1984, following the Atkinson-Skegg approach (1973). The combination of dummy and recovery-trend variables has been used in practice in several previous British studies (Duffy 1996; Jones 1989; Witt and Pass 1984). The four years 1962, 1971, 1977, and 1983 were singled out as containing significant health events in the United Kingdom that coincided with the publication of the four Royal College of Physicians' (RCP) reports on smoking and health. Four dummy variables D1962, D1971, D1977, and D1983 were expected to describe reduction in consumption at the time of publication. The four trend variables R1963, R1972, R1978, and R1984 were used to allow for effects of a gradual return to previous levels of consumption following the time of publication of each RCP report as the health scare wears off in smokers' memories. Table 3 presents definitions for all the variables and the anticipated directions of the effects of the explanatory variables on each dependent variable by NRP (2012).

Table 3. Variables and expected signs of the effects of the explanatory variables on consumption of tobacco products.

Variable	Definition	*A priori* expectation		
		Cigarettes	Pipe and hand-rolling tobacco	Snus
Dependent variable				
Q_{st}	Number of cigarettes consumed in the current year			
Q_{pt}	Quantity of pipe and hand-rolling tobacco consumed in the current year (g)			
Q_{snust}	Quantity of snus per capita consumed in the current year (g)			
Explanatory variable				
Price, income and consumption				
P_{st}	Real price of cigarettes	–	+	+
P_{pt}	Real price of pipe and hand-rolling tobacco	+	–	
P_{snust}	Real price of snus	+		–
Y_t	Real disposable income per capita	+	+	+
Q_{st-1}	Number of cigarettes per capita consumed in the previous year	+		
Q_{st+1}	Number of cigarettes per capita consumed in the following year	+		
Q_{pt-1}	Quantity of pipe and hand-rolling tobacco per capita consumed in the previous year (g)		+	
Q_{pt+1}	Quantity of pipe and hand-rolling tobacco per capita consumed in the following year (g)		+	
$Q_{snust+1}$	Quantity of snus per capita consumed in the following year (g)			+
$Q_{snust+1}$	Quantity of snus per capita consumed in the following year (g)		+	+
Tobacco control				
For all eleven countries				
TCS_t	Magnitude of tobacco control policies implemented in the country	–	?	?
For Finland				
D1964	Health education = 1 for 1964; 0 otherwise	–	–	
For Sweden				
D1960	Health education = 1 for 1960; 0 otherwise	–		–
D1964	Health education = 1 for 1964; 0 otherwise	–		–
For United Kingdom				
D1962	First Report by Royal College of Physicians = 1 for 1962 onwards; 0 otherwise	–		

Table 3. Continued

Variable	Definition	*A priori* expectation		
		Cigarettes	Pipe and hand-rolling tobacco	Snus
D1971	Second Report by Royal College of Physicians = 1 for 1971 onwards; 0 otherwise	–		
D1977	Third Report by Royal College of Physicians = 1 for 1977 onwards; 0 otherwise	–		
D1983	Fourth Report by Royal College of Physicians = 1 for 1983 onwards; 0 otherwise	–		
Control variable				
For Finland				
D1992	Economic depression period = 1 for 1992, 1993 and 1994; 0 otherwise	–	–	
For United Kingdom				
R1963	Relapse rate = 0 prior to 1963 = 1, 2, …, 8 for 1963 to 1970 = 9 for 1971 onwards	+		
R1972	Relapse rate = 0 prior to 1972 = 1, 2, …, 5 for 1972 to 1976 = 6 for 1977 onwards	+		
R1978	Relapse rate = 0 prior to 1978 = 1, 2, …, 5 for 1978 to 1982 = 6 for 1983 onwards	+		
R1984	Relapse rate = 0 prior to 1983 = 1, 2, …, 3 for 1984 to 1986 = 4 for 1987 onwards	+		

Another way to control for the overall impacts of the implemented tobacco control policies on tobacco consumption is to use information on expenditure spent on anti-smoking measures (such as health education activities, media campaigns, prevention and research, and health care services) to reduce smoking and to promote health. This kind of information is not generally available for extended periods of time and could for example not be taken into account by NRP (2012). The impacts of the tobacco control policies on tobacco consumption are assumed to be accounted for by including in the country-specific demand models the TCP index variable and by additional dummy and trend variables. Significant special events can be also represented by specific dummy variables. For

example, as Finland suffered from a deep economic depression in the first half of the 1990s, it may be well motivated to include a dummy variable for that (NRP 2012).

6 Estimation strategies

6.1 Identification

An important issue often addressed in the econometric literature is how to distinguish between the supply and demand of a given product (see e.g. Wilkins et al. 2003). Any movement in the equilibrium point, where the supply and demand curves cross and the price–quantity combination is established, can be the result of a change in the supply curve or in the demand curve or in both curves. Due to this potential problem of identification, a system approach is advised so as to identify the demand curve.

In general, demand and supply in markets are determined simultaneously and it is then not immediately obvious whether a model fitted to quantity and price data depicts the demand or the supply function. This is a case of an identification problem which has to be decided for estimation to be meaningful. In statistics and econometrics it is said that a model is **identifiable** if it is theoretically possible to learn the true values of the model's underlying parameters after obtaining an infinite number of observations from it. If a model is not identified consistent estimation of its parameters is not possible. For a model which fails identification, estimation of the model's parameters is pointless.

However, tobacco markets are typically not perfect. Usually, there are only a limited number of suppliers on the market and price is largely determined by taxes. Often, price is assumed to be exogenous to consumption and observed data on price and consumption then lies on the demand curve. Identification issues for tobacco demand models are discussed by e.g. Bishop and Yoo (1985) and Wilkins et al. (2003).

6.2 Endogenous explanatory variables

The conventional model is often estimated by ordinary least squares (OLS). However, if some of the explanatory variables are in fact endogenous using the OLS method would lead to biased and inconsistent estimators. For example, given that the partial adjustment model is vulnerable to endogeneity of past consumption and the rational addiction model to endogeneity of past and future consumption, using the OLS method bears the risk of giving biased and inconsistent estimators. Partial adjustment and rational addiction demand models can however be estimated with instrumental variables by the two-stage least squares (2SLS) method (e.g. Becker et al 1994). NRP (2012) assumed that the prices of the tobacco products in the selected EU countries are heavily controlled by governments and thus could be assumed to be exogenous. Because prices are strongly correlated with consumption, we believe that they are suitable instruments for consumption. In the partial adjustment models, NRP (2012) used as instruments two lags of own price plus the other explanatory variables. In the rational addiction models, we use as instruments two lags and two leads of own price plus the other explanatory variables.

6.3 Stationarity of time series variables

Since we are dealing with time-series data, there is the danger of having spurious regression if the variables used are non-stationary (see e.g. Enders 2010, Hendry and Juselius 2000). A stationary time series is one whose statistical properties such as mean, variance, autocorrelations etc. are all constant over time. A series with a trend, either deterministic or stochastic, is an example of a non-stationary series. If the trend is stochastic, the variance increases with time. A stationary time series implies that no trend is observed in the series. A time series can be trend-stationary, basically meaning that it is stationary around its deterministic time trend. A variable is said to be integrated of order one, I(1), if it becomes stationary after differencing once, i.e. if $\Delta x_t = x_t – x_{t-1}$ is stationary. Because a stationary series does not need to be differenced, it is said to be integrated of order zero, I(0).

It is of importance to realize the risk of spurious results because of unaccounted trends in time series. For example, Hendry and Juselius (2000) point out that when regressing one

I(1) variable on another I(1) variable, the typical critical value on 5% level of significance in the usual t-test of the regression coefficient exaggeratedly shifts from about 2 to 14.8! Under the null hypothesis of no relation, the distribution of the t-test statistic in the usual t-test explodes. In fact, it no longer follows a t-distribution. Then, one is very likely to find a relation between the variables although there is no such relation.

To account for the nature of the time-series variables analyzed, it is recommended to examine for all individual time series whether they are stationary or not. For Finland results are given in Appendix B, reporting results from so called Augmented Dickey-Fuller (ADF) tests and Phillips-Peron tests. It is concluded that all the variables are non-stationary I(1) and their first differences stationary I(0). NRP (2012, Appendices D1–D11) concluded the same for all the variables of interest for all eleven countries studied. These test results not only imply a risk of spurious relations for the three models with the variables in level form, particularly for the conventional model, but also suggest that the error correction model is well motivated.

6.4 Diagnostic tests of goodness of model fit

Various diagnostic tests are available for evaluating the fitted models. Among these, particular attention should be paid to tests for autocorrelation in residuals, for example with Ljung-Box Q(k) and the Breusch-Godfrey Lagrange-multiplier AR(p) tests. When the test statistics are significant, they signal that the dynamics in the data are not well captured by the estimated model, implying unreliability in the estimation results. In particular, models that use non-stationary variables but do not take care of the non-stationarity are expected to show significant autocorrelation in the residuals. The Ljung–Box test is a test of whether any of the k first autocorrelations are different from zero. Instead of testing autocorrelations separately at each distinct lag, it provides an "overall" test of a number of lags, and is therefore a portmanteau test. The Breusch-Godfrey Lagrange-multiplier test assumes that the error term ε_t of any model, for example one of those in equations (2) - (5), can be written

(6) $$\varepsilon_t = \rho_1\varepsilon_{t-1} + \rho_2\varepsilon_{t-2} + ... + \rho_p\varepsilon_{t-p} + u_t$$

and the null hypothesis to be tested $H_0 : \rho_j = 0$ for all j = 1, 2, …, p means that there is no autocorrelation of any order up to p.

The Augmented Dickey-Fuller test mentioned above can also be used to test for cointegration by checking for stationary residuals out of the estimated equation of the conventional model (2). Results for each of cigarettes and pipe and hand-rolling tobacco are given in Table 4 for Finland along with corresponding results for ten other countries studied by NRP (2012). When the estimated residuals are stationary, cointegration can be established for the demand equation, as is the case in Table 4 for both these tobacco products for Finland as well as for all the other countries. Following this, in each case an error correction model can be set up and is estimated using the Engle-Granger two-step OLS method (Engle and Granger 1987).

Table 4. Testing the stationarity of residuals of the long-run (equilibrium) equations.

Country	Long-run demand equation	Coefficient	ADF test statistic	Number of observations	Are residuals stationary?
Austria 1976–2009					
	Consumption of cigarettes	-0.486	-3.312	33	Yes
Finland 1960–2009/1960–2002					
	Consumption of cigarettes	-0.361	-3.252	49	Yes
	Consumption of pipe and hand-rolling tobacco	-0.422	-3.375	42	Yes
France 1950–2009					
	Consumption of cigarettes	-0.156	-2.215	59	Yes
Germany 1960–2009					
	Consumption of cigarettes	-0.355	-3.258	49	Yes
Ireland 1970–2009					
	Consumption of cigarettes	-0.154	-2.425	39	Yes
Italy 1970–2009					
	Consumption of cigarettes	-0.139	-1.671	39	Yes[#]
Netherlands 1980–2009					
	Consumption of cigarettes	-0.970	-5.097	29	Yes
	Consumption of pipe and hand-rolling tobacco	-0.870	-4.548	29	Yes
Portugal 1970–2009					
	Consumption of cigarettes	-0.311	-2.229	39	Yes
Spain 1960–2009					
	Consumption of cigarettes	-0.546	-4.194	49	Yes
Sweden 1955–2009					
	Consumption of cigarettes	-0.901	-6.635	54	Yes
	Consumption of snus	-0.298	-2.720	54	Yes
United Kingdom 1953–2009					
	Consumption of cigarettes	-0.333	-3.239	56	Yes

Criticical values: 1% = –2.622; 5% = –1.950; 10% = –1.610.
[#] At the significance level of 10%.

6.5 Recursive estimation

Recursive estimation is a powerful tool that can be used to detect structural changes in models and see how parameter estimates and other model characteristics have changed over time. Appropriate estimation techniques are available in PcGive (Doornik and Hendry

2009). Basically, the idea is to fit the model first to an initial sample of, say, M observations and then fit it successively to samples of M+1, M+2, … up to the total number of, say, T observations. The results are best illustrated graphically, as an example see Appendix D for the case of Finland.[8]

6.6 Phases of the estimation strategy

For each analyzed tobacco product and for each model to be estimated we recommend first to test all the variables for stationarity in level form. If it is concluded that a variable is not stationary, take first differences and test again for stationarity. In our experience the variables are typically not stationary in levels, but are so in first differences[9].

Next, the three models (2)–(4) are estimated with variables used in level form and the error correction model (5) with variables used in first differences. For each estimated model, carry out model diagnostic tests. Finally, use recursive estimation techniques to produce recursive least squares graphical constancy statistics for models which are considered to be selected.

6.7 Evaluating and selecting models

As noted, testing for autocorrelation in the residuals from a model for time-series data is a central diagnostic tool to evaluate the model. If significant autocorrelation is present in the residuals from an estimated model, this signals that the model is not "dynamically complete", suggesting that further lags should be included in the model as explanatory variables. Typically, additional lags of the dependent variable would be added to the right-hand side of the demand equation. For example, the first lag, the second lag, the third lag, etc. of the consumption variable in first differences $\Delta \ln Q_{st-1}$, $\Delta \ln Q_{st-2}$, $\Delta \ln Q_{st-3}$, ..., can be added to the error correction model of cigarette demand as additional explanatory variables until the estimated model does not exhibit autocorrelation in the residuals.[10]

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[8] For detailed explanations of interpretation, see Doornik and Hendry (2009).

[9] If a variable has to be differenced say two times to become stationary, it is said to be integrated to order two, I(2).

[10] Lagged versions of differenced price and income can also be added to the error correction model (5). Models that use variables in levels, such as the conventional model (2), the partial adjustment model (3), and the rational addiction model (4), can similarly be augmented with lags of consumption, price, income, and

NRP (2012) did not pursue the approach of extending the model dynamics described above, but focused on the estimation of four models (2)–(5), i.e., the conventional, partial adjustment, rational addiction, and error correction models. However, augmenting the conventional model (2) with the lagged consumption variable on its right-hand side as an additional explanatory variable—whereby the conventional model (2) becomes the partial adjustment model (3)—is in fact a step of this type. In the event that the conventional model (2) results in strong autocorrelation in the residuals, we would not be surprised if the partial adjustment model (3) results in less autocorrelation in the residuals. That is, compared to model (2), model (3) is much improved in terms of autocorrelation because the residual autocorrelation is less serious in model (3). Models (4) and (5) can be seen as adding further dynamic features to model (3).

Table 5. Residual autocorrelation

Country	Conventional model		Partial adjustment model		Rational addiction model		Error correction model	
	Q(1)	AR(2)	Q(1)	AR(2)	Q(1)	AR(2)	Q(1)	AR(2)
Austria	yes	yes	yes	no	yes	no	no	no
Finland								
Cigarettes	yes	yes	no	no	no	no	no	no
Pipe & HRT	yes	yes	yes	yes	yes	no	no	no
France	yes	yes	yes	yes	no	no	no	yes
Germany	yes	yes	yes	no	no	no	no	no
Ireland	yes	yes	yes	no	no	yes	no	no
Italy	yes	yes	yes	yes	yes	no	yes	yes
Netherlands								
Cigarettes	no	no	no	no	no	no	no	no
Pipe & HRT	no	no	no	no	no	no	no	no
Portugal	yes	yes	no	yes	no	no	yes	yes
Spain	yes	yes	yes	yes	yes	no	no	no
Sweden								
Cigarettes	no	no	no	no	yes	no	no	no
Snus	yes	yes	yes	no	yes	no	no	no
United Kingdom	yes	yes	yes	yes	no	no	yes	yes

Note. If not otherwise stated, estimated country-specific models are models of cigarette demand.
Yes (no) = Residual autocorrelation is significant (insignificant) at the significance level of 5%
HRT = Hand-rolling tobacco
Q(1) = Ljung-Box Q test for serial correlation with one lag included
AR(2) = Breusch-Godfrey Lagrange-multiplier test for autocorrelated residuals with two lags included

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other possible explanatory variables. The number of lags can be decided by using t-tests of their significance and other usual model diagnostics, in particular, tests for autocorrelation in residuals.

Table 5 summarizes the results of testing for autocorrelation in residuals for all models and products applied by NRP (2012). It is seen that the conventional model, which is a static model having no lags of any variables on the right-hand side of the equation at all, rarely passes the autocorrelation tests, whereas the more dynamically the model is specified (i.e., the more to the right we move in Table 5), indeed the less often we find autocorrelation in the residuals. Thus, the partial adjustment model passes the autocorrelation tests clearly more often than the conventional model, and the rational addiction model more often than the partial adjustment model. Judging from Table 5, the rational addiction and error correction models perform about equally well on these tests, although there may be other grounds to choose between these two models.

Table 6. Test statistics for t-tests of own price elasticity for conventional, partial adjustment and rational addiction models from NRP (2012).

Country	Product	Conventional model	Partial adjustment model	Rational addiction model
Austria				
	Cigarettes	0,22	-0,04	-0,25
Finland				
	Cigarettes	-10,86	-3,04	-1,8
	Pipe & HRT	-8,22	-1,23	-1,5
France				
	Cigarettes	-6,07	-4,02	-0,81
Germany				
	Cigarettes	-8,26	-5,11	-3,61
Ireland				
	Cigarettes	-4,15	1,34	-0,38
Italy				
	Cigarettes	-6,38	-1,05	-1,12
Netherlands				
	Cigarettes	-9,00	-3,92	-1,92
	Pipe & HRT	0,04	0,02	0,13
Portugal				
	Cigarettes	-4,45	-2,55	-1,13
Spain				
	Cigarettes	-5,14	-2,61	-2,42
Sweden				
	Cigarettes	-1,99	-1,96	-1,8
	Snus	4,16	0,69	0,62
United Kingdom				
	Cigarettes	-16,51	-5,94	-4,15
Average		-5,47	-2,1	-1,44

Table 6 reports test statistics of individual t-tests for own price elasticity in the fourteen different analyses reported by NRP (2012) for conventional, partial adjustment and rational addiction models, as well as their averages. We find a picture that clearly corresponds to that of the residual autocorrelations in Table 5. For example, while the t-statistic for the own price variable is on average −5.47 in the conventional model, it is only −2.10 in the partial adjustment model, which reduces further to −1.44 in the rational addiction model. We observe that for all study countries and tobacco products, when the t-statistic of the own price variable (i.e., the t-statistic of own-price elasticity of demand) is statistically significant, the order of magnitude for the t-statistics resulting from these three models (the conventional model, partial adjustment model, and rational addiction model) is the same.

In addition, in some cases, the coefficient of the own price variable in the conventional model has a very high t-value. For example, for the United Kingdom and Finland, the t-values of the own-price elasticity in the conventional models of cigarette demand are −16.51 and −10.86 respectively. A similar analysis can be done for the t-statistic of the income variable. The combined message from the Tables 5 and 6 is: the more autocorrelation in the residuals, the higher the t-values. Simple – too simple – models give misleadingly high t-values. This illustrates spurious correlation. Obviously models can not be judged on t-values of regression coefficients only. Furthermore, the simpler models tend to give not only more (seemingly!) statistically significant results but also to produce higher estimates of the effects of own price and income on consumption (i.e., own-price elasticity and income elasticity).[11] All in all, we should be aware of the danger of a spurious correlation when dealing with time-series data.

It is not always unambiguous for us to decide on our preferred model. Based on the above discussion, we recommend paying particular attention to autocorrelation in the residuals resulting from the different models. In addition, we look at the plausibility of elasticity estimates from the point of view of theoretical expectations and estimated elasticities from previous studies for various countries. In some cases, the "race" between models will be an undecided tie, as they each seem equally good. In other cases, the model choice seems to some extent to be rather arbitrary.

7. Example of results and conclusions, the case of Finland

For Finland, two tobacco products for which demand is studied are cigarettes and pipe and hand-rolling tobacco. Figure 3 presents per capita annual consumption and the real price of cigarettes consumed in Finland in 1960–2009.

[11] This may also be due to omitted variable bias.

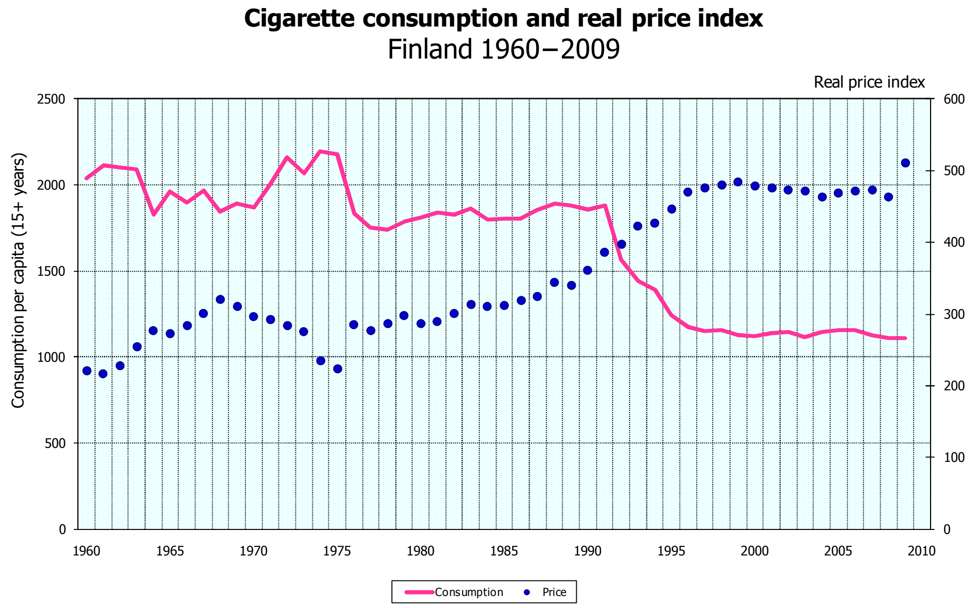


Figure 3. Consumption and real price of cigarettes, Finland 1960–2009

For cigarettes, the estimation results with the signs, magnitudes and t-values of the coefficients as well as the residual autocorrelation tests from the last three demand models generally seem to be reasonable (Table 7). Regarding the conventional model, this exhibits significant autocorrelation in the residuals and obviously some spurious relations. These spurious correlations are addressed most notably by the high short-run price elasticity estimate −0.851 (i.e., the coefficient of the price variable $\ln P_{st}$) and its high t-value −10.86. Both the coefficient and its t-value become smaller in the partial adjustment model, in which lagged consumption $\ln Q_{st-1}$ is added as an explanatory variable, and are even lower in the rational addiction model, which has lagged $\ln Q_{st-1}$ and lead consumption $\ln Q_{st+1}$ as explanatory variables. In both addiction models, lagged consumption $\ln Q_{st-1}$ is statistically significant and positively related to current consumption. In addition, in the rational addiction model, lead consumption $\ln Q_{st+1}$ is positively related to current consumption. Furthermore, the significant coefficient estimate of lagged consumption (0.513) is higher than that of the lead consumption (0.265), which is quite near to significant. These findings are in accordance with our hypotheses, suggesting that past consumption positively influences current consumption more than future consumption, while cigarette consumption is rationally addictive.

Table 7. Estimation results from the demand models for cigarettes, Finland 1960–2009

Variable	Conventional model		Partial adjustment[a] model		Rational addiction[b] model		Error correction model	
	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*
Constant	8.613	11.54	3.769	3.01	2.109	1.56	-0.011	-1.08
D1964	-0.034	-0.48	-0.103	-2.13	-0.101	-2.56		
D1992	0.074	1.81	-0.027	-0.78	-0.012	-0.39		
TCS_t	-0.006	-5.54	-0.002	-1.73	-0.001	-1.28		
lnP_{st}	-0.851	-10.86	-0.357	-3.04	-0.220	-1.80		
lnY_t	0.423	4.94	0.131	1.65	0.092	1.34		
lnQ_{st-1}			0.615	4.83	0.513	4.17		
lnQ_{st+1}					0.265	1.72		
ΔD1964							-0.081	-2.64
ΔD1992							-0.003	-0.10
ΔTCS_t							-0.002	-1.56
ΔlnP_{st}							-0.413	-3.33
ΔlnY_t							0.358	1.53
Adjustment coefficient							-0.153	-1.43
Model		F(5, 44) = 118.53		F(6, 41) = 221.21		F(7, 38) = 255.86		F(6, 42) = 6.15
Adjusted R^2		0.923		0.969		0.976		0.392
Root MSE		0.067		0.044		0.036		0.042
Number of observations		50		48		46		49
Test	Statistic	*p*-value	Statistic	*p*-value	Statistic	*p*-value	Statistic	*p*-value
Ljung-Box Q(1)	21.290	0.000	3.777	0.052	0.917	0.338	0.024	0.877
AR(2)	23.127	0.000	3.651	0.161	1.104	0.576	0.069	0.966
Normality	0.986	0.808	0.951	0.041	0.956	0.067	0.950	0.036
Heteroscedasticity	32.587	0.000	23.883	0.067	40.685	0.006	41.495	0.001
RESET	30.730	0.000					6.900	0.001

[a] The instruments consist of two lag prices of cigarettes plus the other explanatory variables in the model.

[b] The instruments consist of two lead prices and two lag prices of cigarettes plus the other explanatory variables in the model.

Ljung-Box Q(1) = Ljung-Box Q test for serial correlation with one lag included.

AR(2) = Breusch-Godfrey Lagrange-multiplier test for autocorrelated residuals with two lags included.

Normality test is the Shapiro-Wilk test for normal residuals.

Heteroscedasticity test is the White test for heteroscedasticity using squares and cross products.

In the last three demand models for cigarettes, estimated short-run price elasticities of demand for cigarettes vary between −0.22 and −0.41, while short-run income elasticities vary between 0.09 and 0.36 (Table 10). Of these models, the error correction model provides the highest short-run price elasticity and income elasticity.

In the conventional model for cigarettes, the role of the tobacco control scale TCS_t is clearly exaggerated as displayed by both the size of the effect of TCS_t (−0.006) and its highly significant t-value (−5.54) (Table 7). In the last three models, the coefficients of the tobacco control scale variable (i.e., the coefficient of TCS_t in both the addiction models

and the coefficient of ΔTCS_t in the error correction model) are all negative, as we expected, and are not so far from being significant, with t-values of −1.73, −1.28, and −1.56 respectively. In addition, the coefficient of D1964 and that of ΔD1964 are significantly negative. These findings imply that the health scare in 1964 had a decreasing effect on cigarette consumption. Moreover, as expected the estimated adjustment coefficient in the error correction model is negative.

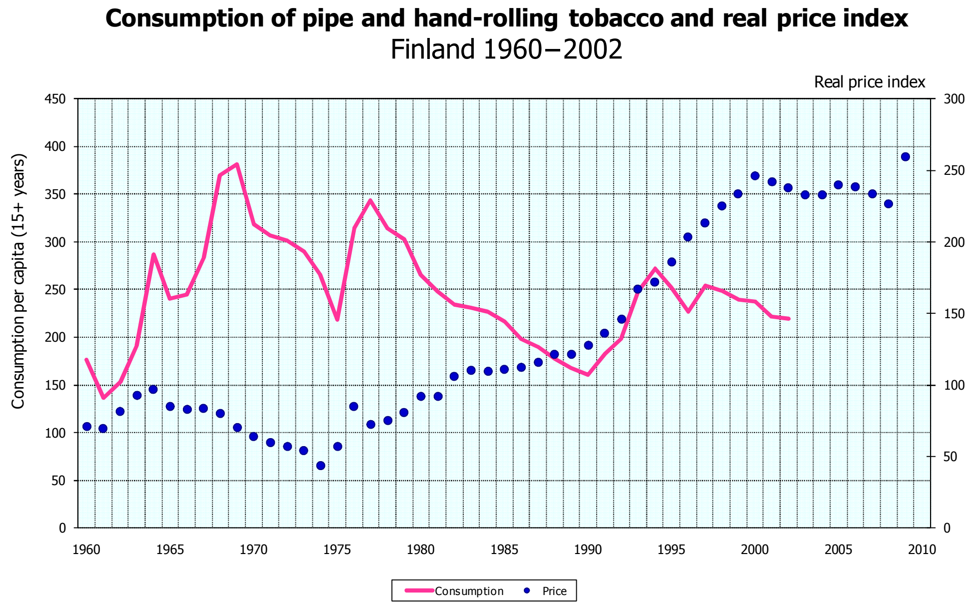


Figure 4. Consumption (g) and real price of pipe and hand-rolling tobacco, Finland 1960–2002

Figure 4 shows how per capita consumption and real price of pipe and hand-rolling tobacco have varied in Finland over the period 1960–2002.[12] For consumption of pipe and hand-rolling tobacco, it is less straightforward to interpret results obtained from the estimated models. As seen, all the first three models show first order autocorrelation in the residuals (Table 8). However, the error correction model does not exhibit residual autocorrelation as described by two reported test results (Ljung-Box Q(1) p = 0.758; AR(2) p = 0.622) (Table 8).

[12] Data on consumption of pipe and hand-rolling tobacco have not been available since 2003.

According to the error correction model of demand for pipe and hand-rolling tobacco, the estimated short-run own-price elasticity (i.e., the coefficient of price of pipe and hand-rolling tobacco $\Delta \ln P_{pt}$) is −0.43, while the cross-price elasticity (i.e., the coefficient of cigarette price $\Delta \ln P_{st}$) is 1.73 (Table 8). A 10% increase in the real price of pipe and hand-rolling tobacco tends to decrease its own demand by 4.3%, while a similar increase in the real price of cigarettes tends to increase the demand for pipe and hand-rolling tobacco by 17.3%. The latter result suggests that when real cigarette price rises, cigarette consumers tend to switch from cigarettes to pipe and hand-rolling tobacco. That is, pipe and hand-rolling tobacco appears to be a substitute for cigarettes. Demand for pipe and hand-rolling tobacco is more responsive to a given percentage change in the price of cigarettes than to the same percentage change in its own price, which has been observed earlier (Pekurinen 1989, 1992).

Table 8. Estimation results from the demand models for pipe and hand-rolling tobacco, Finland 1960–2002

Variable	Conventional model		Partial adjustment[a] model		Rational addiction[b] model		Error correction model	
	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*	Coeff.	*t*
Constant	5.136	3.24	8.499	1.45	7.039	1.14	0.012	0.54
D1964	0.326	2.15	0.223	1.32	0.300	1.40		
D1992	-0.059	-0.67	-0.075	-0.40	-0.258	-1.12		
TCS_t	0.010	3.30	0.013	1.13	0.019	1.48		
$\ln P_{pt}$	-1.163	-8.22	-1.225	-1.23	-1.615	-1.50		
$\ln P_{st}$	2.285	8.40	2.341	1.38	2.742	1.53		
$\ln Y_t$	-0.836	-4.20	-1.111	-1.54	-1.061	-1.41		
$\ln Q_{pt-1}$			-0.167	-0.20	-0.772	-0.82		
$\ln Q_{pt+1}$					0.664	2.09		
ΔD1964							0.245	4.03
ΔD1992							0.000	-0.01
ΔTCS_t							0.004	1.07
$\Delta \ln P_{pt}$							-0.426	-2.47
$\Delta \ln P_{st}$							1.733	5.40
$\Delta \ln Y_t$							-1.257	-2.61
Adjustment coefficient							-0.187	-1.52
Model		$F(6, 36) = 13.57$		$F(7, 33) = 8.97$		$F(8, 30) = 5.36$		$F(7, 34) = 11.85$
Adjusted R^2		0.642		0.546		0.300		0.650
Root MSE		0.141		0.148		0.187		0.083
Number of observations		43		41		39		42
Test	Statistic	*p*-value	Statistic	*p*-value	Statistic	*p*-value	Statistic	*p*-value
Ljung-Box Q(1)	41.951	0.002	43.318	0.001	9.675	0.002	0.095	0.758
AR(2)	19.907	0.000	7.260	0.027	2.961	0.228	0.949	0.622
Normality	0.935	0.018	0.944	0.041	0.986	0.888	0.949	0.059
Heteroscedasticity[c]	28.341	0.020	37.092	0.016	35.260	0.162	10.686	0.711
RESET	0.220	0.883					3.630	0.023

[a] The instruments consist of two lag prices of pipe and hand-rolling tobacco plus the other explanatory variables in the model.

[b] The instruments consist of two lead prices and two lag prices of pipe and hand-rolling tobacco plus the other explanatory variables in the model.

[c] For the error correction model, the White test for heteroscedasticity only uses squares of the explanatory variables.

Ljung-Box Q(1) = Ljung-Box Q test for serial correlation with one lag included.

AR(2) = Breusch-Godfrey Lagrange-multiplier test for autocorrelated residuals with two lags included.

Normality test is the Shapiro-Wilk test for normal residuals.

Heteroscedasticity test is the White test for heteroscedasticity using squares and cross products.

In the error correction model of the demand for pipe and hand-rolling tobacco, perhaps surprisingly, the effect of the tobacco control scale variable ΔTCS_t on consumption is positive and the effect of real income $\Delta \ln Y_t$ on consumption is negative (Table 8). In other words, enhanced tobacco control policies encourage per capita consumption of this tobacco product, but higher real disposable income per capita reduces its consumption. Both these effects are opposite to the results obtained from the models of cigarette demand.

There may be several explanations for the positive effect of tobacco control policies and the negative effect of real income on the consumption of pipe and hand-rolling tobacco. Compared to cigarette consumption, pipe and hand-rolling tobacco is typically used in other circumstances and places as well as among people with distinctive socio-demographic and socio-economic characteristics, such as higher age. Although implemented tobacco control policies have been directed against all forms of tobacco, in effect they affect cigarette consumers to a greater extent than users of other forms of tobacco, including pipe and hand-rolling tobacco. Perhaps, when tobacco control policies are strengthened, they affect cigarette smokers more effectively so that they actually reduce cigarette smoking, but at the same time making cigarette consumers switch from cigarettes to pipe and hand-rolling tobacco. On the other hand, the negative short-run income elasticity seems to indicate that pipe and hand-rolling tobacco is an inferior product, i.e., consumers of pipe and hand-rolling tobacco with higher income would prefer cigarettes to cheaper tobacco. In addition, based on results from many international demand studies, those who currently use pipe and hand-rolling tobacco or have switched from expensive cigarettes to cheaper pipe and hand-rolling tobacco are relatively poorer or in lower income groups (Chaloupka and Warner 2000).

In the error correction model of demand for pipe and hand-rolling tobacco, the direction of the effect of the 1964 health scare (ΔD1964) on consumption is positive and statistically significant (Table 8). This increasing effect is clearly against our hypothesis and also opposite to the significantly decreasing effect of the same variable in the models for cigarettes. We can argue that while D1964 or ΔD1964 in the models of cigarettes is measuring the actual effect of the intervention (health scare) on cigarette consumption, perhaps the same explanatory variable in the models of pipe and hand-rolling tobacco also captures part of the effect of cigarette price changes on consumption of cheap tobacco (Pekurinen 1989, 1992). Alternatively, it is possible that the 1964 health scare increased the use of pipe and hand-rolling tobacco because this form of tobacco, like cigars, were less implicated in the epidemiological studies published than cigarettes.

Table 9. Elasticity estimates of demand for tobacco products, Finland 1960–2009

Model	Cigarettes 1960–2009			Pipe and hand-rolling tobacco 1960–2002			
	Own-price elasticity		Income	Own-price elasticity		Cross-price	Income
	Short run	Long run	elasticity	Short run	Long run	elasticity	elasticity
Conventional model	-0.851		0.423	-1.163		2.285	-0.836
Partial adjustment model	-0.357	-0.929	0.131	-1.225	-1.050	2.341	-1.111
Rational addiction model	-0.220	-0.991	0.092	-1.615	-1.458	2.742	-1.061
Error correction model	-0.413	-0.851	0.358	-0.426	-1.163	1.733	-1.257

Elasticity estimates of demand for both tobacco products for Finland are summarized in Table 9. In summary, in the case of Finland, we prefer to base conclusions on the addiction models or on the error correction models for cigarettes, but for pipe and hand-rolling tobacco we base conclusions on only the error correction model. All these four estimated models passed two residual autocorrelation tests (see Tables 5 and 7–8). The short-run own-price elasticity estimates of demand for cigarettes vary between −0.22 and −0.41, while it is −0.43 for pipe and hand-rolling tobacco. The estimated long-run price elasticity is around −0.9 (more precisely, they vary between −0.85 and −0.99) for cigarettes and −1.2 for pipe and hand-rolling tobacco.

Long-run price elasticity estimates of demand for cigarettes range from −0.2 to −1.5, with the typical value close to −1.0. Due to technical reasons, the long-run price elasticity estimates are more variable and less reliable than the short-run price elasticity estimates and thus one should be very cautious about using the long-run price elasticity estimates.

The cross-price elasticity of demand for pipe and hand-rolling tobacco is estimated to be 1.73. Income elasticities are estimated to be 0.09–0.36 for cigarettes and −1.26 for pipe and hand-rolling tobacco.

Our elasticity estimates for cigarettes for Finland are much in line with corresponding results for other countries as delivered for example by NRP (2012). Previous studies utilizing Finnish aggregate data and different econometric models over 10–40 years between 1950 and 1999 have given short-run price elasticity estimates of demand for cigarettes within the range −0.16 to −0.71 with a median of −0.43 and income elasticities

between 0.02 and 1.24 with a median of 0.37 (Koutsoyannis 1963; Valtonen 1992;[13] Pekurinen 1989, 1992; Stewart 1993; Punkari and Pekurinen 1996; Salo and Pekurinen 1996; Salomaa 1998; Escario and Molina 2001; Leppänen 2001), whereas the long-run price elasticities are −0.77 and −0.85 (Salo and Pekurinen 1996). For pipe and hand-rolling tobacco, the short-run own-price elasticity estimates of demand previously obtained vary between −0.03 and −0.60 with a median of −0.36, whereas the cross-price elasticity estimates of demand with respect to cigarette price vary between 1.50 and 2.36 with a median of 1.86 (Valtonen 1982;[14] Pekurinen 1989, 1992; Punkari and Pekurinen 1996; Salomaa 1998; Leppänen 2001).

Of the recursive estimation graphs for Finland, the one-step residuals 'Res1Step' and one-up Chow '1up CHOWs' -tests show that the error correction model does not manage to accommodate the change in cigarette consumption in 1995, nor the change in consumption of pipe and hand-rolling tobacco in 1988 nor that in 1996 (Appendix D). Furthermore, as seen in Figure 3, the effect of the economic depression from 1992–1994 on cigarette consumption seems rather permanent. Perhaps, the depression captured by the dummy variable D1992 should alternatively be defined as describing a permanent effect. This is a topic for further research.

8. Conclusions

Hopefully this toolkit will at least to some extent help to clear the way for further empirical economic studies of demand for tobacco. As noted in the introduction, such studies should be done for a larger scale of countries. Cross-border trade should then also be taken into account. Not considering cross border trade implies, in absolute values, too high price elasticity estimates. Studies by for example Joossens and Raw (1998, 2000) and Joossens et al. (2009) show that cross-border trade is an important issue. Future econometric work need to pay more attention to this aspect.

[13] Studies cited in Valtonen (1982) were Sehm (1976), Rimpelä et al. (1976), and Sehm (1979).
[14] Studies cited in Valtonen (1982) were Rimpelä et al. (1976) and Sehm (1979).

Previous country-specific studies of elasticity of demand for tobacco products, mainly cigarettes, are based on varying specifications of the analyzed variables and inconsistent data sources as well as on various methodological approaches (Chaloupka and Warner 2000; Gallet and List 2003). If this toolkit contributes even a little towards a more consolidated and consistent methodology for analyzing demand for tobacco, it is an achievement.

Neither the task of collecting data, the role of data quality, nor the econometric assignment should be underestimated. Hopefully, in the future a permanent integrated data source will be established, covering at least all Member States of the European Union, which will make it possible to perform on a regular basis empirical studies of tobacco demand of the type discussed in this report.

With the strengthened tobacco tax and other control policies over the last couple of decades we have seen the key econometric variables displaying clear trends at least in the high income European countries studied by NRP (2012). Trends have clearly become more prominent in the time series, for example we see decreasing consumption per capita and increasing real prices in Figures 1 and 2 in the present report. Similarly, real disposable income per capita and the tobacco control scale exhibit rising trends. This has created a new situation for econometric analysis of tobacco demand. While earlier researchers could experience situations with insufficient variation in the data, now we are surely able to find sufficient variation, both in tobacco consumption and in the variables explaining it.

The type of trending in variables exhibited for example by Figures 1 and 2 implies a risk that regression analysis will mainly focus on modelling and explaining a trend (in tobacco consumption) with other trends (in price, income, and tobacco control policy index) regardless of the factual relationship between the variables. Hence, due to these trends we can expect to find strong but spurious relations between the variables. This emphasizes the need to deal appropriately with trends. Evaluating models by diagnostic specification tests is therefore of special importance, with time series data especially tests for residual autocorrelation. Specification of the dynamic aspects of the model is also of particular

importance for justifying reliable and meaningful results. While this is well known from the time series econometrics literature, we have been emphasizing it throughout this report.

No one single model works for all countries and for all tobacco products. Each country and each tobacco product constitutes an econometric challenge on its own, which should not be underestimated. A separate and detailed econometric analysis will be needed for each country and tobacco product.

Far from all econometric approaches have been covered by this report. Vector autoregressive (VAR) models, whit variables like consumption and price of tobacco and perhaps also income treated as endogenous, is noted among the interesting alternatives.

In conclusion, this work calls for expertise in economics, econometrics, health economics as well as in tobacco issues. Appropriate expertise knowledge needs to be involved.

References

Ashton H, Stepney R. 1982. Smoking: Psychology and Pharmacology. London: Tavistock Press.

Atkinson AB, Skegg JL. 1973. Anti-smoking publicity and the demand for tobacco in the UK. Manchester School 36: 245–272.

Baltagi BH, Levin D. 1986. Estimating Dynamic Demand for Cigarettes Using Panel Data: The Effects of Bootlegging, Taxation and Advertising Reconsidered. Review of Economics and Statistics: 148–155.

Becker GS, Murphy KM. 1988. A Theory of Rational Addiction. Journal of Political Economy 96: 675–700.

Becker GS, Grossman M, Murphy KM. 1991. Rational Addiction and the Effect of Price on Consumption. American Economic Review 81: 237–241.

Becker GS, Grossman M, Murphy KM. 1994. An Empirical Analysis of Cigarette Addiction. American Economic Review 84: 396–418.

Bishop JA, Yoo JH. 1985. Health scare, excise taxes and advertising ban in the cigarette demand and supply. Southern Economic Journal 52: 402–411.

Chaloupka FJ, Warner KE. 2000. The economics of smoking. In Culyer AJ, Newhouse JP, editors. Handbook of Health Economics, Volume 1B. Elsevier: Amsterdam; 1539–1627.

Chaloupka FJ, Tauras JA, Grossman M. 2000. The economics of addiction. In Jha P, Chaloupka FJ, editors. Tobacco Control in Developing Countries: World Bank and World Health Organization.

Chaloupka FJ. 1988. An Economic Analysis of Addictive Behavior: The Case of Cigarette Smoking [Dissertation]. New York: City University of New York Graduate School.

Ciecierski CU, Chaloupka FJ. Data for Econometric Analysis. In Yurekli A, De Beyer J, editors. Tool 2. Tobacco Data. Washington: World Bank. <http://siteresources.worldbank.org/INTPH/Resources/2TobaccoData_Letter.pdf> (Accessed 20 April 2012).

Cox H, Smith R. 1984. Political approaches to smoking control: A comparative analysis. Applied Economics 16: 569–582.

Currie L., 2012. Tobacco Control Policy Index. Pp. 97-133 in Nguyen L., Rosenqvist G, Pekurinen M. Demand for Tobacco in Europe. An Econometric Analysis of 11 Countries for the PPACTE Project. Report 6/2012. Helsinki: National Institute for Health and Welfare. Juvenest Print - Tampereen Yliopistopaino Oy.

Currie L, Townsend J, Leon Roux M., Godfrey F., Gallus S., Gilmore A. B., Levy D, Nguyen L. Rosenqvist G.,Clancy L. Forthcoming (2012). Pricing Policy and Control of Tobacco in Europe: Integration of findings from the PPACTE Project and Recommendations for Tobacco Policy in the European Union.

Doornik JA, Hendry DF. 2009. Empirical Econometric Modelling. PcGive 13 Volume I. London: Timberlake Consultants Ltd.

Duffy M. 1996. An Econometric Study of Advertising and Cigarette Demand in the United Kingdom. International Journal of Advertising 15: 262–284.

Enders W. 2010. Applied econometric time series. John Wiley & Sons, Inc.

Engle RF, Granger CWJ. 1987. Co-integration and error-correction representation, estimation, and testing. Econometrica 55: 251–276.

Escario JJ, Molina JA. 2001. Why do European consumers smoke? Responses from the rational additional model. International Journal of Consumer Studies 25: 24–29.

Fujii ET. 1980. The demand for cigarettes: further empirical evidence and its implications for public policy. Applied Economics 12: 479–489.

Gallet CA, List JA. 2003. Cigarette demand: a meta-analysis of elasticities. Health Economics 12: 821–835.

Gallus S, Schiaffino A, La Vecchia C, et al. 2006. Price and cigarette consumption in Europe. Tobacco Control 15: 114–119.

Grossman M, Chaloupka FJ, Anderson R. 1998. A Survey of Economic Models of Addictive Behavior. Journal of Drug Issues 28: 631–643.

Hendry DF, Juselius K. 2000. Explaining Cointegration Analysis: Part 1. The Energy Journal, International Association for Energy Economics, 21: 1−42.

Hendry DF, Juselius K. 2001. Explaining Cointegration Analysis: Part 2. The Energy Journal, International Association for Energy Economics, 22: 75-12.

Hill C, Laplanche A. 2003. Le tabac en France: les vrais chiffres. Paris: La Documentation francaise.

Houthakker JE, Taylor LD. 1970. Consumer demand in the United States: analyses and projections. Harvard University Press: Cambridge, MA.

IARC. 2009. Handbooks of Cancer Prevention: Tobacco Control. Volume 13. Evaluating the effectiveness of smoke-free policies. Lyon, France: International Agency for Research on Cancer.

IARC. 2011. IARC Handbooks of Cancer Prevention: Tobacco Control. Volume 14. Effectiveness of Price and Tax Policies for Control of Tobacco. Lyon, France: International Agency for Research on Cancer.

Jones AM. 1989. The UK demand for cigarettes 1954–1986, a double-hurdle approach. Journal of Health Economics 8: 133–141.

Joossens L, Raw M. 1998. Cigarette smuggling in Europe: who really benefits? Tobacco Control 7: 66–71.

Joossens L, Raw M. 2000. How can cigarette smuggling be reduced? British Medical Journal 321: 947–950.

Joossens L, Raw M. 2006. The Tobacco Control Scale: a new scale to measure country activity. Tobacco Control 15: 247–253.

Joossens L, Merriman D, Ross H, et al. 2009. How eliminating the global illicit cigarette trade would increase tax revenue and save lives. Paris: International Union against Tuberculosis and Lung Disease. <http://www.tobaccofreecenter.org/files/pdfs/en/ILL_global_cig_trade_full_en.pdf> (Accessed 25 May 2009).

Koutsoyannis AP. 1963. Demand functions for tobacco. Manchester School of Economic and Social Studies 31: 1–19.

Laugesen M, Meads C. 1991. Tobacco restrictions, price, income and tobacco consumption in OECD countries, 1960−1986. British Journal of Addiction 86: 1343–1354.

Leppänen K. 2001. Tupakan kulutuksen ekonometrinen tarkastelu 1960–1999 (Econometric analysis of consumption of tobacco 1960–1999). Stakes Aiheita 16/2001. Helsinki: National Research and Development Centre for Welfare and Health.

Maddala G.S., Lahiri K. 2009. Introductions to Econometrics, 4th Ed. Wiley.

Mills T.C., Patterson K. 2007 (ed.). Palgrave Handbook of Econometrics, Volume 1, Econometric Theory. Palgrave.

Mills T.C., Patterson K. 2009 (ed.). Palgrave Handbook of Econometrics, Volume 2, Applied Econometrics. Palgrave.

Nelson JP. 2003. Cigarette Demand, Structural Change, and Advertising Bans: International Evidence, 1970−1995. Contributions to Economic Analysis & Policy 2: 1–27.

Nguyen L, Rosenqvist G, Pekurinen M (2012). Demand for Tobacco in Europe. An Econometric Analysis of 11 Countries for the PPACTE Project. Report 6/2012. Helsinki: National Institute for Health and Welfare. Juvenest Print - Tampereen Yliopistopaino Oy.

Pekurinen M. 1989. The Demand for Tobacco Products in Finland. British Journal of Addiction 84: 1183–1192.

Pekurinen M. 1992. Economics aspects of smoking. Is there a case for government intervention in Finland? Research Report 16/1991. VAPK-Publishing. National Agency for Welfare and Health: Helsinki.

Punkari M, Pekurinen M. 1996. Lama, hinta ja tupakan kulutus (Economic depression, price and consumption of tobacco). In Rissanen P, Valtonen H, editors. Terveystaloustiede 1996 (Health Economics 1996). Stakes Aiheita 1/1996. Helsinki: National Research and Development Centre for Welfare and Health.

Saffer H, Chaloupka F. 2000. The effect of tobacco advertising bans on tobacco consumption. Journal of Health Economics 19: 1117–1137.

Salo H, Pekurinen M. 1996. Rationaalinen riippuvuus, hinta ja tupakan kulutus (Rational addiction, price and consumption of tobacco). In Rissanen P, Valtonen H, editors. Terveystaloustiede 1996 (Health Economics 1996). Stakes Aiheita 1/1996. Helsinki: National Research and Development Centre for Welfare and Health.

Salomaa J. 1998. Tupakkatuotteiden kulutus ja sitä selittävät tekijät Suomessa vuosina 1970–97 (Consumption of tobacco products and factors associated with tobacco consumption in Finland 1970–97). Statistical Report 35/1998. Helsinki: National Research and Development Centre for Welfare and Health.

Stewart MJ. 1993. The effect on tobacco consumption of advertising bans in OECD countries. International Journal of Advertising 12: 155–180.

Valtonen H. 1982. Tupakkatuotteiden hinnat kulutuksen ja tupakasta saatavien tulojen säätelijöinä (Prices of tobacco products as factors controlling tobacco consumption and tax revenues). Journal of Social Medicine 19: 168–180.

Wilkins N, Yurekli A, Hu T-w. 2003. Economic Analysis of Tobacco Demand. In Yurekli A, De Beyer J, editors. Tool 3. Demand Analysis. Washington: World Bank. <http://www1.worldbank.org/tobacco/pdf/Demand.pdf> (Accessed 30 October 2009).

Witt SF, Pass CLP. 1981. The Effects of Health Warnings and Advertising on the Demand for Cigarettes. Scottish Journal of Political Economy 28: 86–91.

Wooldridge J M (2009): Introductory Econometrics: A Modern Approach. Thomson. 4:ed

World Bank. 1999. Curbing the epidemic and the economics of tobacco control. Series: Development in practice. Washington: World Bank.

Appendix A. Variables specified for tobacco control policies for 11 EU MSs

Country and period	Description	Variable specification
Tobacco Control Policies		
Austria 1976–2009		
	Tobacco control policy data have not been available	
Finland 1960–2009		
1964	Health education	= 1 for 1964; 0 otherwise
1976	Smoking ban in public sites	= 1 for 1976 onwards; 0 otherwise
1995	Smoking ban in work places	= 1 for 1995 onwards; 0 otherwise
2000	Smoking restrictions in restaurants and bars	= 1 for 2000 onwards; 0 otherwise
2008	Smoking ban in restaurants and bars	= 1 for 2008 onwards; 0 otherwise
France 1950–2009		
1976	Restriction of public tobacco advertising	= 1 for 1976; 0 otherwise
1992	Smoking restrictions in public places, work places, restaurants and bars. Total prohibition of tobacco advertising in the press	= 1 for 1992 onwards; 0 otherwise
2007	Smoking ban in public places	= 1 for 2007 onwards; 0 otherwise
2008	Smoking ban in restaurants and bars	= 1 for 2008 onwards; 0 otherwise
Germany 1960–2009		
1975	Advertising ban for TV and radio	= 1 for 1975; 0 otherwise
2003	Regulations on smoking in indoor work places	= 1 for 2003 onwards; 0 otherwise
2007	Advertising ban in print media and internet	= 1 for 2007 onwards; 0 otherwise
Ireland 1970–2009		
2004	National smoking cessation campaign and smoking ban	= 1 for 2004 onwards; 0 otherwise
Italy 1970–2009		
1992	Ban on television advertising of tobacco products	= 1 for 1992; 0 otherwise
2005	Smoking ban in public places	= 1 for 2005 onwards; 0 otherwise
Netherlands 1980–2009		
1990	Tobacco advertising ban	= 1 for 1990; 0 otherwise
2003	Ban on tobacco advertising and sponsorship	= 1 for 2003 onwards; 0 otherwise
2004	Smoking ban in work places and public transport	= 1 for 2004 onwards; 0 otherwise
2008	Smoking ban in hospitality, sport, and art/culture sector	= 1 for 2008; 0 otherwise
Portugal 1970–2009		
1981	Tobacco advertising ban (TV, radio, newspapers, points of sales, etc.)	= 1 for 1981 onwards; 0 otherwise
1982	Prohibition of smoking outside of designated smoking areas	= 1 for 1982 onwards; 0 otherwise
1990	Prohibition of smoking in establishments (restaurants, bakeries, breweries, etc.)	= 1 for 1990 onwards; 0 otherwise
Spain 1960–2009		
1989	Ban of tobacco consumption in public centres and transportations and some workplaces	= 1 for 1989 onwards; 0 otherwise
1995	Total ban of tobacco advertisement	= 1 for 1995; 0 otherwise
2006	Smoking ban in public places and transportation	= 1 for 2006 onwards; 0 otherwise

Appendix A. Continued

Country and period	Description	Variable specification
Sweden 1955–2009		
1960	Health education	= 1 for 1960; 0 otherwise
1964	Health education	= 1 for 1964; 0 otherwise
1979	Advertising restrictions	= 1 for 1979; 0 otherwise
1994	Smoking restriction in public places	= 1 for 1994 onwards; 0 otherwise
1995	Advertising ban	= 1 for 1995; 0 otherwise
2006	Smoking ban in restaurants and bars	= 1 for 2006 onwards; 0 otherwise
United Kingdom 1953–2009		
1962	First Report by Royal College of Physicians	= 1 for 1962 onwards; 0 otherwise
1971	Second Report by Royal College of Physicians	= 1 for 1971 onwards; 0 otherwise
1977	Third Report by Royal College of Physicians	= 1 for 1977 onwards; 0 otherwise
1983	Fourth Report by Royal College of Physicians	= 1 for 1983 onwards; 0 otherwise
1992	Prohibiting the supply of oral tobacco and the sale of tobacco products exceeding the maximum tar yields. National Health Service Regulations	= 1 for 1992 onwards; 0 otherwise
2003	Restrictions on tobacco product advertising and promotion	= 1 for 2003 onwards; 0 otherwise
2007	Smoking ban in public places and work places	= 1 for 2007 onwards; 0 otherwise
Trend variables		
Finland 1960–2009		
R1976	Relapse rate	= 1, 2, …, 15 for 1977 to 1991 = 0 otherwise
United Kingdom 1953–2009		
R1963	Relapse rate	= 0 prior to 1963 = 1, 2, …, 8 for 1963 to 1970 = 9 for 1971 onwards
R1972	Relapse rate	= 0 prior to 1972 = 1, 2, …, 5 for 1972 to 1976 = 6 for 1977 onwards
R1978	Relapse rate	= 0 prior to 1978 = 1, 2, …, 5 for 1978 to 1982 = 6 for 1983 onwards
R1984[#]	Relapse rate	= 0 prior to 1983 = 1, 2, …, 8 for 1984 to 1991 = 9 for 1992 onwards

[#] This variable specification is used if the tobacco control scale index variable is not used in the empirical models as an explanatory variable.

Appendix B. Testing stationarity of time series, Finland.

Description	Specification	Testing stationarity	ADF test Statistic	ADF test p	Phillips-Perron test Statistic	Phillips-Perron test p	Level of integration
ln (number of cigarettes)	$\ln(Q_{st})$[a]	L	-1.84	0.687	-1.91	0.652	I(1)
		D	-4.04	0.008	-6.33	0.000	I(0)
ln (quantity of pipe and hand-rolling tobacco)	$\ln(Q_{pt})$[b]	L	-3.69	0.023	-2.39	0.386	I(1)
		D	-5.08	0.000	-5.86	0.000	I(0)
ln (real price index of cigarettes)	$\ln(P_{st})$[a]	L	-2.30	0.434	-2.14	0.522	I(1)
		D	-5.16	0.000	-6.20	0.000	I(0)
ln (real price index of pipe and hand-rolling tobacco)	$\ln(P_{pt})$[b]	L	-1.98	0.611	-1.92	0.646	I(1)
		D	-5.46	0.000	-5.88	0.000	I(0)
ln (real disposable income)	$\ln(Y_t)$[a]	L	-1.93	0.637	-2.27	0.451	I(1)
		D	-4.74	0.001	-6.02	0.000	I(0)
tobacco control scale	TCS_t[a]	L	-2.59	0.283	-2.66	0.251	I(1)
		D	-4.96	0.000	-7.06	0.000	I(0)

[a] Using cigarette demand data 1960–2009.
[b] Using pipe and hand-rolling tobacco demand data 1960–2002.

Appendix C. Time-series graphs of the variables used, Finland.

Consumption of cigarettes 1960 and pipe and hand-rolling tobacco, 1960–2002

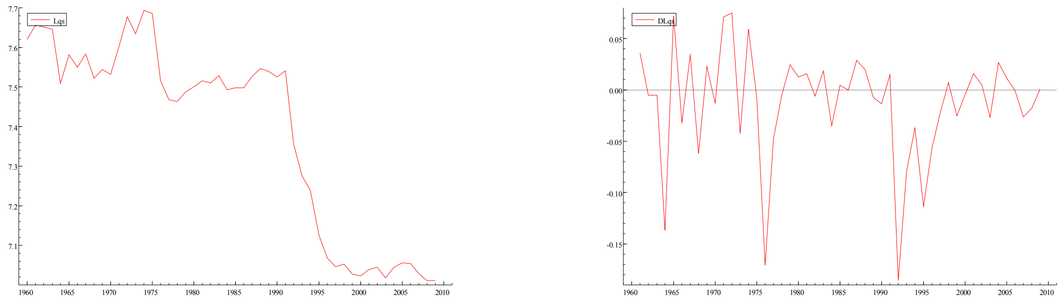


Figure Ca. Cigarette consumption in log-level form (left) and in log-first-difference form (right)

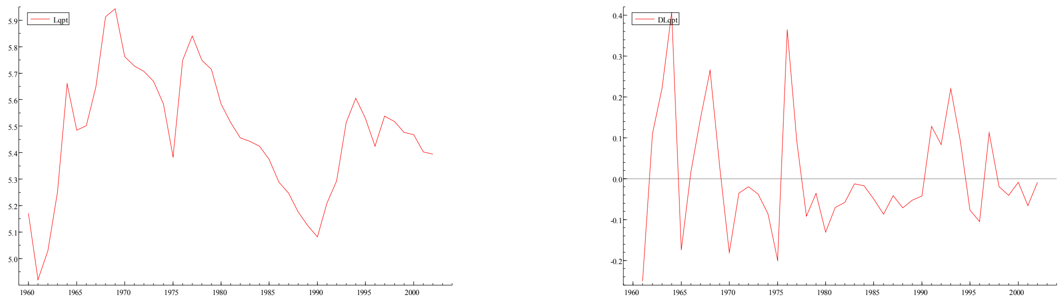


Figure Cb. Consumption of pipe and hand-rolling tobacco in log-level form (left) and in log-first-difference form (right)

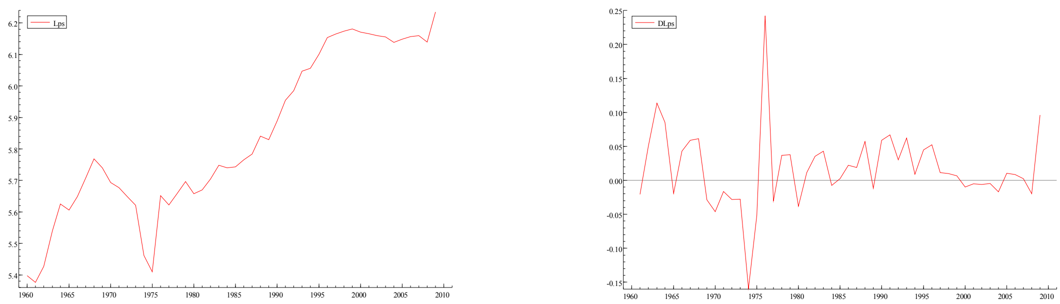


Figure Cc. Real cigarette price index in log-level form (left) and in log-first-difference form (right)

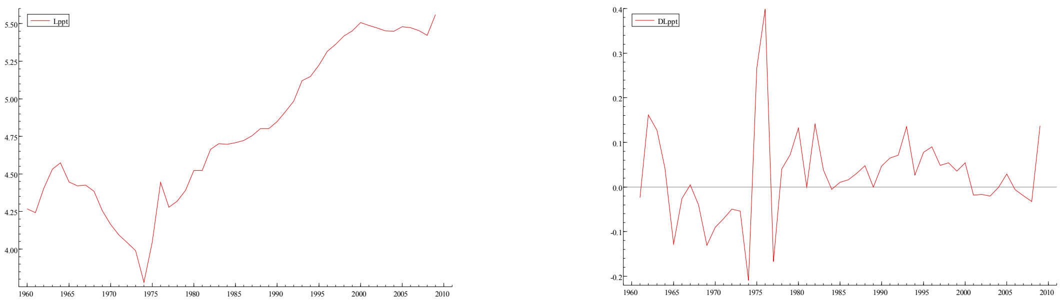


Figure Cd. Real price index of pipe and hand-rolling tobacco in log-level form (left) and in log-first-difference form (right)

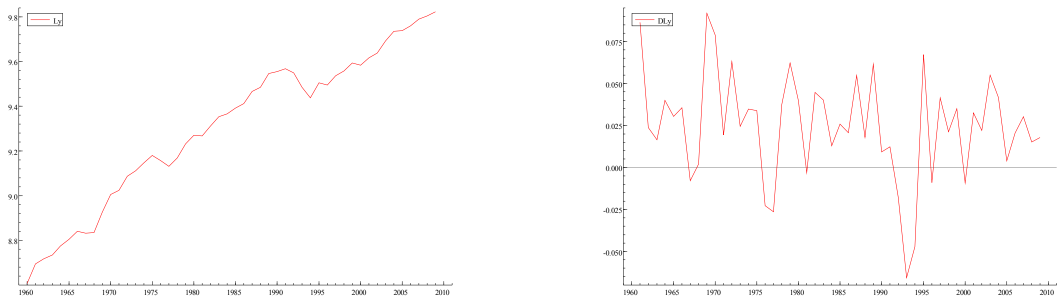


Figure Ce. Real income in log-level form (left) and in log-first-difference form (right)

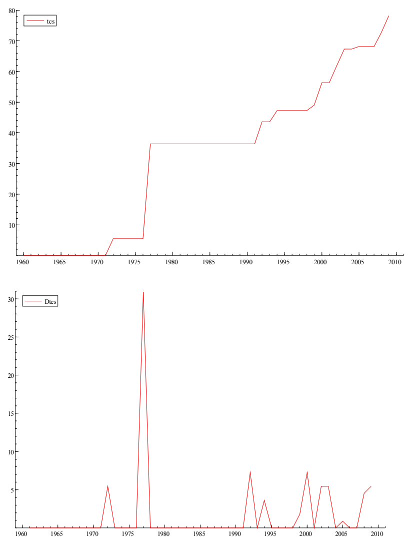
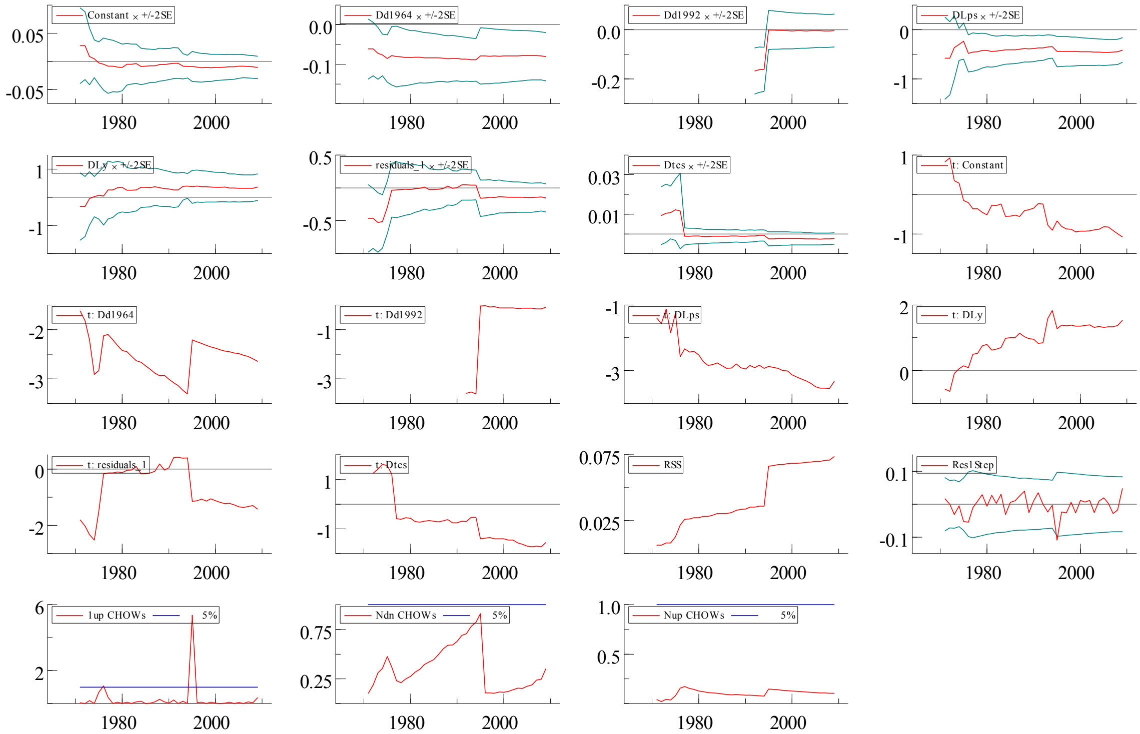


Figure Cf. Tobacco control policy index in log-level form (left) and in log-first-difference form (right)

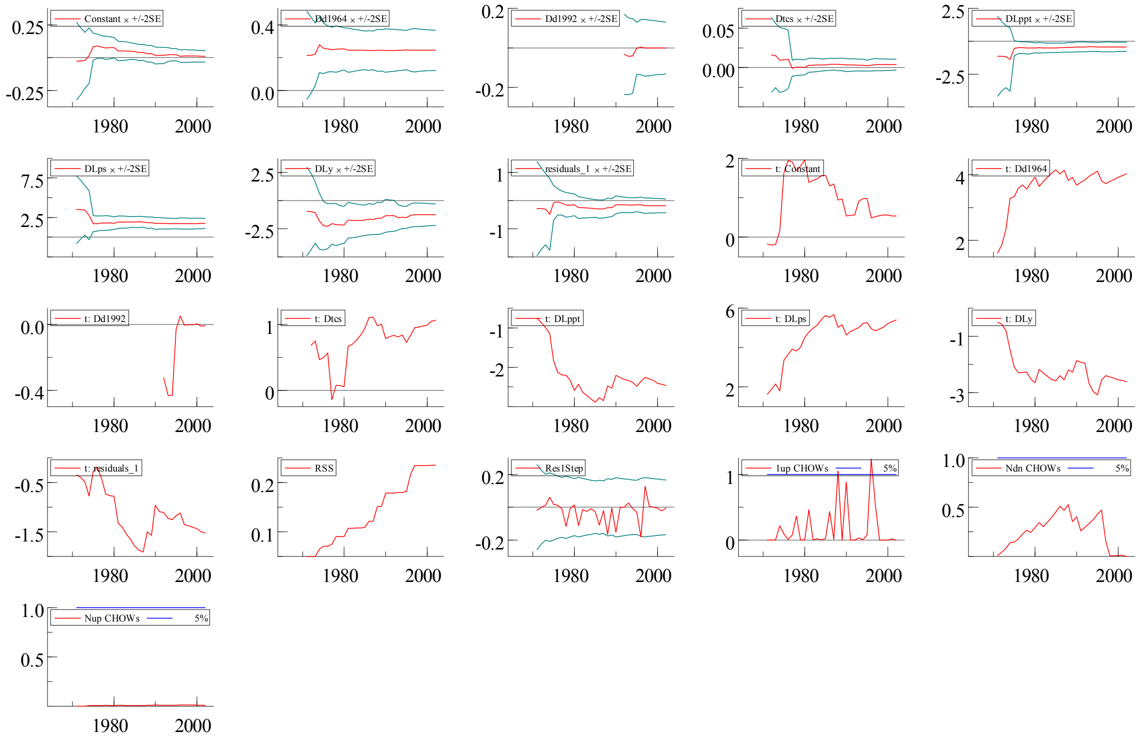
Appendix D. Recursive least squares graphical constancy statistics, Finland.

In this appendix, recursive least squares graphical constancy statistics are presented for the estimated error correction model for Finland for demand for cigarettes 1960-2009 and for demand for pipe and hand rolling tobacco 1960-2009, that are reported in section 7.

Cigarette consumption, Finland 1960–2009



Consumption of pipe and hand-rolling tobacco, Finland 1960–2002



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