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Econometric Models of Alcohol Demand in the United Kingdom

by

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Summary and Acknowledgements

This paper reports the results of a recent re-estimation of the alcohol demand models at HM Customs and Excise (HMCE).

Objectives

The objectives of the study were to update the demand equations for alcoholic beverages in the UK with new observations, overcoming difficulties experienced in the previous attempts at re-estimation.

The new models: statistical adequacy, economic interpretability, and forecasting accuracy

Four sets of empirical demand models have been built for on-trade beer, off-trade beer, spirits, and wine excluding coolers. The new models' structure departs from the original AIDS specification, and follows a single-equation approach based on the standard consumer demand theory. Estimation and testing of the models have followed the widely practised general-to-specific econometric methodology, with application of unit root tests and co-integration techniques. The chosen models are dynamic error-correction models with broadly satisfactory diagnostic statistics, mostly sensible estimates of parameters, and generally clear economic interpretability. Tests on the out-of-sample prediction performance and on model stability have further supported the robustness and usefulness of these models. New estimates of the long-run price elasticities, especially those with respect to own prices, appear reasonable and are in line with what have been suggested in the literature.

Summary of achievements

The achievements of this study, in comparison with the existing literature, are summarised as follows:

- successfully updating the forecasting models with data up to 2002Q1;
- following the general-to-specific and cointegration modelling approach;
- achieving estimates of broadly sensible parameters and elasticities;
- providing separate treatments of the on/off beer markets;
- excluding the 'coolers' component from wine;
- removing tobacco from the demand system;
- producing accurate out-of-sample forecasts.

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1 Introduction

Objectives

The following objectives have been set for the modelling exercises reported in this paper:

- to update the existing alcohol forecasting models with new observations,
- to overcome the difficulties and to solve the problems encountered in previous updating exercises.

Motivations

The current working version of the alcohol forecasting models used at HM Customs and Excise (HMCE) were estimated in 1999 using data up to 1998Q2[1], and were in need of updating as more recent information has become available. However, a number of subsequent efforts to bring the models up to date failed to produce conclusive and acceptable results.[2] The problems with the new estimation were either extremely poor forecasting performance or dubious parameter estimates rejected on theoretical grounds, such as a positive and statistically significant own-price elasticity. Hence the current exercise was required.

The current modelling approach

The existing alcohol model was estimated using the AIDS specification (*A*lmost *I*deal *D*emand *S*ystem, see Deaton and Muellbauer (1980)). As it has proved extremely difficult to update the models within the existing AIDS framework, alternative modelling approaches have been tried. The results reported below have been obtained using single equation methods. We have adopted the general-to-specific modelling approach (or the 'LSE tradition', as it is sometimes called in the econometric literature), involving the estimation and progressive simplification of a general model, often in the autoregressive distributed lag (ADL) form, to achieve a parsimonious error-correction model. Long-run co-integrating relationships are tested and established, and incorporated into the final dynamic model as a disequilibrium force to drive the short-run adjustment process.

The system approach, admittedly, is theoretically appealing. The departure from that approach is due more to pragmatic than theoretical considerations. However, some arguments can also be advanced in support of the alternative approaches. The

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[1] Chambers, M. J. (1999): "Consumers' Demand and Excise Duty Receipts Equations for Alcohol, Tobacco, Petrol and DERV", *Government Economic Service Working Paper* No. 138, November 1999, HM Treasury, London. The models have now been replaced by those reported in the present paper.

[2] Peacock, C (2001): "Re-estimation of Excise Quantity Equations for Alcohol, Tobacco, Petrol and DERV", HM Customs & Excise, Internal Discussion Paper, September.

Chambers, M. J. (2001, 2002): "Re-estimation of Alcohol and Tobacco Systems: Part 1 – Part 6", mimeo, HM Customs & Excise.

underlying data-generating process (DGP) may be too complex to be adequately captured by a rather restrictive demand system, be it AIDS, LES, or Rotterdam. Further, the lack of strong empirical evidence in support of some cross-equation restrictions imposed by the theoretical system models (such as symmetry) casts some doubts on the perceived benefits of having such systems as the basis to build empirically-based forecasting models. The single equation approach gives us more flexibility to experiment with more sophisticated specifications and lag structures.

Further arguments for adopting the current approach, and some description of technical details are given in section 2 and Appendix A.

Structure of the paper

The paper is organised as follows. The next section starts with a brief introduction to consumer demand theory, explains the specification of the models, discusses the data used, and presents the numerical estimates of the demand equations. The test of the models' out-of-sample prediction power, and the investigation of how the creation of the single European market (SEM) affects consumer behaviour are covered in section 3. This is followed by section 4 summarising the new estimates of price and income elasticities, which are of great interest to people working on tax policy. Finally, section 5 summarises the main findings and concludes the study.

The paper has 2 appendices, containing more technical details. Appendix A explains the econometric methodology. Appendix B gives detailed econometric results from estimation and testing.

2 Model Specification and Estimation

Introduction

There are three sub-sections covering model specification, data, and estimation results.

2.1 Model Specification

Theory of consumer demand

Consumer theory suggests that the demand of a utility-maximising consumer for a consumption product depends on the prices of all the products available to him and his total expenditure,

$$Q_i = f\,(P_1, P_2, \ldots, P_i, \ldots P_n, V_C),\ \ i = 1, 2, \ldots, n. \qquad (1)$$

where Q_i and P_i are the quantity and price of the *i*th product, there are *n* products in total, and V_C (= $\sum Q_i * P_i$) is total current expenditure.

There are three sets of basic variables in a demand system: prices, income (sum of all expenditures), and demand (quantities). Theory also suggests some important ‘laws of demand’ that the demand curves should satisfy, including

- Homogeneity of Degree Zero: Demand functions are homogeneous of degree zero in prices and income. Doubling all prices and income leads to no change in demand. Money illusion is ruled out.
- The Adding-up Property: The weighted average of income elasticities of demand is unity, the weights being the relative shares of each good in total expenditure. If some goods have income elasticities below unity, others must have income elasticities above unity.
- Negative Substitution Effect: If P_i rises and V_C is simultaneously adjusted in order to keep utility u constant, Q_i falls. This is the most important of the laws of demand: the law of the downward-sloping compensated demand curve.
- Symmetry of Cross-Substitution Effects. This implies a symmetrical pattern of “cross effects”, in that the effect of changing P_j on demand for Q_i equals the effect of changing P_i on demand for Q_j, after adjusting for income effects and the relative size in total consumption of the two goods.

In empirical work, however, it is not always the case that all the theoretical ‘laws’ are validated by the data. Often empirical findings contradict the theoretical predictions, for example, the property of symmetry. Such contradictions do not necessarily lead to the dismissal of theory. Rather, the tension between theory and empirics is often regarded as suggesting inadequacy in the data, in model specification or estimation techniques, and leads to the use of alternative modelling approaches. At the same time there are also theoretical advances in light of new empirical findings.[3]

Model specification

In building empirical models, the ‘degree of freedom’ problem means that the prices entering the demand function are limited. Often included are own prices, prices of close substitutes and complements, and some general price level to represent price of the rest. The functional forms are often assumed to be linear, or log-linear. Also included are other relevant variables believed to affect demand. Thus equation (1) is simplified as

$$\ln Q_i = \alpha_0 + \alpha_1 \ln P_i + \alpha_2 \ln P_s + \alpha_3 \ln P_C + \alpha_4 \ln V_C + \sum \beta_k \ln Z_k + \varepsilon_i , \qquad (2)$$

where P_S is a vector of prices of the close substitutes and complements, P_C is the general consumer price level, and the vector of Z_k represents other determinants.

Dynamic specification

The model in equation (2) is more appropriately regarded as representing the equilibrium relationship in the long run, but is unlikely to hold exactly in every single period. A dynamic specification allows the model to capture the short-run adjustment process without losing information about the long-run equilibrium behaviour as suggested by the economic theory. Applying cointegration techniques and formulating the empirical relationship as the more interpretable error-correction model, we have the following dynamic model of consumer demand.

$$\begin{aligned}\Delta \ln Q_{i,t} &= \beta_0 + \sum_{j=1}^{m1} \beta_{1,j} \Delta \ln Q_{i,t-j} + \sum_{j=0}^{m2} \beta_{2,j} \Delta \ln P_{i,t-j} + \sum_{j=0}^{m3} \beta_{3,j} \Delta \ln P_{s,t-j} + \sum_{j=0}^{m4} \beta_{4,j} \Delta \ln P_{C,t-j} \\ &\quad + \sum_{j=0}^{m5} \beta_{5,j} \Delta \ln V_{C,t-j} + \sum_{j=0}^{m6} \sum_{k=1}^{K} \beta_{6k,j} \Delta \ln Z_{k,t-j} - \gamma\, ECM_{i,t-1} + \varepsilon_{it} \qquad (3)\end{aligned}$$

where the term ECM_i is the error-correction mechanism derived from a cointegrating vector. This vector gives a stationary variable as a linear combination of a group of non-stationary variables. The ECM can be obtained by several methods. For example, they can be postulated based on theoretical considerations and previous empirical evidence, estimated using the Engle-Granger two-stage procedure, applying Johansen’s maximum likelihood approach, or derived from an autoregressive distributed lag equation. Whatever method is used, a valid *ECM* represents the empirical long-run relationship of the underlying variables, as given by equation (2).

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[3] For example, recent theoretical work has introduced a more realistic description of within-household decision-making process, which leads to departures from Slutsky symmetry, see Browning and Chiappori (1998), and Lechene and Preston (2000).

In the case of the Engle-Granger two-stage estimation procedure, ECM_i is simply the residual derived from the estimated equation (2).[4]

Econometric methods

The modelling strategy follows the widely practised general-to-specific modelling approach with application of co-integration techniques. The models attempt to capture both the long-run properties and short-run adjustments in the underlying data generating process (DGP). The final chosen models are dynamic models with an error-correction mechanism. Some descriptions of the general-to-specific methodology and the co-integration tests are given in Appendix A.

The econometric package used is *Microfit 4.1* (Pesaran and Pesaran, 2001).

Re-considering the AIDS framework

The existing models of alcohol demand, described in Chambers (1999), are based on the theoretical structure of an almost ideal demand system (AIDS) (Deaton and Muellbauer, 1980). Instead of carrying out the re-estimation work within the AIDS framework, this study relies on a single equation approach to estimate the demand equations. Apart from the very practical reason that previous attempts within the same framework failed to produce sensible results (Peacock 2001, Chambers 2001/2), other arguments can be advanced in support of this departure.

- Departure from AIDS should not be regarded as a move from a simultaneous equation system to a single equation setting, for AIDS is in fact not a set of simultaneous equations. In the AIDS framework, the variables on the right hand side – prices and real income – are determined outside the model, not within the model. As such they are exogenous to the system. Each of the share equations is like a single equation. The existing AIDS model was in effect estimated by a single equation method.
- A related observation is that AIDS on its own is not a complete forecasting system. To be able to forecast demand for those commodities, one needs other forecasting equations for total consumption and prices. A single equation approach to modelling consumer demand does not change this situation.

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[4] In general there may be more than one ECM term in an equation. In the case of multiple cointegration the unique Engle-Granger cointegrating vector is a linear combination of the co-integrating vectors. The relationship is based on economic theory and can be regarded as giving economic interpretation of the parameters in the statistical models of cointegrated VARs. Further discussions on economic interpretation and identification in cointegrated vector autoregressive models (VARs) can be found in Hall, Mizon and Welfe (2000).

- It is true that demand theory implies some cross-equation restrictions of the AIDS model, typically symmetry. By going to a single equation formulation, this restriction is not explicitly present. However, it is often the case that most empirical studies fail to support such theoretical properties. Therefore, at least empirically, this restriction seems to carry little importance. Moreover, in single equations, symmetry can still be tested.
- The underlying data generation process (DGP) is usually very complex, and the AIDS may be too simple and too restrictive to adequately capture the process. The single equation approach provides more flexibility and the feasibility to apply the general-to-specific method for specification search, which should help to capture the generality of DGP and to finally obtain the valid simplification of the DGP.
- Markets for the different types of alcoholic drinks have rather different characteristics and have experienced different developments. Treating each of them separately is more likely to produce models that represent more accurately the behaviour of these individual markets.
- The new model structure has a more straightforward and intuitive interpretability. This is a useful feature in the context of policy discussions.

Other issues in the existing models

We also consider several other issues in the existing Chambers models.

Firstly, on-trade and off-trade consumptions are not separated. This may not be entirely appropriate if behaviours of these two market types differ significantly.

Secondly, ‘coolers’, or ready-to-drink cocktails, are included within the model as part of wine consumption. As demand for ‘coolers’ has been distinctly different from wine, this may have distorted the consumption behaviour in this model.

Thirdly, ONS data now include smuggling and this needs to be taken into account.

Finally, tobacco demand is included in the current demand system, but is of little use when forecasting. This is because tobacco markets are characterised by smuggling activities on a substantial scale.[5] The estimated tobacco equation does not take into account smuggling, and is unable to generate a satisfactory forecasting performance. Forecasting tobacco does not use the estimated relationship, relying instead on

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[5] *Tackling Tobacco Smuggling,* by HM Customs and Excise and HM Treasury, published in March 2000.

alternative models and an assessment of the smuggling activities. As the currently available data are not adequately sufficient to construct a rigorous econometric model to accurately describe and forecast tobacco consumption and tax revenue, we decided to drop the explicit presence of tobacco in our alcohol demand equations.

2.2 Data Sources

Data description and sources

A large number of variables have been used in this exercise. The relevant ones appearing in the final equations are listed in Table 1 below.

Table 1: Variable Definitions and Data Sources

Variables	Definitions	ONS Codes/ Transformation
Q_{BN}	On-trade Beer, NSA £m(1995)	UUNN
Q_{BF}	Off-trade Beer, NSA £m(1995)	UUSC
Q_S	Spirits Total (On & Off), NSA £m(1995)	CCFS
Q_{WX}	Wine Total (On & Off) excl. coolers, NSA £m(1995)	$Q_W - Q_{CLN} - Q_{CLF}$,
P_{BN}	Implied deflator, On-trade Beer, NSA, 1995=100.	OSRE
P_{BF}	Implied deflator, Off-trade Beer, NSA, 1995=100.	AWLW
P_S	Implied deflator, Spirits Total (On & Off), NSA, 1995=100.	ISHP
P_{WX}	Implied deflator, Wine Total (On & Off) exc Coolers, NSA, 1995=100.	$V_{WX} / Q_{WX} *100$,
P_C	Implied deflator, total household final consumption expenditure, NSA, 1995=100.	ABQU
V_C	Total household final consumption expenditure, NSA, £m	ABPB
R_{EM}	Employment rate, ratios	EMP/POPWK
Q_W	Wine Total (On & Off), NSA £m(1995)	CCFT
Q_{CLN}	On-trade Coolers consumption, £m(1995)	Market Research/HMCE
Q_{CLF}	Off-trade Coolers consumption, £m(1995)	Market Research /HMCE
V_W	Wine Total (On & Off), NSA £m	CDCY
V_{WX}	Wine Total (On & Off) exc Coolers, NSA £m	$V_W - V_{CLN} - V_{CLF}$,
V_{CLN}	On-trade Coolers consumption, £m	Market Research /HMCE
V_{CLF}	Off-trade Coolers consumption, £m	Market Research /HMCE
EMP	Total employment (UK), 000s	MGRZ
POPWK	Population of working age, 000s	YBTF

Note: All the data series are of a quarterly frequency. NSA = not seasonably adjusted. £m = millions of pounds in current prices. £m(1995) = millions of pounds in 1995 constant prices.

Most of the data series come from the ONS directly, the principal source being the ONS publication, *Consumer Trends*. A few others - mainly the coolers data - are processed using sales and price data surveyed by independent market research and the clearance data from Customs and Excise. ‘Coolers’ refer to the spirits-based ready-to-drinks, which had previously been taxed as made-wine when not exceeding 5.5% alcohol by volume (ABV), until Budget 2002 which introduced the change to tax them as spirits. Various other names are also used loosely to describe this type of “designer” beverage, such as flavoured alcoholic beverages (FABs), alcoholic mixables or alcohol pops, and ready-to-drink cocktails (RTDs). On-trade beer refers to beer consumed in pubs and restaurants which effectively includes services provided, while off-trade beer is simply sales from retail shops for consumption off the premises.

Models are built for on- and off-trade beers, spirits, and wine

Effectively, four sets of equations have been created: on-trade beer (BN), off-trade beer (BF), spirits (S), and wine excluding ‘coolers’ (WX). The distinction between on and off consumption of beer is an attempt to capture more accurately the behaviours of these different markets, the on-trade market comprising a considerable service element. No similar treatments have been applied to spirits and wine. This is largely due to the fact that reliable and satisfactory data to separate on/off consumption of spirits and wine are not available, and that the models we have estimated on total consumption (combining on and off trade) give broadly satisfactory results.

Coolers are excluded from wine

The exclusion of ‘coolers’ from wine is due to two considerations. Firstly, the growth in coolers consumption in recent years has been exceptionally strong, in the range of 30-60% pa. Such a phenomenon seems to be more readily explained by changing consumer tastes and marketing success than by economic fundamentals such as prices and income. To include this component within total wine is likely to introduce a distortion into the underlying economic relationship we are trying to estimate. Secondly, since the Budget 2002, coolers have been taxed at the same rate as spirits, so the duty revenues from coolers have from this point been included in spirits receipts. The forecasting equations must be able to forecast wine alone, not wine and coolers as in the past. As a result, the new wine model is for wine excluding coolers. Coolers are forecast separately in a less formal framework, using market information and judgement. There is no formal estimated coolers equation, as the market is relatively new and far from settled. It is not possible to apply econometric estimation to such a rapidly changing process.[6]

Alcohol data include smuggling

Starting with *the Blue Book* 2001 edition, the UK national accounts have included the contribution of tobacco and alcohol smuggling to economic activity, in line with the European System of Accounts (1995). The alcohol expenditure data used in this study are from ONS *Consumer Trends*, which include smuggling. The estimated equations are therefore for alcohol consumption with smuggling included. However, for the purpose of forecasting alcohol duty revenues, smuggling should be excluded from the tax base. The difficulty is that hard data in a form useable in the modelling process are not readily available, and any adjustments made to the published data may introduce further errors. Experiments have been carried out to obtain the consumption data exclusive of smuggling, using available estimates on the sizes of smuggling. But the estimated equations showed little difference from those with the unadjusted series.[7] Given the crude nature of the adjustment and its effect on the estimation, we have chosen to estimate the models using the consumption series as originally published. We recognise that smuggling is now part of the total consumption being modelled, and the estimation and use of the receipts equations, which relate revenue receipts to consumption, should take this into account. The specification of the receipt equations allows a departure of the forecast quantity from the theoretical tax base, and the estimated parameters can pick up the effects of such a departure.[8] As long as the smuggling share in total consumption remains relatively stable, the inclusion of smuggling in total consumption presents no problems to revenue forecasting. If evidence and judgement suggest a significantly different trend in smuggling activity, we can adjust the model-based outcomes to reflect the effects of such changes. It is

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[6] The rise of coolers might be expected to have an effect on consumption of other alcoholic drinks, for example to displace beer consumption. In testing the model specifications, we included the coolers consumption in all the demand equations but did not find a significant effect. Therefore, the perceived effect cannot be formally captured by the estimated models, but is left as an off-model judgemental item when using the models.

[7] The ONS has published annual figures of total alcohol smuggling for the years of 1994-2000, which indicated smuggling amounted to about 2-2.5% of total consumption in the more recent years. No further breakdown, either into each component of alcohols or into each quarter, is given. There are some internal departmental estimates for the breakdown into beer, spirits and wine. As part of the model testing, these estimates were used to adjust the ONS consumption data to obtain the data series exclusive of smuggling. Estimation was carried out with these adjusted consumption series. The result was that these equations were hardly different from those with the unadjusted consumption series.

[8] See Chambers (1999), pp39-40 for more detailed discussions on the theory and specification of the receipt equations.

important that we keep monitoring the forecasting performance of the models, and make necessary updates or adjustments so as to accurately capture the effects of smuggling activities, either on or off model.

2.3 Estimation Results

Introduction

Four sets of equations have been estimated. Instead of building one single model for total beer, two separate models have been built for on-trade and off-trade beers. This should provide a more accurate estimation of the consumption relationships, as the two markets have different behaviours. For wine, consistent data are not available to permit a similar treatment. For spirits, a single equation has given satisfactory results.

For ease of reference, particularly for the model users, the four models are presented together in Table 2 in a more compact form, with no details of the standard econometric test statistics.

This is followed by more detailed descriptions and discussions of the estimation and testing results for each of the four models.

A complete record of the results as reported in the econometric package *Microfit* is given in Appendix B.

The estimated models in summary

The four demand equations in Table 2 are all dynamic error-correction models. The error-correction terms are formed from the residuals of the estimated static equations, which also give long-run price and income elasticities. The variables are in natural logarithms. The data series used are not seasonally adjusted (NSA) and the models include seasonal dummies. The use of NSA data is due to the fact that data for duty revenues are NSA.

Time series properties

Prior to estimation, the time series properties of all the variables were examined. First, the variables in levels were subject to unit root tests, with ADF tests applied to $ln\mathbf{Q}_{BN}$, $ln\mathbf{Q}_{BF}$, $ln\mathbf{Q}_{S}$, $ln\mathbf{Q}_{WX}$, $ln\mathbf{P}_{BN}$, $ln\mathbf{P}_{BF}$, $ln\mathbf{P}_{S}$, $ln\mathbf{P}_{WX}$, $ln\mathbf{P}_{C}$, $ln\mathbf{V}_{C}$, $ln\mathbf{R}_{EM}$. The results clearly show that none of them are stationary. Second, applying ADF tests to the first difference of each variable suggests that these differences are stationary. We therefore conclude that these variables are generated by I(1) processes, ie they are integrated of order one.

Table 2: Estimated Alcohol Demand Equations: Summary

On-trade Beer

$$\Delta \ln \mathbf{Q}_{BN}(t) = -0.056495 + 0.23097 * S2(t) - 0.20934 * \Delta \ln \mathbf{Q}_{BN}(t-1) - 0.37369 * \Delta \ln \mathbf{Q}_{BN}(t-2) - 0.56477 * \Delta \ln \mathbf{Q}_{BN}(t-3) - 0.67932 * \Delta \ln \mathbf{P}_{BN}(t-3) - 0.17669 * \Delta \ln \mathbf{P}_{BF}(t-2) - 0.32233 * \Delta \ln \mathbf{P}_{WX}(t) - 0.60863 * \Delta \ln \mathbf{P}_{WX}(t-2) + 1.4919 * \Delta \ln \mathbf{P}_{C}(t-2) + 0.44819 * \Delta \ln \mathbf{V}_{C}(t-1) - 0.27077 * \Delta \ln \mathbf{V}_{C}(t-2) - 0.73074 * \mathbf{ECM}_{BN}(t-1);$$

$$\mathbf{ECM}_{BN}(t) = \{\ln \mathbf{Q}_{BN}(t) - 9.5639 - 0.15792 * S2(t) - 0.19946 * S3(t) - 0.18133 * S4(t) + 0.47598 * \ln \mathbf{P}_{BN}(t) - 0.43242 * \ln \mathbf{P}_{BF}(t) + 0.14741 * \ln \mathbf{P}_{S}(t) + 0.31740 * \ln \mathbf{P}_{WX}(t) - 0.68987 * \ln \mathbf{P}_{C}(t) + 0.18150 * \ln \mathbf{V}_{C}(t) - 1.1735 * \ln \mathbf{R}_{EM}(t)\}.$$

Off-trade Beer

$$\Delta \ln \mathbf{Q}_{BF}(t) = -0.2236 + 0.36851 * S2(t) + 0.28608 * S3(t) + 0.31482 * S4(t) - 0.21073 * \Delta \ln \mathbf{Q}_{BF}(t-1) - 0.23428 * \Delta \ln \mathbf{Q}_{BF}(t-2) - 0.37670 * \Delta \ln \mathbf{Q}_{BF}(t-3) + 0.28091 * \Delta \ln \mathbf{P}_{BN}(t) - 0.31146 * \Delta \ln \mathbf{P}_{BN}(t-1) + 0.58351 * \Delta \ln \mathbf{P}_{BF}(t-1) - 0.50229 * \Delta \ln \mathbf{P}_{BF}(t-2) - 0.94972 * \Delta \ln \mathbf{P}_{BF}(t-3) - 0.69013 * \Delta \ln \mathbf{P}_{S}(t) - 0.44487 * \Delta \ln \mathbf{P}_{S}(t-1) + 0.79730 * \Delta \ln \mathbf{P}_{C}(t-2) + 0.36946 * \Delta \ln \mathbf{V}_{C} - 0.60582 * \mathbf{ECM}_{BF}(t-1);$$

$$\mathbf{ECM}_{BF}(t) = \{\ln \mathbf{Q}_{BF}(t) - 2.2635 - 0.16576 * S2(t) - 0.19789 * S3(t) - 0.34199 * S4(t) - 0.057221 * \ln \mathbf{P}_{BN}(t) + 1.0293 * \ln \mathbf{P}_{BF}(t) + 0.29442 * \ln \mathbf{P}_{S}(t) + 0.069779 * \ln \mathbf{P}_{WX}(t) - 0.78116 * \ln \mathbf{P}_{C}(t) - 0.55512 * \ln \mathbf{V}_{C}(t) + 0.0038504 * \mathbf{T1}_{BF} - 0.0072945 * \mathbf{T2}_{BF}\}.$$

Spirits

$$\Delta \ln \mathbf{Q}_{S}(t) = -0.42435 + 0.6063 * S2(t) + 0.44097 * S3(t) + 0.66205 * S4(t) - 0.1757 * \Delta \ln \mathbf{Q}_{S}(t-1) - 0.33509 * \Delta \ln \mathbf{Q}_{S}(t-2) - 0.4126 * \Delta \ln \mathbf{Q}_{S}(t-3) - 0.97496 * \Delta \ln \mathbf{P}_{BN}(t) + 0.61519 * \Delta \ln \mathbf{P}_{BF}(t) - 1.6617 * \Delta \ln \mathbf{P}_{S}(t) - 0.44921 * \Delta \ln \mathbf{P}_{S}(t-2) - 0.52559 * \Delta \ln \mathbf{P}_{WX}(t-3) + 1.8567 * \Delta \ln \mathbf{P}_{C}(t) + 0.97597 * \Delta \ln \mathbf{V}_{C}(t) - 0.61395 * \mathbf{ECM}_{S}(t-1);$$

$$\mathbf{ECM}_{S}(t) = \{\ln \mathbf{Q}_{S}(t) - 2.1634 - 0.11883 * S2(t) - 0.13472 * S3(t) - 0.59661 * S4(t) + 0.94989 * \ln \mathbf{P}_{BN}(t) - 0.45818 * \ln \mathbf{P}_{BF}(t) + 1.31321 * \ln \mathbf{P}_{S}(t) - 0.30071 * \ln \mathbf{P}_{WX}(t) - 0.8171 * \ln \mathbf{P}_{C}(t) - 0.68711 * \ln \mathbf{V}_{C}(t)\}.$$

(Table 2 continued)

Wine excluding ‘coolers’

$$\Delta \mathit{ln}\, \mathbf{Q}_{wx}(t) = -0.20460 + 0.23628 *S2(t) + 0.34677 *S3(t) + 0.40137 *S4(t) - 0.62577 * \Delta \mathit{ln}\, \mathbf{Q}_{wx}(t-1) - 0.43373*\Delta \mathit{ln}\, \mathbf{Q}_{wx}(t-2) - 0.51404*\Delta \mathit{ln}\, \mathbf{Q}_{wx}(t-3) - 0.76857*\Delta \mathit{ln}\, \mathbf{P}_{BN}(t-1) + 2.0806*\Delta \mathit{ln}\, \mathbf{P}_{BF}(t) + 0.61750*\Delta \mathit{ln}\, \mathbf{P}_{BF}(t-1) - 0.79628*\Delta \mathit{ln}\, \mathbf{P}_{S}(t) - 0.73231*\Delta \mathit{ln}\, \mathbf{P}_{S}(t-1) - 0.67083*\Delta \mathit{ln}\, \mathbf{P}_{WX}(t) - 0.90551*\Delta \mathit{ln}\, \mathbf{P}_{WX}(t-3) - 0.13688 * \mathbf{ECM}_{wx}(t-1);$$

$$\mathbf{ECM}_{wx}(t) = \{ \mathit{ln}\, \mathbf{Q}_{WX}(t) + 3.4545 - 0.15771*S2(t) - 0.13566*S3(t) - 0.40263*S4(t) + 0.71413*\mathit{ln}\, \mathbf{P}_{BN}(t) - 0.55825*\mathit{ln}\, \mathbf{P}_{BF}(t) + 0.33344*\mathit{ln}\, \mathbf{P}_{S}(t) + 0.75*\mathit{ln}\, \mathbf{P}_{WX}(t) + 0.27072*\mathit{ln}\, \mathbf{P}_{C}(t) - 1.51*\mathit{ln}\, \mathbf{V}_{C}(t) \}.$$

Notations

Q – Quantity of alcohol consumption, in millions of pounds in 1995 prices, £m(1995).

P – Price indices of consumption, 1995 = 100.

V – Total consumption expenditure, in millions of pounds in current prices (£m).

R – Rate of employment (R_{EM}), ratios.

ECM – Error correction mechanism, the residuals from equations of level variables.

S1, S2, S3, S4 – Seasonal dummies.

$T1_{BF}$ – Dummy variable for off-trade beer, defined as a linear trend for 1986Q4-1994Q4, and 0 elsewhere.

$T2_{BF}$ – Dummy variable for off-trade beer, defined as a linear trend for 1995Q4-2000Q2, and 0 elsewhere.

ln – natural logarithm, ie, $y = e^x \Rightarrow \mathit{ln}(y) = x$.

Δ – Difference operator, $\Delta x = x(t) - x(t-1)$.

Subscripts $_{BN,\ BF,\ S,\ WX,\ C,\ EM}$ stand for on-trade beer (BN), off-trade beer (BF), spirits (S), wine excluding ‘coolers’ (WX), household consumption (C), and employment (EM).

t is the current period, *(t-k)* is the period lagged by *k*.

Testing cointegration

In the modelling process, a number of methods have been tried, including estimating general autoregressive distributed lag (ADL) models and carrying out model reduction and reparameterisation. In *Microfit* there is also an ARDL option which can test co-integration and select the final model from a general ADL according to statistical criteria after hundreds of estimations. However, the final models reported in this paper have been obtained by applying the Engle-Granger two-step estimation procedure. Details of the procedure are given in Appendix A.

The first step is to run a static regression and test if the residuals are stationary. The following pages report the results of this estimation and testing for the four categories of alcohols: on-trade beer, off-trade beer, spirits, and wine (excl. coolers).

Variable transformation

As a common practice, prices and expenditure are transformed into *relative* prices and *real* expenditure, ie, they are divided by a common price level, the implied deflator of total household final consumption expenditure. This effectively imposes homogeneity and can also help to reduce multicollinearity between the regressors. The transformation is listed below.

$\mathbf{P}_{BNR} = \mathbf{P}_{BN} / \mathbf{P}_C$,

$\mathbf{P}_{BFR} = \mathbf{P}_{BF} / \mathbf{P}_C$,

$\mathbf{P}_{SR} = \mathbf{P}_S / \mathbf{P}_C$,

$\mathbf{P}_{WXR} = \mathbf{P}_{WX} / \mathbf{P}_C$,

$\mathbf{V}_{CR} = \mathbf{V}_C / \mathbf{P}_C$.

On-trade beer

The estimation results for on-trade beer are shown in Table 3.

Table 3: Estimated Static Equation and ADF Test of Residuals: On-Beer

$$\begin{array}{llllllll}
\mathit{ln}\,\mathbf{Q}_{BN} = & 9.5639 & + .15792\ S2 & + 0.19946\ S3 & + .18133\ S4 & - .47598\ \mathit{ln}\,\mathbf{P}_{BNR} & + .43242\ \mathit{ln}\,\mathbf{P}_{BFR} \\
& (1.0561) & (.013057) & (.015489) & (.019814) & (.17072) & (.10478) \\
& - .14741\ \mathit{ln}\,\mathbf{P}_{SR} & -.31740\ \mathit{ln}\,\mathbf{P}_{WXR} & - .18150\ \mathit{ln}\,\mathbf{V}_{CR} & + 1.1735\ \mathit{ln}\,\mathbf{R}_{EM} & & \\
& (.13674) & (.099706) & (.14032) & (.33691) & &
\end{array}$$

$\overline{R}^2 = .83573$, D.W. = 2.1621,

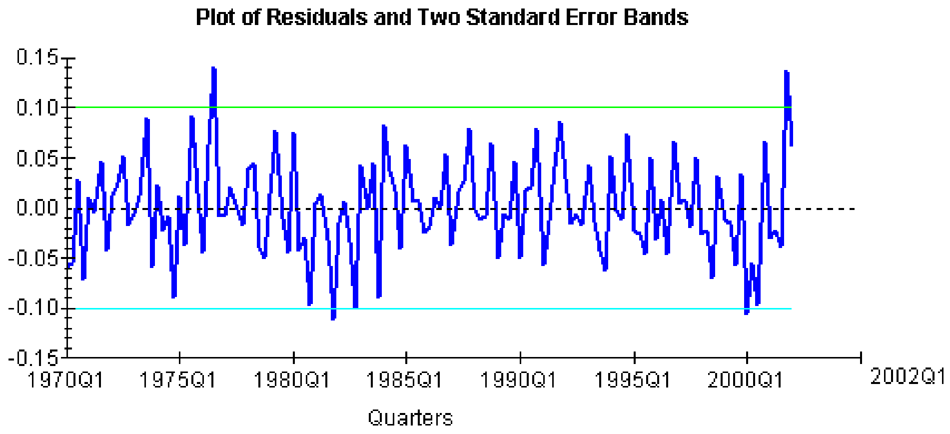
T = 129, Sample 1970Q1 - 2002Q1, OLS estimation, Standard errors in parentheses.

```
                         Unit root tests for residuals

       Test Statistic      LL           AIC           SBC           HQC
DF       -12.0489       196.1834      195.1834      193.7814      194.6140
ADF(1)     -8.2912      196.3943      194.3943      191.5903      193.2554
ADF(2)     -7.7606      198.2529      195.2529      191.0468      193.5445
ADF(3)     -3.3376      218.1697      214.1697      208.5617      211.8919
ADF(4)     -3.7961      220.0184      215.0184      208.0083      212.1711
ADF(5)     -3.8640      220.4202      214.4202      206.0082      211.0035
ADF(6)     -4.0843      221.2983      214.2983      204.4843      210.3122

95% critical value for the Dickey-Fuller statistic =   *NONE*
Critical value not available for the number of regressors in the regression!
LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```

The residuals are also plotted in the chart below.



Although the actual critical value for the ADF test is not available, the size of the test statistic and the pattern of the residuals suggest that they are likely to be a stationary series. Thus, we will use this residual in the differenced equation to model the dynamic behaviour.

The inclusion of the rate of employment may reflect consumers' sense of job security and the strength of the economic climate, which affects demand in addition to the basic demand variables of prices and total expenditure.

The prices and expenditure variables used as regressors are the transformed variables, to impose homogeneity and mitigate multicollinearity. Almost all the parameters are statistically significant. The coefficient of the own price has the expected negative sign. On the other hand, income has a negative coefficient, suggesting that on-trade beer is an inferior good. More discussions on this are given in section 4. The estimated equation can be converted into a relationship between the dependent variable and the original explanatory variables, from which elasticities can be derived. This is given as follows (Table 2 also lists this relationship).

$$\begin{aligned} \ln \mathbf{Q}_{BN} = {} & 9.5639 + .15792\ S2 + 0.19946\ S3 + .18133\ S4 - .47598 \ln \mathbf{P}_{BN} + .43242 \ln \mathbf{P}_{BF} \\ & - .14741 \ln \mathbf{P}_{S} - .31740 \ln \mathbf{P}_{WX} + 0.68987 \ln \mathbf{P}_{C} - .18150 \ln \mathbf{V}_{C} + 1.1735 \ln \mathbf{R}_{EM} \end{aligned}$$

Off-trade beer

The static regression of off-trade beer and the related unit root tests for the residuals are given in Table 4.

Table 4: Estimated Static Equation and ADF Test of Residuals: Off-Beer

$$\mathit{ln}\ \mathbf{Q}_{BF} = 2.2635 + .16576\ S2 + .19789\ S3 + .34199\ S4 + .057221\ \mathit{ln}\ \mathbf{P}_{BNR} - 1.0293\ \mathit{ln}\ \mathbf{P}_{BFR}$$

$$(.57247)\quad (.011333)\quad (.012431)\quad (.014264)\quad (.12323)\quad (.080630)$$

$$-.29442\ \mathit{ln}\ \mathbf{P}_{SR} - .069779\ \mathit{ln}\ \mathbf{P}_{WXR} + .55512\ \mathit{ln}\ \mathbf{V}_{CR} - .0038504\ \mathbf{T1}_{BF} + .0072945\ \mathbf{T2}_{BF}$$

$$(.11785)\quad (.10077)\quad (.082470)\quad (.6129E\text{-}3)\quad (.0012638)$$

$\bar{R}^2$ = .94584, D.W. = 1.7279

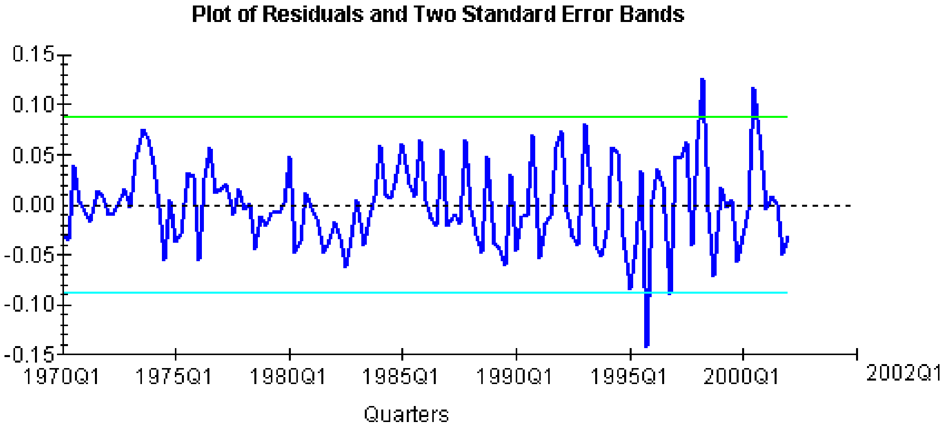
T = 129, Sample 1970Q1 - 2002Q1, OLS estimation, Standard errors in parentheses.

```
                         Unit root tests for residuals

       Test Statistic     LL            AIC           SBC           HQC
DF          -9.5719     211.6305      210.6305      209.2284      210.0610
ADF(1)      -8.5852     213.6263      211.6263      208.8223      210.4874
ADF(2)      -6.7051     213.6263      210.6263      206.4203      208.9180
ADF(3)      -3.9528     221.2061      217.2061      211.5980      214.9283
ADF(4)      -4.6508     224.3489      219.3489      212.3389      216.5017
ADF(5)      -4.4262     224.4444      218.4444      210.0323      215.0277
ADF(6)      -4.5751     225.2715      218.2715      208.4575      214.2854

95% critical value for the Dickey-Fuller statistic =   *NONE*
Critical value not available for the number of regressors in the regression.
LL   = Maximized log-likelihood      AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion     HQC = Hannan-Quinn Criterion
```

The chart below shows the residuals of the estimated equation.



The inclusion of the dummies $\mathbf{T1}_{BF}$ and $\mathbf{T2}_{BF}$ helps to improve the diagnostic results, in particular the stationarity of the residuals. However, the parameter estimates would only be slightly different without these dummies. So their effects are limited.

From the table and the chart, we similarly conclude that the residuals are stationary. The variables in the static equation appear to be co-integrated, and this justifies an error-correction presentation in the dynamic model to be shown later.

The estimated model can also be converted to the original variables, where elasticities can be derived (also shown in Table 2).

$$\ln \mathbf{Q}_{BF} = 2.2635 + .16576\ S2 + .19789\ S3 + .34199\ S4 + .057221 \ln \mathbf{P}_{BN} - 1.0293 \ln \mathbf{P}_{BF}$$

$$-.29442 \ln \mathbf{P}_{S} - .069779 \ln \mathbf{P}_{WX} + 0.78116 \ln \mathbf{P}_{C} + .55512 \ln \mathbf{V}_{C} - .0038504\ \mathbf{T1}_{BF}$$

$$+.0072945\ \mathbf{T2}_{BF}$$

Spirits Table 5 has the results for the static equation of spirits and the residuals are displayed in the graph that follows. Similar conclusions are reached of co-integration among the variables involved, and the residuals will enter the dynamic equation with other stationary differenced variables.

Table 5: Estimated Static Equation and ADF Test of Residuals: Spirits

$$\ln \mathbf{Q}_{S} = \underset{(.80323)}{2.1634} + \underset{(.016452)}{.11883}\ S2 + \underset{(.017954)}{.13472}\ S3 + \underset{(.020507)}{.59661}\ S4 \underset{(.17477)}{-.94989} \ln \mathbf{P}_{BNR} + \underset{(.11351)}{.45818} \ln \mathbf{P}_{BFR}$$

$$\underset{(.15449)}{-\ 1.3132} \ln \mathbf{P}_{SR} + \underset{(.12689)}{.30071} \ln \mathbf{P}_{WXA} + \underset{(.11511)}{.68711} \ln \mathbf{V}_{CR}$$

$\bar{R}^2$ = .95376, D.W. = 1.7945

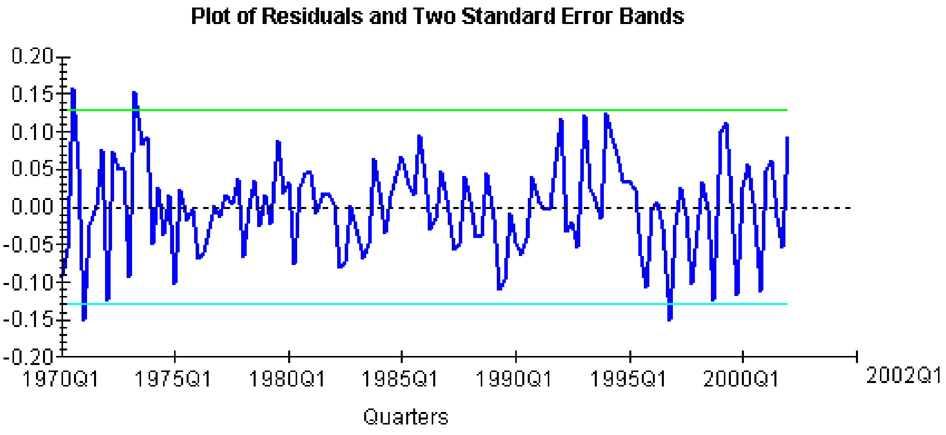
T = 129, Sample 1970Q1 - 2002Q1, OLS estimation, Standard errors in parentheses.

```
                         Unit root tests for residuals

       Test Statistic      LL           AIC           SBC           HQC
DF          -9.8659      171.3953      170.3953      168.9933      169.8259
ADF(1)      -8.3866      172.5390      170.5390      167.7350      169.4001
ADF(2)      -6.7734      172.5448      169.5448      165.3387      167.8364
ADF(3)      -2.7834      202.0082      198.0082      192.4002      195.7304
ADF(4)      -4.0379      211.5769      206.5769      199.5669      203.7297
ADF(5)      -4.7516      214.8886      208.8886      200.4765      205.4719
ADF(6)      -3.9096      215.5202      208.5202      198.7061      204.5340

95% critical value for the Dickey-Fuller statistic =   *NONE*
Critical value not available for the number of regressors in the regression!

LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```



The relationship in the original variables is derived as follows (also shown in Table 2).

$$ln\ \mathbf{Q}_S = 2.1634 + 0.11883S2 + 0.13472\ S3 + 0.59661\ S4 - 0.94989\ ln\ \mathbf{P}_{BN} + 0.45818\ ln\ \mathbf{P}_{BF} - 1.31321\ ln\ \mathbf{P}_S + 0.30071\ ln\ \mathbf{P}_{WX} + 0.8171\ ln\ \mathbf{P}_C + 0.68711\ ln\ \mathbf{V}_C.$$

Wine excl. coolers

Finally, for wine excluding coolers, the estimation involves two steps. Firstly, a new variable, $\mathbf{Q}_{WXR}$, is created as a linear combination of $\mathbf{Q}_{WX}$, $\mathbf{P}_{WXR}$ and $\mathbf{V}_{CR}$. This has the effect of imposing the own-price and income elasticities, which are preferred to the unrestricted estimation results.[9] The coefficients of this linear transformation are taken from averaging the estimated price and income elasticities in a number of previous studies (see Table 14 in Section 4). This new variable is then regressed on the remaining other prices. Table 6 and the chart below give the results. Here the evidence to reject unit root is weaker than in the other equations, but there is no discernible trend in the plot. In the dynamic model, we still treat the residuals as a stationary series, entering the equation along with other stationary regressors.

---

[9] The unrestricted estimation produced insignificant and unstable coefficients, which failed to adequately identify own-price or income effects on consumption. This might be caused by the time-series data on wine volumes and prices not properly reflecting changes over time in the quality of wine.

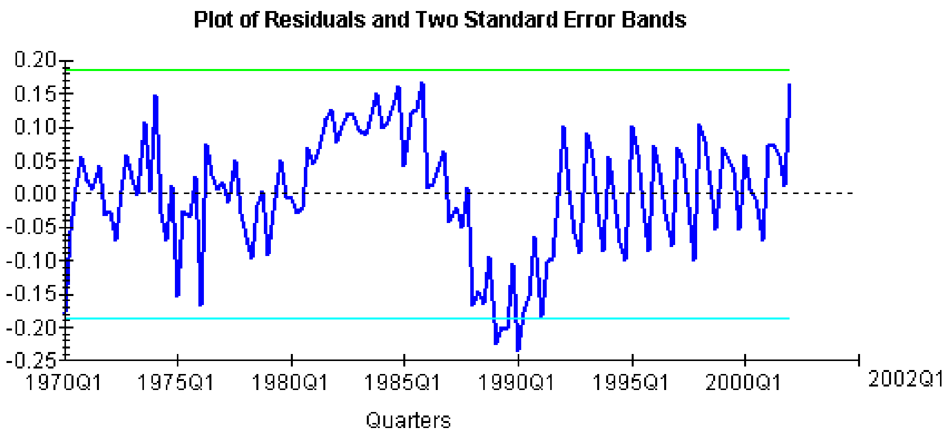


Table 6: Estimated Static Equation and ADF Test of Residuals: Wine (ex coolers)

First, create a new variable:

$$\ln \mathbf{Q}_{WXR} = \ln \mathbf{Q}_{WX} + 0.75 \ln \mathbf{P}_{WXR} - 1.51 \ln \mathbf{V}_{CR}$$

Then run the regression

$$\ln \mathbf{Q}_{WXR} = \underset{(.019083)}{-3.4545} + \underset{(.023074)}{.15771}\, S2 + \underset{(.023053)}{.13566}\, S3 + \underset{(.022968)}{.40263}\, S4 - \underset{(.077689)}{.71413} \ln \mathbf{P}_{BNR} + \underset{(.12359)}{.55825} \ln \mathbf{P}_{BFR}$$

$$- \underset{(.13611)}{.33344} \ln \mathbf{P}_{SR}$$

$\bar{R}^2$ = .78965, D.W. = .83928

T = 129, Sample 1970Q1 - 2002Q1, OLS estimation, Standard errors in parentheses.

```
                         Unit root tests for residuals
       Test Statistic      LL            AIC           SBC           HQC

DF          -5.5852     143.7415      142.7415      141.3395      142.1720
ADF(1)      -3.8046     147.6159      145.6159      142.8119      144.4770
ADF(2)      -2.8224     150.5917      147.5917      143.3856      145.8833
ADF(3)      -1.4598     168.2543      164.2543      158.6463      161.9765
ADF(4)      -1.8478     171.1906      166.1906      159.1805      163.3433
ADF(5)      -2.4160     175.7112      169.7112      161.2992      166.2945
ADF(6)      -2.4275     175.7819      168.7819      158.9678      164.7957

95% critical value for the Dickey-Fuller statistic =   *NONE*
Critical value not available for the number of regressors in the regression.
LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```

Similar to the other equations, a relationship in the original variables can also be derived as follows (also shown in Table 2).

$$\ln \mathbf{Q}_{WX} = -3.4545 + 0.15771\,S2 + 0.13566\,S3 + 0.40263\,S4 - 0.71413 \ln \mathbf{P}_{BN} + 0.55825 \ln \mathbf{P}_{BF} - 0.33344 \ln \mathbf{P}_{S} - 0.75 \ln \mathbf{P}_{WX} - 0.27072 \ln \mathbf{P}_{C} + 1.51 \ln \mathbf{V}_{C}.$$

The dynamic models with ECM

Having tested co-integration and identified a valid co-integrating vector for the variables of interest, the second step of the Engle-Granger procedure is to estimate a dynamic model involving only stationary variables, including the residuals from the estimated equation in the first step. The term of derived residuals from the static equation is the error-correction mechanism (ECM), interpreted as the disequilibrium correcting force driving the system towards equilibrium.

We start with a more general model with sufficiently long lags of both the dependent and independent variables, and the lagged error correction mechanism ECM(-1). The model is estimated and evaluated according to the summary statistics and diagnostics. It is simplified by imposing valid deletion of the insignificant terms. The simplification continues until the most parsimonious models are obtained with reasonable parameters and statistics. The final models chosen are presented in Table 7. More details about the methodology can be found in Appendix A, and the results in Appendix B.

The parameter estimates are generally significant with the expected signs and sensible sizes. The statistics are mostly satisfactory. Further tests on structural stability and prediction performance are presented in the next section.

Table 7: Estimated ECM for On/Off Beers, Spirits and Wine: Final Equations

	$\Delta\ln Q_{BN}$		**$\Delta\ln Q_{BF}$**		**$\Delta\ln Q_{S}$**		**$\Delta\ln Q_{WX}$**	
	Coeff	Std Error	**Coeff**	Std Error	**Coeff**	Std Error	**Coeff**	Std Error
Intercept	**-0.056495**	0.015139	**-0.22360**	0.039048	**-0.42435**	0.062766	**-0.2046**	0.042527
S2	**0.23097**	0.045854	**0.36851**	0.068191	**0.6063**	0.094569	**0.23628**	0.070030
S3			**0.28608**	0.051571	**0.44097**	0.097916	**0.34677**	0.054086
S4			**0.31482**	0.051576	**0.66205**	0.088352	**0.40137**	0.060199
$\Delta\ln Q_{AL}$ (-1)	**-0.20934**	0.14908	**-0.21073**	0.11414	**-0.1757**	0.09554	**-0.62577**	0.086866
$\Delta\ln Q_{AL}$ (-2)	**-0.37369**	0.11267	**-0.23428**	0.096597	**-0.33509**	0.089239	**-0.43373**	0.083168
$\Delta\ln Q_{AL}$ (-3)	**-0.56477**	0.072452	**-0.37670**	0.077234	**-0.4126**	0.063677	**-0.51404**	0.070211
$\Delta\ln P_{BN}$			**0.28091**	0.20317	**-0.97496**	0.31194		
$\Delta\ln P_{BN}$ (-1)			**-0.31146**	0.21227			**-0.76857**	0.30946
$\Delta\ln P_{BN}$ (-2)								
$\Delta\ln P_{BN}$ (-3)	**-0.67932**	0.20040						
$\Delta\ln P_{BF}$					**0.61519**	0.36335	**2.0806**	0.33338
$\Delta\ln P_{BF}$ (-1)			**0.58351**	0.25890			**0.61750**	0.34194
$\Delta\ln P_{BF}$ (-2)	**-0.17669**	0.27752	**-0.50229**	0.26459				
$\Delta\ln P_{BF}$ (-3)			**-0.94972**	0.23150				
$\Delta\ln P_{S}$			**-0.69013**	0.17059	**-1.6617**	0.24531	**-0.79628**	0.28027
$\Delta\ln P_{S}$ (-1)			**-0.44487**	0.18935			**-0.73231**	0.25965
$\Delta\ln P_{S}$ (-2)					**-0.44921**	0.23913		
$\Delta\ln P_{S}$ (-3)								
$\Delta\ln P_{WX}$	**-0.32233**	0.22505					**-0.67083**	0.37952
$\Delta\ln P_{WX}$ (-1)								
$\Delta\ln P_{WX}$ (-2)	**-0.60863**	0.27244						
$\Delta\ln P_{WX}$ (-3)					**-0.52559**	0.27983	**-0.90551**	0.28681
$\Delta\ln P_{C}$					**1.8567**	0.61899		
$\Delta\ln P_{C}$ (-1)								
$\Delta\ln P_{C}$ (-2)	**1.4919**	0.46423	**0.79730**	0.47758				
$\Delta\ln P_{C}$ (-3)								
$\Delta\ln V_{C}$			**0.36946**	0.23754	**0.97597**	0.35025		
$\Delta\ln V_{C}$ (-1)	**0.44819**	0.26390						
$\Delta\ln V_{C}$ (-2)	**-0.27077**	0.15374						
$\Delta\ln V_{C}$ (-3)								
ECM_{AL} (-1)	**-0.73074**	0.17438	**-0.60582**	0.13784	**-0.61395**	0.13146	**-0.13688**	0.072872
Summary Stat								
$\bar{R}^2$	**0.90568**		**0.97535**		**0.98580**		**0.97552**	
S.E.	**0.040409**		**0.037188**		**0.051529**		**0.053640**	
RSS	**0.17472**		**0.14244**		**0.27880**		**0.30211**	
D.W.	**1.7683**		**1.8620**		**1.6701**		**1.7615**	
Diagnostic		[Prob]		[Prob]		[Prob]		[Prob]
Ser Corr	$\chi^2(4)=7.629$	[.106]	$\chi^2(4)=2.807$	[.591]	$\chi^2(4)=17.774$	[.001]	$\chi^2(4)=7.351$	[.118]
RESET	$\chi^2(1)=2.309$	[.129]	$\chi^2(1)=1.383$	[.240]	$\chi^2(1)=3.350$	[.067]	$\chi^2(1)=3.490$	[.062]
Normality	$\chi^2(2)=0.649$	[.723]	$\chi^2(2)=0.421$	[.810]	$\chi^2(2)=27.715$	[.000]	$\chi^2(2)=4.202$	[.122]
Heterosc'ty	$\chi^2(1)=0.025$	[.874]	$\chi^2(1)=0.016$	[.901]	$\chi^2(1)=1.268$	[.260]	$\chi^2(1)=2.743$	[.098]

Note: In the table, subscript AL represents one of the four alcohols being modelled. Depending on the context, AL can be BN, BF, S, or WX.

3 Model Stability and the Effects of the Single European Market

The issues Clearly, for econometric models to be of practical use, they must exhibit a certain degree of stability. The models we have estimated are based on historical data describing past behaviours, and one of their main uses is to make forecasts into the future. The validity of making such a use depends on the validity of the assumption that there is no significant change over time in the behaviours as captured by the econometric models.

Apart from the general issue of model stability, there is also a specific interest in the effects of the single European market, created from 1993, on consumer behaviour towards excise goods. For instance, has increased cross-border shopping significantly changed the model parameters so that the estimated models need some special treatment and amendments to capture those effects?

To address these issues, we have carried out two statistical tests in this section: out-of-sample *ex post* forecast and the Chow test.

3.1 Out-of-Sample Forecast

All the models are estimated using data for 1970Q2-2000Q1, leaving the last eight available observations in 2000Q2-2002Q1 for testing the accuracy of these models' out-of-sample forecasting performance.

The results are shown in graphs, followed by the summary statistics for the equation's dynamic forecast. The models are evidently capable of producing accurate out-of-sample forecasts. The results suggest that the models' structure and parameters are stable and that the estimates are robust.

Out-of-sample forecast: Beer-on

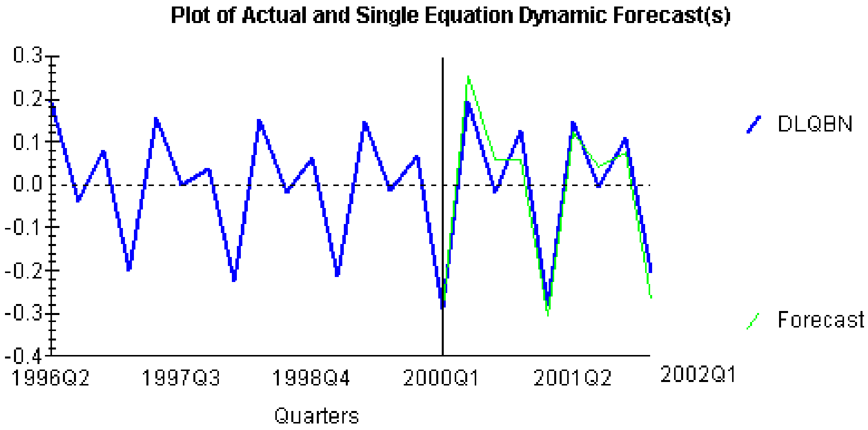


Table 8: Summary statistics for single equation dynamic forecasts: Beer-on

```
Based on 8 observations from 2000Q2 to 2002Q1
Mean Prediction Errors      .0042115   Mean Sum Abs Pred Errors      .051053
Sum Squares Pred Errors     .0029570   Root Mean Sumsq Pred Errors   .054378
Predictive failure test   F(   8, 107)=   1.2013[.305]
```

Out-of-sample forecast: Beer-off

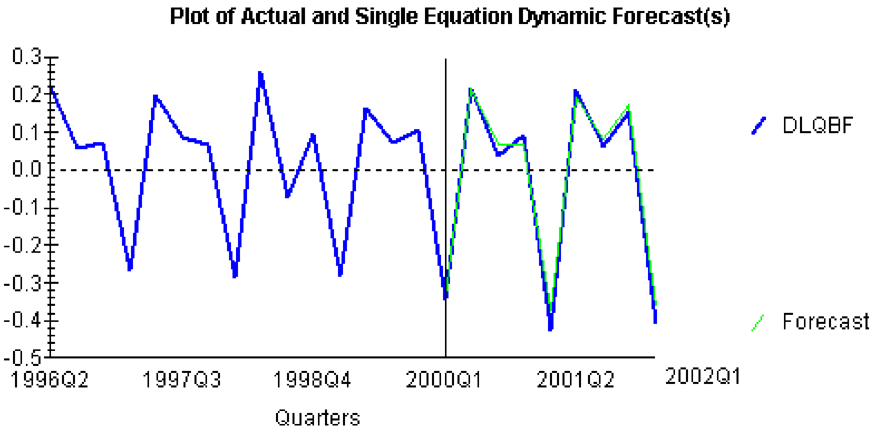


Table 9: Summary statistics for single equation dynamic forecasts: Beer-off

```
 Based on 8 observations from 2000Q2 to 2002Q1
Mean Prediction Errors      -.014571   Mean Sum Abs Pred Errors      .024574
Sum Squares Pred Errors     .8366E-3   Root Mean Sumsq Pred Errors   .028925
Predictive failure test   F(   8, 103)=   .54627[.819]
```

Out-of-sample forecast: Spirits

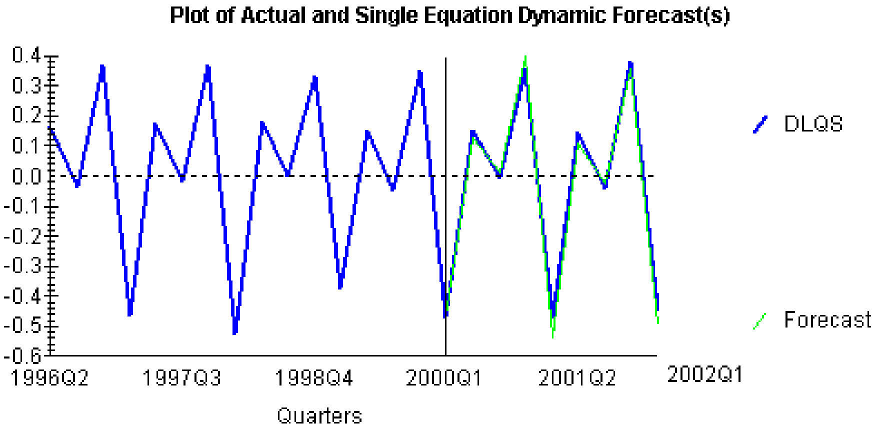


Table 10: Summary statistics for single equation dynamic forecasts: Spirits

```
Based on 8 observations from 2000Q2 to 2002Q1
Mean Prediction Errors        .014555    Mean Sum Abs Pred Errors      .035070
Sum Squares Pred Errors      .0014897    Root Mean Sumsq Pred Errors   .038597
Predictive failure test   F(    8, 105)=    .55209[.815]
```

Out-of-sample forecast: Wine excl. 'coolers'

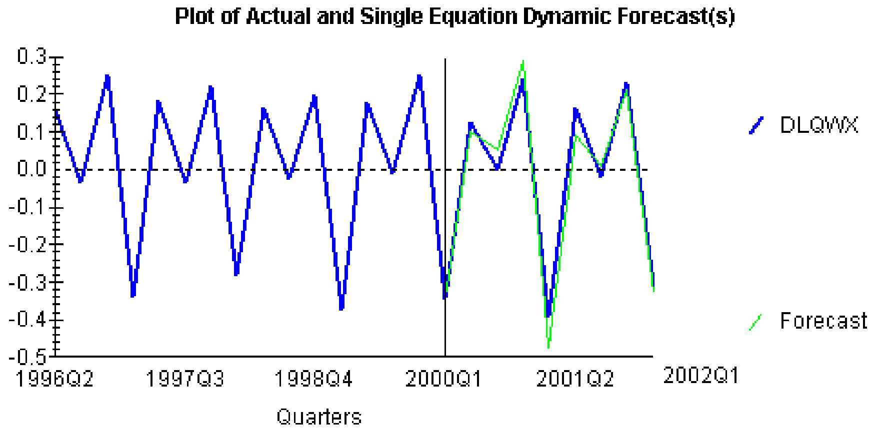


Table 11: Summary statistics for single equation dynamic forecasts: WineX

```
Based on 8 observations from 2000Q2 to 2002Q1
Mean Prediction Errors        .011274    Mean Sum Abs Pred Errors      .043984
Sum Squares Pred Errors      .0024526    Root Mean Sumsq Pred Errors   .049523
Predictive failure test   F(    8, 105)=    .78405[.618]
```

3.2 The Effects of the Single Market

Since the introduction of the Single Market, there has been a noticeable increase in cross-border shopping activities. This has become an alternative supply to satisfy domestic demand for alcohol, and has inevitably had an impact on alcohol duty revenue. In the context of modelling, the important issue is whether there have been significant changes in the elasticities, or other parameters, of the demand equations following the creation of the Single Market. Is it necessary to introduce an explicit treatment in the model specification to capture such effects, or is it valid to use the models estimated without such a treatment? This section investigates this issue.

The Chow test

The Chow test is widely used in econometrics to examine whether the regression coefficients and variances differ between sub-samples. In our application, the whole sample is split into two: pre- and post-SEM (Single European Market).

The test statistics

Consider the following model:[10]

$$y_t = X_t \beta_1 + u_{1t}; \quad u_{1t} \sim N(0, \sigma_1^2): t \in \overline{T}_1$$

$$y_t = X_t \beta_2 + u_{2t}; \quad u_{2t} \sim N(0, \sigma_2^2): t \in \overline{T}_2$$

where $\overline{T}_1 = \{1,2,..., T_1)$, $\overline{T}_2 = \{ T_1 +1, ... ,T)$. The total number of observations is $T = T_1 + T_2$, with T_1 and T_2 being the sample size of sub-period 1 ($t=1,2,..., T_1$) and sub-period 2 ($t= T_1 +1,..., T$) respectively. The question here is whether the parameters in the two sub-periods actually differ, given that they are always estimated with an error. The null hypothesis, which assumes no structural change, is:

$H_0 : \beta_1 = \beta_2$ and $\sigma_1^2 = \sigma_2^2$.

This is a joint hypothesis and involves two separate hypotheses:

$H_0^1 : \beta_1 = \beta_2$, $\quad H_0^2 : \sigma_1^2 = \sigma_2^2$. $(H_0 = H_0^1 \cap H_0^2)$

It is generally of more interest to test H_0^1 than H_0^2.

Chow(1960) proposed the statistics to test the above hypotheses.[11] Two cases are distinguished between $T_2 > k$ and $T_2 < k$, where k is the number of regressors in the model. In the former case the model can be estimated for both sub-periods, while in

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[10] More details can be found in econometrics textbooks such as Cuthbertson *et al* (1992).

[11] Chow, G. C. (1960): “Tests of equality between sets of coefficients in two linear regressions”, *Econometrica*, 28 (3), 591-605, July.

the latter only sub-period 1 can be estimated. In our application, only the case where $T_2 > k$ is relevant.

The test statistic, *CHOW*, is constructed using the residual sum of squares from the estimated models in the whole period (T), sub-period 1 (T_1) and sub-period 2 (T_2). Under the null, the statistic has an F-distribution. Suppose these residual sums of squares are RSS_T , RSS_1 and RSS_2 , we have

$$CHOW = \left(\frac{RSS_T - (RSS_1 + RSS_2)}{RSS_1 + RSS_2} \right) \left(\frac{T-2k}{k} \right) \overset{H_0}{\sim} F\,(\mathrm{k, T\text{-}2k})$$

The results Applying the Chow test to the four equations estimated over three samples, 1970Q2-1992Q4, 1993Q1-2002Q1, and 1970Q2-2002Q1, we obtained the following results, as summarised in Table 12. The evidence firmly supports the stability of the ‘beer-on’, ‘beer-off’ and ‘spirits’ equations, whereas the ‘wine excl. coolers’ equation is marginally stable (critical values are about 1.7 or 2.1 depending on whether 5% or 2.5% significance levels are used). This indicates that the creation of the Single Market has probably had stronger effects on off-beer and wine consumption than on the other categories. This is consistent with the evidence suggesting that cross-border shopping is more important to wine than the other alcohol groups. Nonetheless, there does not appear to be significant structural change in the empirical relationships estimated over the longer period. These remain largely stable, and so can be used in the relevant policy analysis and to forecast.

Table 12: Testing Structural Changes using the Chow Test

		Beer-On	Beer-Off	Spirits	Wines excl 'coolers'
RSS1	1970q2-92q4	0.1058	0.0791	0.1903	0.1719
RSS2	1993q1-02q1	0.0165	0.0191	0.0317	0.0072
RSST	1970q2-02q1	0.1549	0.1423	0.2744	0.2612
T		128	128	128	128
K		21	24	20	20
T-2k		86	80	88	88
Chow		**1.0933**	**1.4982**	**1.0378**	**2.0159**

Sources: This study.

Cautions Although the formal test allows us to reject the hypothesis of any significant changes in parameters following SEM, we still need to be cautious. It might be that the changes are more gradual, with the effects taking longer to exhibit themselves. An extended and revised data set in the future may lead to alternative conclusions. In using the models, we will still take into account possible effects of cross-border shopping and smuggling activities. We will continuously assess the accuracy of the models' forecasts, and make adjustments and updates as new evidence emerges.

4 Elasticities

For many users of the estimated equations, particularly tax policy analysts, price and income elasticities as suggested by the models are most important parameters. This section summarises the findings regarding the elasticity estimates.

New estimates of elasticities

Table 13 gives the new estimates of the own-price elasticities, cross-price elasticities, and elasticities with respect to total expenditure (sometimes simply income elasticities). These are based on long-run static equations estimated, as presented in section 2.

Table 13: Elasticities Estimated in This Study

	On-trade Beer	Off-trade Beer	Spirits	Wine exc ‘coolers’
With respect to prices:				
P_{BN}	**-0.48**	0.06	-0.95	-0.71
P_{BF}	0.43	**-1.03**	0.46	0.56
P_{S}	-0.15	-0.29	**-1.31**	-0.33
P_{WX}	-0.32	-0.07	0.30	**-0.75**
With respect to income:				
V_{C}	-0.18	0.55	0.69	1.51

Source: This study.

The magnitude and signs of these estimates look reasonable in general. In particular, the own-price elasticities are intuitively acceptable, and are in fact in line with other findings suggested in a large number of previous studies. Some of the cross-price elasticities do not have the desirable property of symmetry. Though not entirely satisfactory, this is not uncommon in other studies. It has generally been recognised that cross-price elasticities are less accurately and reliably estimated. This may be due, at least partly, to the multicollinearity between the regressors. Muticollinearity makes it difficult to separate the individual effects of each regressor, though collectively the explanatory variables explain well the behaviour of the dependent variable.

To facilitate comparisons with previous studies, Table 14 summarises estimates of the elasticities found in the literature. Other studies do not usually separate on- and off-trade beer markets. From the two tables, it can be seen that the new estimates are broadly within the range of earlier studies, although the range itself is fairly large. One new finding is that on-trade beer appears to be regarded by consumers as an inferior good, as the income elasticity is negative. This is consistent with the observation that the budget share of on-trade beer has been declining, suggesting that over time consumption has shifted away from on-trade beer to other categories, noticeably to wine. This is supported by a previous study, shown in the table (MB02). The work by

Moosa and Baxter (2002) is the most recent of other similar research in this area, using data up to 1995Q1. On the other hand, their own-price elasticity estimates seem to be much larger in size than the others. The authors appear to believe that changes in the markets have taken place, particularly for beer, which underlies the discrepancies between their results and others. They also quoted an earlier study by Duffy (1983), who obtained a wine price elasticity of comparable size.

Estimates in previous studies

Table 14: Elasticities Estimated by Other Studies

	Own-Price Elasticity			Income Elasticity			Data Period
	Beer	*Spirits*	*Wine*	*Beer*	*Spirits*	*Wine*	
S88	-0.20	-0.79	-0.49	0.41	2.18	1.74	1955-85
C89	-1.05	-2.42	-0.91	0.92	2.09	2.56	1970-88
J89	-0.27	-0.95	-0.77	0.31	1.14	1.46	1964Q1-83Q4
BMS90	-0.99	-0.92	-1.12	0.85	0.94	1.59	1970-86
CO91	-0.30	-0.49	-0.30	0.68	1.35	0.80	1965-89
D91	-0.09	-0.86	-0.75	0.54	2.07	1.87	1963Q1-83Q1
BN97	-0.95	-1.32	-0.93	0.89	0.98	1.61	1952-92
SB97	-0.10	-1.16	-0.66	0.70	1.06	1.42	1963Q1-93Q1
C99A	-0.15	-2.03	-0.75	0.39	0.39	0.42	1965Q1-98Q1
C99B	-0.60	-1.20	-0.40	0.56	0.62	0.41	1965Q1-98Q1
C99B1	-0.59	-1.37	-0.38	0.49	0.56	0.31	1965Q1-98Q1
C99C	-0.99	-0.99	-0.99	0.52	1.17	1.96	1965Q1-98Q1
MB02	-3.20		-2.30	-1.80		2.30	1964Q1-95Q1

Sources: Mostly taken from Table 18 in Chambers (1999), p38.

Note: More details of those studies are given below.

Code	**Authors**	**Published**	**Model**
S88	Selvanathan, E.A.	1988	Rotterdam
C89	Crooks, E.	1989	AIDS
J89	Jones, A.M.	1989	AIDS
BMS90	Baker, P., S. McKay and E. Symons	1990	AIDS
CO91	Cuthbertson, K. and P. Ormerod	1991	ADL
D91	Duffy, M.	1991	Rotterdam
BN97	Black, D. and A. Nied	1997	AIDS
SB97	Salisu, M. A. and V. N. Balasubramanyam	1997	CVAR
C99A	Chambers, M. J.	1999	AIDS-ECM, No.4
C99B	Chambers, M. J.	1999	AIDS-ECM, No.10
C99B1	Chambers, M. J. (Chambers 1999, p102)	1999	AIDS-ECM, No.10 With 1995-based data
C99C	Chambers, M. J.	1999	LES, No. 7
MB02	Moosa, I. A. and J. L. Baxter	2002	AIDS

5 Conclusions

Objectives have been met

The objectives set out at the beginning of the study have been achieved. Demand equations for alcoholic beverages in the UK have been successfully re-estimated with an extended sample including the latest available observations up to 2002Q1. The problems experienced in previous re-estimation attempts have been resolved.

The new models: statistical adequacy, economic interpretability, and forecasting accuracy

Four sets of empirical demand models have been built for on-trade beer, off-trade beer, spirits, and wine excluding coolers. The new models' structure departs from the original AIDS specification, and follows a single-equation approach based on the standard consumer demand theory. Estimation and testing of the models have followed the widely practised general-to-specific econometric methodology, with application of unit root tests and co-integration techniques. The chosen models are dynamic error-correction models with broadly satisfactory diagnostic statistics, mostly sensible estimates of parameters, and generally clear economic interpretability. Tests on the out-of-sample prediction performance and on model stability have further supported the robustness and usefulness of these models. New estimates of the long-run price elasticities, especially those with respect to own prices, appear reasonable and are in line with what have been suggested in the literature.

Summary of achievements

The achievements of this study, in comparison with the existing literature, are summarised as follows:

- successfully updating the forecasting models with data up to 2002Q1;
- following the general-to-specific and cointegration modelling approach;
- achieving estimates of broadly sensible parameters and elasticities;
- providing separate treatments of the on/off beer markets;
- excluding the 'coolers' component from wine;
- removing tobacco from the demand system;
- producing accurate out-of-sample forecasts.

Caveats

We recognise that not all of the econometric test statistics are adequately conclusive and entirely satisfactory. Alternative specifications or refinements may lead to further improvements on the present results. Similarly, some parameters may be less accurately and intuitively measured by the estimation method, especially those of the cross-price elasticity terms. This may partly be due to multicollinearity between most price variables. Moreover, the demand effects of coolers, smuggling, and the single

European market, though not formally captured by the estimated equations, should not be completely dismissed. It may be that the current sample is insufficient to identify these effects. However, an extended or updated sample may change the outcome in the future. In using the estimated models, we still consider these effects and are prepared to make adjustments as necessary to allow for their presence. We will closely monitor the performance of these models in forecasting and other uses, correct possible model weaknesses using judgement, and continue updating them with new information.

Further research and applications

The dynamic adjustment process of the demand equations need to be further investigated. The application of the models in forecasting revenue and in evaluating policy options will further reveal the properties and behaviours of the models and can suggest directions for future changes. Further, the new elasticity estimates can be used to address the issue of revenue maximisation, often related to the current spirits duty rate.

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Appendix A: Econometric Methodology and Practices

Introduction

This appendix briefly explains the general-to-specific modelling approach, unit root tests, co-integration and error correction, and their relevance to the modelling exercises carried out in this study.[12]

A.1 The General-to-Specific Dynamic Modelling Approach

Econometric Methodology

Applied econometric work essentially involves economic theory, data and real-world institutional knowledge, estimation techniques, and econometric methodology. Econometric methodology guides the practitioners to effectively use the estimation techniques and to evaluate the adequacy of estimated results.

Of the several influential methodologies developed in the last two decades, the ‘general to specific’ approach (see Hendry (1993, 1995), among others) is widely practised. It was largely initiated and developed by econometricians based at the London School of Economics, and is often referred to as the LSE tradition, or Hendry’s methodology in association with its leading proponent. Furthermore, the development in the theory of "co-integration" (Engle and Granger 1987) has provided a solid statistical foundation for the error correction mechanism (ECM), a widely adopted practice closely associated with the LSE dynamic modelling approach.

The current modelling approach

The modelling approach of this study follows the general-to-specific methodology, and applies unit root tests and co-integration techniques to address the issue of data non-stationarity and to capture both the short-run dynamics and the long-run equilibrium property of the underlying process being modelled.

Basic ideas

The basic philosophy of the LSE approach is that economic time-series data are generated by a process of immense generality and complexity. This process is termed the data generating process (DGP), and is a benchmark against which all models are compared and evaluated. Because of the complexity and generality involved in the actual DGP, the econometric modelling process is viewed as an effort to seek for the judicious simplification of this DGP, based on the observable and related to prior theory. However, there is no guarantee that any prior economic theory will capture every main feature of the data, especially their dynamic features, and empirical models

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[12] Materials in this appendix have been drawn upon from various papers and books. The author claims no originality in formulating the ideas and techniques.

have to be developed interactively to characterise the data adequately, and be consistent with the theory. The general-to-specific methodology suggests, therefore, that we start from the most ‘general’ model, including all possible lags and variables, based on previous research evidence, economic theory, data frequency, and common sense. We then proceed with a simplification process which sequentially reduces the general model to simpler models. The simplification is based on imposing restrictions on the more general model, and its validity has to be ensured by the F-type tests and an improvement (or no deterioration) of the equation's standard error. Diagnostic tests are frequently applied to the general model and the simpler models to ensure that the underlying assumptions of the models are not violated (no mis-specification). The diagnostic statistics also provide an indication of possible directions of model reduction and reparametrisation. The simplification process is continued in this fashion, until we have reached the most parsimonious version of the model, which gives sufficient economic interpretability while at the same time satisfies the diagnostic tests for the statistical assumptions. A number of criteria have been proposed in the literature as a benchmark for the acceptance of a model, including (a) theory consistency, (b) innovation error, (c) weak exogeneity, (d) parameter constancy, (e) data admissibility, and (f) encompassing.

Formalisation

To formalise the above general ideas, we start with a representation of the DGP. This is simply the joint probability of all the sample data. Let x_t denote a vector of observations on all variables in period t, and $X_{t-1} = (x_{t-1}, ..., x_1)$. The joint probability of the sample x_t may be stated as

$$\prod_{t=1}^{T} D\ (x_t \mid X_{t-1}; \Theta)$$

where Θ is a vector of unknown parameters of the joint density function *D*. The econometric modelling process is to simplify this DGP, consisting of the following four stages, which are by no means sequential (See Cuthbertson *et al* 1992, Ch.4).

1. Marginalise the DGP. Select only a subset of variables that are of interest to the problem concerned, and ignore others.

2. Conditioning. From the selected variables, we choose a subset of endogenous variables y_t , which are then conditioned or determined by the remaining variables z_t. z_t are supposed to be at least weakly exogenous.

After valid marginalising and conditioning the simplified DGP becomes:

$$\prod_{t=1}^{T} D\ (y_t \mid Y_{t-1}; Z_t; \phi)$$

3. Functional form. The above conditioned marginalised DGP is still in a general form, and a specific functional form has to be assumed before estimation and other statistical inferences can be carried out.

4. Estimation. Replace the unknown parameters with numerical values obtained by the appropriate estimation methods.

Implementation

Putting the above into practice, the "general to specific" approach essentially involves four steps, as summarised in Pagan(1987).

Step 1: Formulate a general model. Economic theory suggests which variables should enter a relationship, while the dynamics are left to be determined by the data. Suppose Y is the economic variable to be explained. $X_t = (X_1 \ldots X_m)_t$ is a set of m explanatory variables suggested by economic theory. The general model is usually represented by the following autoregressive distributed lag (ADL) function:

$$Y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i Y_{t-i} + \sum_{k=1}^{m} \sum_{i=0}^{n} \beta_{k\,i} X_{k\,t-i} + u_t,$$

where u_t is a white noise disturbance. The length of the lags is usually deliberately chosen to be large enough to cover all possible dynamics of the system. The generality of this ADL representation is reflected by the fact that a large number of economic models can be derived from it, as illustrated in Hendry and Richard (1983).[13] This model is then estimated.

Step 2. Reparametrisation of the ADL model. The ADL model represents the least restricted statistical model, which serves as a benchmark for the subsequent models to be compared with. However, the ADL model may not possess the desirable properties required for efficient estimation, such as stationarity, orthogonality, etc. It would normally have little direct economic interpretability. Therefore, this formulation has to be rearranged to obtain near orthogonal explanatory variables and more interpretable expressions in terms of the final equilibrium.

Step 3. Simplification of the model until the most parsimonious form is found. This involves imposing restrictions on a more general model to obtain a more restricted

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[13] Hendry, D. F. and Richard , J.-F. (1983): “The econometric analysis of economic time series”, *International Statistical Reviews*, 51, 111-163.

model. The restrictions have to be validated by the F-type tests. This is also referred to as specification tests (Spanos 1986).[14]

Step 4. Extensive evaluation of the resulting model. This is to assure that the statistical assumptions underlying the model are not violated, and that the model does adequately characterise the DGP. Most tests are based on analysis of the residuals, since these reflect how well the model explains the actual phenomenon. The residuals also provide a proxy for the disturbance term in the model, which is unobservable.

There can be no automation in model building.

The above four steps characterise the dynamic modelling methodology, but they are neither mechanical nor necessarily sequential. No procedures can actually be offered to 'automate' the process of designing an empirical econometric model, and some adjustment by the analyst is often required. In applied work, the reparameterisation and simplification of a more general model are usually undertaken at the same time. Diagnostic tests for misspecification are applied in the whole simplification process, which gives useful information to indicate possible directions for further simplification/reparametrisation. In moving from a general ADL to an empirical econometric model, one common practice is to introduce an error correction mechanism (ECM) into the model. The presence of an ECM incorporates the steady-state effects into a dynamic model and provides a convenient way for a model to capture both the long-run relationship, usually implied by economic theory, and the short-run dynamics.

A.2 Cointegration and Error-Correction

Cointegration reconciles statistical and theoretical requirements in applied econometrics

The development of co-integration analysis has extended and formalised the ECM specification. This technique addresses a long-recognised inconsistency in applied econometrics, namely the obvious non-stationarity of many economic time series and the standard econometric theories which are based on the assumption that the data are stationary. Differencing the series can achieve stationarity, but involves loss of long run equilibrium relationships. On the other hand, the ECM specification developed in the LSE tradition retains levels information which is then incorporated into a dynamic model involving only stationary series. The notion of co-integration reveals the relationship among a number of variables which are individually non-stationery, but a linear combination of which might result in a stationary series. In Engle and Granger

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[14] Spanos, A. (1986): *Statistical Foundations of Econometric Modelling,* Cambridge University Press, Cambridge.

(1987) it is proved that cointegrated series have an ECM representation, and conversely ECM generates a cointegrated series. Therefore the theory of co-integration reconciles the statistical requirement and economic theories, and it justifies the legitimate use of level variables in the dynamic modelling process.

Integrated series

A non-stationary series x_t which can be transformed to a stationary series by differencing d times is said to be integrated of order d, or $x_t \sim I(d)$.

Testing for the order of integration

The Augmented Dickey-Fuller test (ADF) and/or Dickey-Fuller test (DF) is used for this purpose. Briefly, the ADF test involves first running the following regression:

$$\Delta x_t = \beta x_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta x_{t-j} + e_t$$

The choice of k is to ensure that the residual e_t is empirically white noise. When k=0, the test becomes the DF test. The null hypothesis is H_0: $x_t \sim I(1)$, against H_1: $x_t \sim I(0)$. The test statistic is the ‘ t’ - value of the estimated $\hat{\beta}$. If it is negative and significant, i.e., smaller than some critical value (larger in absolute value), then we reject the null in favour of H_1, concluding that $x_t \sim I(0)$. If we cannot reject the null, we continue the test with higher order differenced variables, and so on, until we reject the null in favour of the alternative. The ‘t’-statistic used in this test does not actually have a t-distribution. Critical values with different significance levels, originally generated by Fuller (1976), are usually provided by econometric packages.

Defining cointegration

Time series x_t and y_t are said to be cointegrated of order d, b where $d \geq b \geq 0$, written as: x_t , $y_t \sim CI(d, b)$, if (i) both series are integrated of order d, and (ii) there exists a linear combination of these variables, say $(\alpha_1 x_t + \alpha_2 y_t)$, which is integrated of order d-b. The vector $[\alpha_1, \alpha_2]$ is called a cointegrating vector. The most common application is the case where $d = b = 1$ and $(d - b) = 0$: x_t and y_t are both non-stationary but $(\alpha_1 x_t + \alpha_2 y_t)$ becomes stationary. The definition is easily generalised to more variables.

Testing for cointegration

Having tested and found out the order of integration for the variables of interest, the next step is to test possible co-integration among these variables. Various test procedures exist in the literature. But commonly used are two methods: the residual-based ADF test, and Johansen's ML approach.

The ADF residual test involves first running the co-integrating regression, $y_t = a x_t + c + e_t$, where y_t and x_t are both non-stationary $I(1)$ variables, then testing whether the residual e_t follows an I(0) process using ADF. If y_t and x_t are co-integrated, e_t is stationary.

The Johansen procedure offers a unified framework for estimation and testing of cointegration relations in the context of vector autoregressive (VAR) error correction models. Cointegration inference is based on testing the rank of the matrix **Π** in the following model

$$\Delta \mathbf{Y_t} = \sum_{i=1}^{k} \mathbf{\Gamma_i}\, \Delta \mathbf{Y_{t-i}} + \mathbf{\Pi}\, \mathbf{Y_{t-k}} + \varepsilon_t ,$$

which is an error-correction representation of the unrestricted VAR model:

$$Y_t = \sum_{i=1}^{k} A_i\, Y_{t-i} + \varepsilon_t$$

Y_t is an (n × 1) vector of *I*(1) variables, A_i is a (n × n) matrix of coefficients and ε_t is a vector of random errors, $\Gamma_i = - I + A_1 + ... + A_i$, $\Pi = - (I - A_1 - ... - A_k)$.

If the rank of **Π** is *n*, the vector process Y_t is stationary, ie, $Y_t \sim I(0)$. If the rank of **Π** is r < n, there exists a representation of **Π** such that $\mathbf{\Pi} = \alpha \cdot \beta'$, where α and β are both n × r matrices. The matrix β is the *cointegrating matrix* and has the property that $\beta' \mathbf{Y_t} \sim I(0)$, while $\mathbf{Y_t} \sim I(1)$. Hence, the variables in $\mathbf{Y_t}$ are cointegrated. The number of distinct cointegrating vectors which exist between the variables of $\mathbf{Y_t}$ is given by the rank *r*, and the columns of the cointegating matrix β form these cointegrating vectors.

Testing starts from $r = 0$, ie, from the hypothesis that there are no cointegrating vectors in a VAR model, and continues to a higher number if the hypothesis is rejected. The test stops when the null cannot be rejected.

Both the residual-based and Johansen tests are available with *Microfit 4.1*.

The Engle-Granger two-stage procedure

The final models reported in this study have been estimated using the Engle-Granger two-stage procedure for modelling cointegrated series, briefly illustrated below.

On the condition that both y_t and x_t are I(1) series, *first* estimate the static equation

$$y_t = \beta x_t + u_t$$

by OLS and test for stationarity of the residuals. *Second*, if this is not rejected, estimate the dynamic model

$$\Delta y_t = \alpha_1 \Delta x_t + \alpha_2 (y_{t-1} - \beta x_{t-1}) + \varepsilon_t ,$$

replacing β by its previously computed OLS estimate $\hat{\beta}$. The second stage estimation only involves variables of identical order of integration: Δy_t, Δx_t, and $(y_{t-1} - \hat{\beta} x_{t-1})$ are all I(0) and consequently, provided the model is properly specified, ε_t is also I(0).

In practice, the second stage starts with a more general model than the above, with long lagged differenced dependent and independent variables. Simplification and testing continue until we achieve the most parsimonious and adequate model.

Appendix B: Complete Microfit Output

This appendix gives the estimation results as reported in *Microfit*. Slightly different notations are used here. Their relationships to those used in the main text are shown below.

LQBN = $ln\ \mathbf{Q}_{BN,}$,	DLQBN = $\Delta ln\ \mathbf{Q}_{BN,}$,	On-beer quantity in log.
LPBN = $ln\ \mathbf{P}_{BN,}$,	DLPBN = $\Delta ln\ \mathbf{P}_{BN,}$,	On-beer price in log.
LQBF = $ln\ \mathbf{Q}_{BF,}$,	DLQBF = $\Delta ln\ \mathbf{Q}_{BF,}$,	Off-beer quantity in log.
LPBF = $ln\ \mathbf{P}_{BF,}$,	DLPBF = $\Delta ln\ \mathbf{P}_{BF,}$,	Off-beer price in log.
LQS = $ln\ \mathbf{Q}_{S,}$,	DLQS = $\Delta ln\ \mathbf{Q}_{S,}$,	Spirits quantity in log.
LPS = $ln\ \mathbf{P}_{S,}$,	DLPS = $\Delta ln\ \mathbf{P}_{S,}$,	Spirits price in log.
LQWX = $ln\ \mathbf{Q}_{WX,}$,	DLQWX = $\Delta ln\ \mathbf{Q}_{WX,}$,	Wine (excl. coolers) quantity in log.
LPWX = $ln\ \mathbf{P}_{WX,}$,	DLPWX = $\Delta ln\ \mathbf{P}_{WX,}$,	Wine (excl. coolers) price in log.
LVC = $ln\ \mathbf{V}_{C,}$,	DLVC = $\Delta ln\ \mathbf{V}_{C,}$,	Total consumers expenditure in log.
LPC = $ln\ \mathbf{P}_{C,}$,	DLPC = $\Delta ln\ \mathbf{P}_{C,}$,	Consumer price in log.
LEMPR = $ln\ \mathbf{R}_{EM,}$,		Rate of employment in log.

The transformed variables used in the static equation, as shown on pages 16 and 21 of the main text, are listed in the following.

LPBNR = LPBN - LPC;

LPBFR = LPBF - LPC;

LPSR = LPS - LPC;

LPWXR = LPWX - LPC;

LVCR = LVC - LPC;

LQWXR = LQWX+0.75*LPWXR-1.51*LVCR

B.1 On-trade Beer

The long-run static equation

```
The level equation for LQBN, 1970q1-2002q1

                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is LQBN
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                       9.5639             1.0561              9.0563[.000]
 S2                         .15792            .013057             12.0944[.000]
 S3                         .19946            .015489             12.8780[.000]
 S4                         .18133            .019814              9.1515[.000]
 LPBNR                     -.47598             .17072             -2.7880[.006]
 LPBFR                      .43242             .10478              4.1269[.000]
 LPSR                      -.14741             .13674             -1.0780[.283]
 LPWXR                     -.31740            .099706             -3.1833[.002]
 LVCR                      -.18150             .14032             -1.2935[.198]
 LEMPR                      1.1735             .33691              3.4830[.001]
******************************************************************************
 R-Squared                     .84728   R-Bar-Squared                   .83573
 S.E. of Regression           .050502   F-stat.    F(  9, 119)   73.3572[.000]
 Mean of Dependent Variable    8.1603   S.D. of Dependent Variable      .12460
 Residual Sum of Squares       .30351   Equation Log-likelihood       207.3218
 Akaike Info. Criterion      197.3218   Schwarz Bayesian Criterion    183.0227
 DW-statistic                  2.1621
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
******************************************************************************
*                     *                          *
* A:Serial Correlation*CHSQ(   4)=  39.3119[.000]*F(   4, 115)=  12.6016[.000]
*                     *                          *
* B:Functional Form   *CHSQ(   1)=   .11211[.738]*F(   1, 118)=   .10264[.749]
*                     *                          *
* C:Normality         *CHSQ(   2)=   .97865[.613]*       Not applicable
*                     *                          *
* D:Heteroscedasticity*CHSQ(   1)= .1328E-3[.991]*F(   1, 127)= .1307E-3[.991]
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```

Unit root tests

```
                         Unit root tests for residuals
******************************************************************************
 Based on  OLS regression of LQBN on:
 INPT            S2              S3              S4              LPBNR
 LPBFR           LPSR            LPWXR           LVCR            LEMPR
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
        Test Statistic      LL           AIC          SBC          HQC
 DF        -12.0489      196.1834      195.1834      193.7814      194.6140
 ADF(1)     -8.2912      196.3943      194.3943      191.5903      193.2554
 ADF(2)     -7.7606      198.2529      195.2529      191.0468      193.5445
 ADF(3)     -3.3376      218.1697      214.1697      208.5617      211.8919
 ADF(4)     -3.7961      220.0184      215.0184      208.0083      212.1711
 ADF(5)     -3.8640      220.4202      214.4202      206.0082      211.0035
 ADF(6)     -4.0843      221.2983      214.2983      204.4843      210.3122
******************************************************************************
 95% critical value for the Dickey-Fuller statistic =   *NONE*
 Critical value not available for the number of regressors in the regression!
 LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
 SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```

The short-run dynamic equation

```
Final ECM for on-beer DLQBN.
                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is DLQBN
 120 observations used for estimation from 1970Q2 to 2000Q1
******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                     -.056495            .015139            -3.7317[.000]
 S2                         .23097            .045854             5.0371[.000]
 DLQBN(-1)                 -.20934             .14908            -1.4042[.163]
 DLQBN(-2)                 -.37369             .11267            -3.3168[.001]
 DLQBN(-3)                 -.56477            .072542            -7.7854[.000]
 DLPBN(-3)                 -.67932             .20040            -3.3899[.001]
 DLPBF(-2)                 -.17669             .27752            -.63665[.526]
 DLPWX                     -.32233             .22505            -1.4323[.155]
 DLPWX(-2)                 -.60863             .27244            -2.2340[.028]
 DLPC(-2)                   1.4919             .46423             3.2138[.002]
 DLVC(-1)                   .44819             .26390             1.6983[.092]
 DLVC(-2)                  -.27077             .15374            -1.7612[.081]
 ECM_BN(-1)                -.73074             .17438            -4.1906[.000]
******************************************************************************
 R-Squared                     .91519   R-Bar-Squared                   .90568
 S.E. of Regression           .040409   F-stat.    F( 12, 107)   96.2199[.000]
 Mean of Dependent Variable -.0010389   S.D. of Dependent Variable      .13157
 Residual Sum of Squares       .17472   Equation Log-likelihood       221.6524
 Akaike Info. Criterion      208.6524   Schwarz Bayesian Criterion    190.5337
 DW-statistic                  1.7683
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
******************************************************************************
*                      *                          *
* A:Serial Correlation*CHSQ(   4)=   7.6291[.106]*F(   4, 103)=   1.7482[.145]
*                      *                          *
* B:Functional Form   *CHSQ(   1)=   2.3089[.129]*F(   1, 106)=   2.0796[.152]
*                      *                          *
* C:Normality         *CHSQ(   2)=   .64936[.723]*       Not applicable
*                      *                          *
* D:Heteroscedasticity*CHSQ(   1)=  .025297[.874]*F(   1, 118)=  .024880[.875]
*                      *                          *
* E:Predictive Failure*CHSQ(   8)=   9.6105[.293]*F(   8, 107)=   1.2013[.305]
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
   E:A test of adequacy of predictions (Chow's second test)
```

B.2 Off-trade Beer

The long-run static equation

```
The level equation for LQBF, 1970q1-2002q1

                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is LQBF
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                       2.2635             .57247             3.9539[.000]
 S2                         .16576            .011333            14.6264[.000]
 S3                         .19789            .012431            15.9185[.000]
 S4                         .34199            .014264            23.9764[.000]
 LPBNR                     .057221             .12323             .46436[.643]
 LPBFR                     -1.0293            .080630           -12.7660[.000]
 LPSR                      -.29442             .11785            -2.4981[.014]
 LPWXR                    -.069779             .10077            -.69245[.490]
 LVCR                       .55512            .082470             6.7312[.000]
 T1BF                    -.0038504           .6129E-3            -6.2826[.000]
 T2BF                     .0072945           .0012638             5.7720[.000]
******************************************************************************
 R-Squared                     .95007   R-Bar-Squared                   .94584
 S.E. of Regression           .044229   F-stat.    F( 10, 118)  224.5295[.000]
 Mean of Dependent Variable    6.2599   S.D. of Dependent Variable      .19005
 Residual Sum of Squares       .23083   Equation Log-likelihood       224.9767
 Akaike Info. Criterion      213.9767   Schwarz Bayesian Criterion    198.2477
 DW-statistic                  1.7279
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
******************************************************************************
*                     *                          *
* A:Serial Correlation*CHSQ(   4)=  20.9640[.000]*F(   4, 114)=   5.5303[.000]
*                     *                          *
* B:Functional Form   *CHSQ(   1)=   3.6794[.055]*F(   1, 117)=   3.4351[.066]
*                     *                          *
* C:Normality         *CHSQ(   2)=   2.2207[.329]*       Not applicable
*                     *                          *
* D:Heteroscedasticity*CHSQ(   1)=   5.8307[.016]*F(   1, 127)=   6.0120[.016]
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```

Unit root tests

```
                         Unit root tests for residuals
******************************************************************************
 Based on  OLS regression of LQBF on:
 INPT            S2              S3              S4              LPBNR
 LPBFR           LPSR            LPWXR           LVCR            T1BF
 T2BF
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
        Test Statistic      LL          AIC           SBC           HQC
 DF          -9.5719      211.6305      210.6305      209.2284      210.0610
 ADF(1)      -8.5852      213.6263      211.6263      208.8223      210.4874
 ADF(2)      -6.7051      213.6263      210.6263      206.4203      208.9180
 ADF(3)      -3.9528      221.2061      217.2061      211.5980      214.9283
 ADF(4)      -4.6508      224.3489      219.3489      212.3389      216.5017
 ADF(5)      -4.4262      224.4444      218.4444      210.0323      215.0277
 ADF(6)      -4.5751      225.2715      218.2715      208.4575      214.2854
******************************************************************************
 95% critical value for the Dickey-Fuller statistic =   *NONE*
 Critical value not available for the number of regressors in the regression!
 LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
 SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```

The short-run dynamic equation

```
Final ECM for off-beer DLQBF.

                       Ordinary Least Squares Estimation
*******************************************************************************
 Dependent variable is DLQBF
 120 observations used for estimation from 1970Q2 to 2000Q1
*******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                      -.22360           .039048              -5.7263[.000]
 S2                         .36851           .068191               5.4041[.000]
 S3                         .28608           .051571               5.5473[.000]
 S4                         .31482           .051576               6.1040[.000]
 DLQBF(-1)                 -.21073            .11414              -1.8462[.068]
 DLQBF(-2)                 -.23428           .096597              -2.4254[.017]
 DLQBF(-3)                 -.37670           .077234              -4.8773[.000]
 DLPBN                      .28091            .20317               1.3826[.170]
 DLPBN(-1)                 -.31146            .21227              -1.4673[.145]
 DLPBF(-1)                  .58351            .25890               2.2538[.026]
 DLPBF(-2)                 -.50229            .26459              -1.8984[.060]
 DLPBF(-3)                 -.94972            .23150              -4.1025[.000]
 DLPS                      -.69013            .17059              -4.0456[.000]
 DLPS(-1)                  -.44487            .18935              -2.3495[.021]
 DLPC(-2)                   .79730            .47758               1.6694[.098]
 DLVC                       .36946            .23754               1.5553[.123]
 ECM_BF(-1)                -.60582            .13784              -4.3950[.000]
*******************************************************************************
 R-Squared                     .97867   R-Bar-Squared                    .97535
 S.E. of Regression           .037188   F-stat.    F( 16, 103)  295.3368[.000]
 Mean of Dependent Variable  .0031566   S.D. of Dependent Variable       .23688
 Residual Sum of Squares       .14244   Equation Log-likelihood        233.9065
 Akaike Info. Criterion      216.9065   Schwarz Bayesian Criterion     193.2128
 DW-statistic                  1.8620
*******************************************************************************


                               Diagnostic Tests
*******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
*******************************************************************************
*                     *                          *
* A:Serial Correlation*CHSQ(   4)=   2.8070[.591]*F(   4,  99)=   .59280[.669]
*                     *                          *
* B:Functional Form   *CHSQ(   1)=   1.3829[.240]*F(   1, 102)=   1.1892[.278]
*                     *                          *
* C:Normality         *CHSQ(   2)=   .42141[.810]*       Not applicable
*                     *                          *
* D:Heteroscedasticity*CHSQ(   1)=  .015571[.901]*F(   1, 118)=  .015313[.902]
*                     *                          *
* E:Predictive Failure*CHSQ(   8)=   4.3702[.822]*F(   8, 103)=   .54627[.819]
*******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
   E:A test of adequacy of predictions (Chow's second test)
```

B.3 Spirits

The long-run static equation

```
The levels equation for LQS, 1970q1-2002q1

                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is LQS
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                       2.1634              .80323            2.6934[.008]
 S2                         .11883             .016452            7.2232[.000]
 S3                         .13472             .017954            7.5035[.000]
 S4                         .59661             .020507           29.0932[.000]
 LPBNR                     -.94989              .17477           -5.4350[.000]
 LPBFR                      .45818              .11351            4.0364[.000]
 LPSR                      -1.3132              .15449           -8.5003[.000]
 LPWXR                      .30071              .12689            2.3699[.019]
 LVCR                       .68711              .11511            5.9690[.000]
******************************************************************************
 R-Squared                     .95665   R-Bar-Squared                   .95376
 S.E. of Regression           .064404   F-stat.    F(  8, 120)  331.0031[.000]
 Mean of Dependent Variable    7.2593   S.D. of Dependent Variable      .29950
 Residual Sum of Squares       .49775   Equation Log-likelihood       175.4140
 Akaike Info. Criterion      166.4140   Schwarz Bayesian Criterion    153.5449
 DW-statistic                  1.7945
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version          *
******************************************************************************
*                     *                          *                            *
* A:Serial Correlation*CHSQ(   4)=  47.2093[.000]*F(   4, 116)=  16.7387[.000]*
*                     *                          *                            *
* B:Functional Form   *CHSQ(   1)=   6.1762[.013]*F(   1, 119)=   5.9839[.016]*
*                     *                          *                            *
* C:Normality         *CHSQ(   2)=  .087128[.957]*       Not applicable       *
*                     *                          *                            *
* D:Heteroscedasticity*CHSQ(   1)=   1.8349[.176]*F(   1, 127)=   1.8326[.178]*
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```

Unit root tests

```
                         Unit root tests for residuals
******************************************************************************
 Based on  OLS regression of LQS on:
 INPT            S2              S3              S4              LPBNR
 LPBFR           LPSR            LPWXR           LVCR
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
        Test Statistic       LL           AIC           SBC           HQC
 DF         -9.8659      171.3953      170.3953      168.9933      169.8259
 ADF(1)     -8.3866      172.5390      170.5390      167.7350      169.4001
 ADF(2)     -6.7734      172.5448      169.5448      165.3387      167.8364
 ADF(3)     -2.7834      202.0082      198.0082      192.4002      195.7304
 ADF(4)     -4.0379      211.5769      206.5769      199.5669      203.7297
 ADF(5)     -4.7516      214.8886      208.8886      200.4765      205.4719
 ADF(6)     -3.9096      215.5202      208.5202      198.7061      204.5340
******************************************************************************
 95% critical value for the Dickey-Fuller statistic =   *NONE*
 Critical value not available for the number of regressors in the regression!
 LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
 SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```

The short-run dynamic equation

```
Final ECM for spirits DLQS:

                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is DLQS
 120 observations used for estimation from 1970Q2 to 2000Q1
******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                      -.42435             .062766            -6.7609[.000]
 S2                         .60630             .094569             6.4112[.000]
 S3                         .44097             .097916             4.5035[.000]
 S4                         .66205             .088352             7.4933[.000]
 DLQS(-1)                  -.17570             .095540            -1.8390[.069]
 DLQS(-2)                  -.33509             .089239            -3.7549[.000]
 DLQS(-3)                  -.41260             .063677            -6.4796[.000]
 DLPBN                     -.97496              .31194            -3.1254[.002]
 DLPBF                      .61519              .36335             1.6931[.093]
 DLPS                      -1.6617              .24531            -6.7740[.000]
 DLPS(-2)                  -.44921              .23913            -1.8785[.063]
 DLPWX(-3)                 -.52559              .27983            -1.8782[.063]
 DLPC                       1.8567              .61899             2.9996[.003]
 DLVC                       .97597              .35025             2.7865[.006]
 ECM_S(-1)                 -.61395              .13146            -4.6703[.000]
******************************************************************************
 R-Squared                     .98747   R-Bar-Squared                   .98580
 S.E. of Regression           .051529   F-stat.    F( 14, 105)  591.2448[.000]
 Mean of Dependent Variable  .0065013   S.D. of Dependent Variable      .43248
 Residual Sum of Squares       .27880   Equation Log-likelihood       193.6127
 Akaike Info. Criterion      178.6127   Schwarz Bayesian Criterion    157.7065
 DW-statistic                  1.6701
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
******************************************************************************
*                     *                          *
* A:Serial Correlation*CHSQ(   4)=  17.7742[.001]*F(   4, 101)=   4.3903[.003]
*                     *                          *
* B:Functional Form   *CHSQ(   1)=   3.3501[.067]*F(   1, 104)=   2.9868[.087]
*                     *                          *
* C:Normality         *CHSQ(   2)=  27.7152[.000]*       Not applicable
*                     *                          *
* D:Heteroscedasticity*CHSQ(   1)=   1.2680[.260]*F(   1, 118)=   1.2602[.264]
*                     *                          *
* E:Predictive Failure*CHSQ(   8)=   4.4167[.818]*F(   8, 105)=   .55209[.815]
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
   E:A test of adequacy of predictions (Chow's second test)
```

B.4 Wine Excluding ‘Coolers’

The long-run static equation

```
Wine excl coolers: Level equation for LQWXR, 1970q1-2002q1

Transformation: LQWXR = LQWX+0.75*LPWXR-1.51*LVCR

                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is LQWXR
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
 Regressor              Coefficient       Standard Error        T-Ratio[Prob]
 INPT                      -3.4545            .019083          -181.0205[.000]
 S2                         .15771            .023074             6.8351[.000]
 S3                         .13566            .023053             5.8848[.000]
 S4                         .40263            .022968            17.5298[.000]
 LPBNR                     -.71413            .077689            -9.1921[.000]
 LPBFR                      .55825             .12359             4.5170[.000]
 LPSR                      -.33344             .13611            -2.4498[.000]
******************************************************************************
 R-Squared                     .78965   R-Bar-Squared                   .77930
 S.E. of Regression           .092474   F-stat.    F(  6, 122)   76.3292[.000]
 Mean of Dependent Variable   -3.1642   S.D. of Dependent Variable      .19684
 Residual Sum of Squares       1.0433   Equation Log-likelihood       127.6822
 Akaike Info. Criterion      120.6822   Schwarz Bayesian Criterion    110.6729
 DW-statistic                  .83928
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
******************************************************************************
*                     *                          *
* A:Serial Correlation*CHSQ(   4)=  68.4111[.000]*F(   4, 118)=  33.3085[.000]
*                     *                          *
* B:Functional Form   *CHSQ(   1)=  18.1874[.000]*F(   1, 121)=  19.8594[.000]
*                     *                          *
* C:Normality         *CHSQ(   2)=   5.0479[.080]*       Not applicable
*                     *                          *
* D:Heteroscedasticity*CHSQ(   1)=   .29793[.585]*F(   1, 127)=   .29399[.589]
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
```

Unit root tests

```
                         Unit root tests for residuals
******************************************************************************
 Based on  OLS regression of LQWXR on:
 INPT            S2              S3              S4              LPBNR
 LPBFR           LPSR
 129 observations used for estimation from 1970Q1 to 2002Q1
******************************************************************************
       Test Statistic      LL           AIC           SBC           HQC
 DF         -5.5852      143.7415      142.7415      141.3395      142.1720
 ADF(1)     -3.8046      147.6159      145.6159      142.8119      144.4770
 ADF(2)     -2.8224      150.5917      147.5917      143.3856      145.8833
 ADF(3)     -1.4598      168.2543      164.2543      158.6463      161.9765
 ADF(4)     -1.8478      171.1906      166.1906      159.1805      163.3433
 ADF(5)     -2.4160      175.7112      169.7112      161.2992      166.2945
 ADF(6)     -2.4275      175.7819      168.7819      158.9678      164.7957
******************************************************************************
 95% critical value for the Dickey-Fuller statistic =   *NONE*
 Critical value not available for the number of regressors in the regression!
 LL  = Maximized log-likelihood      AIC = Akaike Information Criterion
 SBC = Schwarz Bayesian Criterion    HQC = Hannan-Quinn Criterion
```

The short-run dynamic equation

```
Final ECM for wine excl coolers DLQWX.

                       Ordinary Least Squares Estimation
******************************************************************************
 Dependent variable is DLQWX
 120 observations used for estimation from 1970Q2 to 2000Q1
******************************************************************************
 Regressor              Coefficient       Standard Error         T-Ratio[Prob]
 INPT                      -.20460            .042527            -4.8111[.000]
 S2                         .23628            .070030             3.3740[.001]
 S3                         .34677            .054086             6.4114[.000]
 S4                         .40137            .060199             6.6675[.000]
 DLQWX(-1)                 -.62577            .086866            -7.2039[.000]
 DLQWX(-2)                 -.43373            .083168            -5.2151[.000]
 DLQWX(-3)                 -.51404            .070211            -7.3213[.000]
 DLPBN(-1)                 -.76857             .30946            -2.4836[.015]
 DLPBF                      2.0806             .33338             6.2410[.000]
 DLPBF(-1)                  .61750             .34194             1.8059[.074]
 DLPS                      -.79628             .28027            -2.8411[.005]
 DLPS(-1)                  -.73231             .25965            -2.8203[.006]
 DLPWX                     -.67083             .37952            -1.7676[.080]
 DLPWX(-3)                 -.90551             .28681            -3.1572[.002]
 ECMWXR(-1)                -.13688            .072872            -1.8784[.063]
******************************************************************************
 R-Squared                     .97840   R-Bar-Squared                   .97552
 S.E. of Regression           .053640   F-stat.    F( 14, 105)  339.6776[.000]
 Mean of Dependent Variable   .014113   S.D. of Dependent Variable      .34281
 Residual Sum of Squares       .30211   Equation Log-likelihood       188.7952
 Akaike Info. Criterion      173.7952   Schwarz Bayesian Criterion    152.8890
 DW-statistic                  1.7615
******************************************************************************


                               Diagnostic Tests
******************************************************************************
*    Test Statistics  *        LM Version        *         F Version
******************************************************************************
*                     *                          *
* A:Serial Correlation*CHSQ(   4)=   7.3507[.118]*F(   4, 101)=   1.6476[.168]
*                     *                          *
* B:Functional Form   *CHSQ(   1)=   3.4896[.062]*F(   1, 104)=   3.1149[.081]
*                     *                          *
* C:Normality         *CHSQ(   2)=   4.2021[.122]*       Not applicable
*                     *                          *
* D:Heteroscedasticity*CHSQ(   1)=   2.7429[.098]*F(   1, 118)=   2.7603[.099]
*                     *                          *
* E:Predictive Failure*CHSQ(   8)=   6.2724[.617]*F(   8, 105)=   .78405[.618]
******************************************************************************
   A:Lagrange multiplier test of residual serial correlation
   B:Ramsey's RESET test using the square of the fitted values
   C:Based on a test of skewness and kurtosis of residuals
   D:Based on the regression of squared residuals on squared fitted values
   E:A test of adequacy of predictions (Chow's second test)
```