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UK Consumers' Habits

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"UK Consumers' Habits"[1]

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Abstract

We follow Fuhrer (2000) in estimating via Maximum Likelihood a log-linear consumption function on UK data. In doing so we consider various habit formation assumptions. We show that a model of purely "external" habits as in Fuhrer (2000) fits the UK data remarkably well, and possibly in a superior way than US data where, according to our estimates, consumers' habits look more "internal" in that they appear indexed to past average consumption of only a subset of (peer) consumers in the economy, rather than total past per capita consumption. We also find that for about one seventh of UK consumers, current consumption equals current income—a strong violation of the permanent income hypothesis. Embedded in a sticky price-sticky inflation open-economy monetary model, the model that we estimate helps mimic the hump-shaped response of the output gap to income and interest rate shocks observed in the UK. Estimates of output Euler equations for the UK using a similar method agree with our general results. The consumption and output models that we estimate forecast significantly better than unrestricted open-economy VARs.

Keywords: consumption, habit formation, output gap channel
JEL Classification Codes: D12, E52, E43

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1. Introduction

Hall's (1978) well-known Euler equation for consumption assumes that consumers are rational in intertemporally allocating their wealth on consumption. In his model, household optimisation leads to a first order condition such that consumption today can be expressed as a function of tomorrow's expected consumption, the short-term *ex ante* real interest rate and an innovation error.

On one hand, Hall's model is compatible with the older consumption function literature, namely the Modigliani-Brumberg (1954, 1980) life-cycle hypothesis (LCH) and Friedman's (1957) permanent income hypothesis (PIH), which assert a stable relationship between consumption and wealth (lifetime resources for LCH; permanent income for PIH). Hall's model is also immune to the Lucas critique because it incorporates the representative agent hypothesis and so solves the expectation problem faced by previous theories.[1]

On the other hand, however, simple descriptions of consumer behaviour as in Hall's REPIH (rational expectations permanent income hypothesis) model have proved to have a difficult time matching key dynamic features of aggregate data (see for example Deaton, 1987, 1992; Campbell and Deaton, 1989; Muellbauer, 1983, 1994; and more recently, Fuhrer, 2000, on US data; and Fernandez-Corugedo and Price, 2002, on UK data). This is because these descriptions assume that consumption jumps immediately and fully in response to current 'news' about lifetime resources, a consequence of the pure forward-looking behaviour of consumption in Hall's simplest Euler equation specification.

To resolve this issue, since Hall's seminal work, researchers have suggested various modifications to the basic REPIH model. These include allowing for precautionary savings motives[2] (see e.g. Carroll, 1992, 2001; and Deaton, 1992), for liquidity constraints (see e.g. Hall and Mishkin, 1982; and Campbell and Mankiw, 1989, 1991) and for habit formation in consumption (see e.g. Carroll, Overland and Weil, 2000; and Fuhrer, 2000).[3]

In this paper we focus on the last kind of "hybrid" models that generalise the REPIH by introducing habits. These models allow for inertial consumption behaviour by assuming that households' utility depends not only on the level of consumption in each period, but also on the level in previous periods. In other words, they allow for 'habit formation' implying that consumers' preferences are not time-separable in consumption. This helps models replicate the excess smoothness typically observed in consumption data relative to income data, thereby improving the empirical fit of Hall's original formulation.

[1] In addition, the aggregate consumption model is derived from the representative agent's intertemporal optimising behaviour.

[2] Allowing for precautionary savings does not require modifying the REPIH model, but simply assuming more general (non-quadratic) utility preferences. So, in fact, it implies a generalisation rather than a modification of Hall's original model.

[3] Duesenberry (1949) pioneered the idea of habit formation in consumption.

In particular we follow Fuhrer (2000) in estimating via Maximum Likelihood a log-linear consumption function with habit formation on UK data.[4] This model encompasses various interesting alternatives, including: Hall's basic REPIH model,[5] the basic REPIH model with a fraction of consumers whose current consumption equals current income ('rule-of-thumbers'), and the REPIH modified to allow for habit formation in spending patterns.

When modelling habits, we consider two different habit formation assumptions. First, as in Fuher (2000), we assume that consumers index their consumption habits to past per capita aggregate consumption. This behaviour is described in the literature as "catching up with the Joneses" (see, among others, Abel, 1990) or "external" habit formation (Campbell and Cochrane, 1999), in that it is aggregate—rather than individual consumption—that matters for the habit. At heart, this assumption implies that the consumers' reference level for the habit is a function of everybody's past consumption, viz, of the spending of both forward-looking' and rule-of-thumb consumers in the past. Second, we assume that consumers form their habit using as a benchmark past average consumption of the forward-looking consumers, i.e. consumption of their peer group, but not average consumption of the rule-of-thumbers. Although it does not imply that the habit is purely "internal" (i.e. uniquely indexed to individual rather than aggregate consumption), this second way of specifying the habit allows for the possibility that consumers are particularly concerned about "catching up" with the spending patterns of their peer group, rather than catching up with anybody's average consumption. Looking at two instead of one habit model enables us to test the robustness on UK data of the habit specification originally used for the US. It also allows us to throw some light on whether that specification is indeed the best on US data.

In line with Fuhrer's results for the US, we find that, in general, habit formation in consumption is an economically important determinant in the utility function of British households. This is consistent with previous findings in Batini, Harrison and Millard (2001), which indicate that augmenting a stochastic general equilibrium model calibrated on UK data to allow for habits in consumption helps capture the hump-shaped response of the output gap to a monetary policy innovation observed in empirical models estimated on that data.[6] With regard to different habits' assumptions, we show that

[4] There is a debate in the literature on whether it is possible to estimate Euler equations for consumption. Carroll (2001), for instance, showed that the standard cross-section procedures for microeconomic estimation of consumption Euler equation do not work. This follows from the fact that these procedures imply estimating the first-order approximated or log-linearised versions of the Euler equation, ignoring the fact that higher-order terms are endogenous with respect to the first-order terms and omitted variables. On the other hand, Fuhrer (2000) examined several measures of the accuracy of the approximation used in his paper—which is the one used here—and finds that the linear model offers a very reliable approximation of the behaviour implied by the nonlinear model. Also, partly in response to Carroll's claims, Attanasio and Low (2000) showed that it is nevertheless viable to obtain consistent estimates of the preference parameters in an Euler equation for consumption using time-series estimation, as long as utility is isoelastic and the sample of data used in estimation covers a long enough span of time. These conditions hold in our case, and our model is like Fuhrer's (2000), so we assume that Carroll's potential approximation errors do not prevent proceeding with the estimation.

[5] Throughout we refer to Hall's model as one where the real interest rate is allowed to vary. Hall's (1978) original formulation assumed for simplicity that the real interest rate is constant, but this assumption is unrealistic in practice and so, as Fuhrer (2000) does, we relax it.

[6] As shown using US data by Abel (1990), Jermann (1998) and Campbell and Cochrane (1999), among others, models with generalised habit formation can go a long way in explaining the 'equity premium puzzle' that undermines the empirical consistency of consumption capital asset pricing model (C-CAPM). Clerc, Harrison

for the UK a model of habits indexed to per capita aggregate consumption as in Fuhrer (2000) fits the UK data remarkably well, and possibly in a superior way than US data where, according to our estimates, consumers' habits look more "internal" in that they appear indexed to past average consumption of only a subset of (peer) consumers in the economy, rather than total past per capita consumption. More specifically, our estimates suggest a level of habits and a curvature of the utility function that are similar to those found by Fuhrer (2000) for the US for a comparable habit assumption. However, we find a more muted response of the consumption–to–income ratio to real interest rates in the UK relative to the US, and one more in line with the constraints implied by the structural model. This may suggest that monetary policy in the UK works more by influencing inflation expectations and through the exchange rate channel than it is the case in the US.

We also find that for about one seventh of UK consumers, current consumption equals current income—a strong violation of the permanent income hypothesis. This is consistent with the evidence on credit restrictions in the UK (cf. Jappelli and Pagano,1989; Campbell and Mankiw, 1989, 1991; Muellbauer, 1994), since it is usually assumed that consumption is equal to current income for the credit-constrained (see Hall and Mishkin, 1982). It also squares with findings in Muellbauer and Lattimore (1995) and Bakhshi (2000), which suggest that aggregate consumption in the UK is more sensitive to changes in human wealth (and labour income) than predicted by the PIH. The excess sensitivity of aggregate consumption to current income possibly indicates, in fact, that some UK consumers are unable to borrow off their future labour income, that is, they are credit-constrained.[7]

We show how the Fuhrer (2000) model with habits indexed on past per capita aggregate consumption and its various nested alternatives are good at capturing auto and cross-correlation functions observed in UK data. In general, as in Fuhrer (2000), we find that the habit formation is successful at capturing the persistence in the own correlation of consumption, as well as the persistent dynamic correlations between consumption and income, interest rates and inflation. This is in contrast with the pure REPIH model that cannot replicate the dynamics of the UK spending and inflation data.

We progressively add restrictions to the unconstrained VAR equations used in the habit formation model to predict leads of regressors to Fuhrer's per capita consumption equation. Our VAR differs from Fuhrer's original one in that we include changes in the real exchange rate in the set of endogenous variables in consideration of the openness of the UK economy. Yet, as in Fuhrer's case, our constrained models largely replicate the dynamic behaviour of the unconstrained open-economy VAR.

Finally, we analyse the implications that habits in consumption have on output in the UK. We do so by estimating a parallel output Euler equation which allows for habit formation, as done in Fuhrer and Rudebusch (2002). Habits give a rationale for including both forward and backward-looking components in the Euler equation for output. We find mixed results regarding the importance of forward-looking variables in modelling output dynamics in the UK. However, out-of-sample forecast

and Neiss (2001) show that this puzzle is present in UK data as well, so our model may lend support to the presence of habit formation in the UK too.

[7] For a discussion of this finding on US data see Campbell and Mankiw (1989, 1991) and Darby and Ireland (1994).

exercises suggest that models with forward-looking components improve significantly upon forecasts from purely backward-looking models.

The paper is organised as follows. In Section 2 we briefly lay out the habit formation model that we employ, and compare its intuition with that behind the traditional Hall's Euler equation for consumption. A modified version of this model incorporates the possibility that some consumers are 'rule-of-thumbers'. In this section we also look at an alternative, more 'internal' habit formation assumption. In Section 3 we show and discuss empirical results obtained when estimating the model on UK data when habits are as in Fuhrer (2000). In this section we also discuss how good are this habit formation model and its nested alternatives at portraying observed auto and cross-correlation functions of UK data. We then look at the fit of UK and US data on the alternative, more "internal" habit model. In Section 4 we add restrictions to the unconstrained VAR used in Section 2 and examine the ability of the constrained VAR to match the dynamic behaviour of its unconstrained version. In Section 5 we extend our analysis to estimate an Euler equation for output as in Fuhrer and Rudebusch (2002). Finally, in Section 6, we compare the forecasting accuracy of the various consumption and output models analysed in this paper. Section 7 concludes. We append to the paper a description of the data used in estimation and details about the restrictions that we impose in Section 4.

2. Hall's model and the treatment of habits

2.1 Hall's REPIH consumption model

Hall's standard model of optimal consumer behaviour assumes that society is populated by a continuum of households. Each household is infinitely lived and has identical preferences defined over consumption. The aim of the representative household is to maximise its life-long utility function:

$$E_t \sum_{\tau=0}^{T-t} (1+\beta)^{-\tau} u(C_{t+\tau}) \tag{1}$$

subject to the intertemporal budget constraint:

$$\sum_{\tau=0}^{T-t} (1+r)^{-\tau} (C_{t+\tau} - W_{t+\tau}) = A_t \tag{2}$$

where E_t is the mathematical expectation operator conditional on all information available in period *t*, β is the subjective time preference rate, r is the real rate assumed constant over time, where $r \geq \beta$, T is the length of the representative agent's life, here equal to infinity, $u(C_t)$ is the instantaneous utility function which is assumed to be strictly concave, C_t is consumption in period *t*, W_t are earnings in period *t*, and finally, A_t are assets apart from human capital (i.e. non-human wealth).

Substituting the ensuing first order condition for C_t into that for C_{t+1}, gives Hall's familiar Euler equation for consumption:

$$E_t u'(C_{t+1}) = \frac{1+\beta}{1+r} u'(C_t) \tag{3}$$

Equation (3) says that for the consumption plan to be optimal, today's marginal utility must equal next period's marginal utility, adjusted for the ratio of subjective and market discount rates. Relaxing Hall's arbitrary assumption of a constant real rate, and approximating the representative consumer's first order condition with its log-linear approximation about the steady state value for *C*, we get:

$$c_t = E_t c_{t+1} - \psi r_t + \eta_t \tag{4}$$

where c_t is the natural logarithm of consumption, C_t; the real rate, r_t, is now time-varying; and the parameter $\psi > 0$ represents the intertemporal elasticity of substitution in private spending, alias, in this simple case, the real interest elasticity of consumption. Equation (4) implies that consumption today can be expressed as a function of tomorrow's expected consumption, the short-term *ex ante* real interest rate and an innovation error, η_t. Relaxing the assumption of constant real rate implicates that Hall's model can no longer be mapped into a random-walk process for consumption. Nevertheless, also with a time-varying real rate, consumption tends to jump immediately in response to unanticipated shocks, changes in consumption being fully elastic to current 'news' about lifetime resources.[8]

2.2 Introducing habits

In practice, as shown by Deaton (1987, 1992) and Campbell and Deaton (1989), consumption does not respond immediately to news, but rather, its behaviour through time is remarkably smooth; this is entirely in conflict with the 'extra responsiveness' of consumption to shocks implied by Hall's model. One direct implication of this is that the REPIH basic model of consumption—even augmented with Campbell-Mankiw rule-of-thumb behaviour—is unable to capture adequately the dynamic interaction of consumption, income and interest rates observed in the data. Looking at US data, for instance, Fuhrer (2000) points out that the REPIH model is particularly unsuccessful at capturing the 'hump-shaped' response of consumption to income shocks that appear to characterise aggregate (US) data.

To address this puzzle, Carrol, Overland and Weil (2000) first, and Fuhrer (2000) later, follow Abel (1990) and modify the expression for period utility $u(\bullet)$ to include habit formation.

In essence, habit formation implies that preferences are not time-separable in consumption, so that households' utility depends not only on the level of consumption in each period, but also on their level in the previous period(s). Intuitively, it is plausible that consumers follow persistent patterns in their spending decisions, and that they, hence, attempt to smooth not just their level of spending but also the rate at which they change their spending from one period to another. And the literature on the equity premium puzzle both in the US (Abel, 1990; Constantinides, 1990; Jermann, 1998; Campbell and Cochrane, 1999; and Wachter, 2002, among others) and in the UK (Allais, Cadiou and Dees, 2000[9]), lends support to the view that habits may play an important role in consumption/saving decisions by consumers in these two countries.

Importantly, because habit formation conveys a utility-based smoothing motive for both changes and levels of consumption, assuming habit behaviour enhances the ability of the model to match the dynamic response of consumption to shocks. Fuhrer (2000) illustrates how including habit formation betters the empirical fit of the consumption equation on US data. Similarly, using UK data, Batini, Harrison and Millard (2001), show that augmenting a calibrated stochastic general equilibrium model to allow for habits in consumption helps capturing the hump-shaped response of the output gap to a monetary policy innovation of an empirical model estimated on UK data.

Carroll et al' (2000) and Fuhrer's (2000) model with habits implies a re-specification of the utility function such that consumers' *t*-period utility like:

$$u_t = \frac{1}{(1-\sigma)}\left(\frac{C_t}{Z_t^{\gamma}}\right)^{(1-\sigma)} \tag{5}$$

where Z_t is the habit formation reference consumption level, defined as:

$$Z_t = \rho\, Z_{t-1} + (1-\rho)C_{t-1} \tag{6}$$

So in contrast with Hall's model in equation (1), where *t*-period utility depended merely on the level of time-*t* consumption, here utility depends on current consumption relative to past consumption (given by the habit-formation reference level). According to this modified specification of the utility function, utility is no longer time-separable because the decision on how much to consume today affects the future habit reference level in all future periods' utility from tomorrow onwards. Note that equation (6) implies that each representative agent indexes consumption to the average of past consumption of *all* agents in the economy. We discuss this assumption further in Sub-section 2.3 when we introduce the possibility of rule-of-thumb behaviour.

[8] 'News' about lifetime resources are news about permanent income, defined as that income level which, sustained over the life cycle, has the same present value as the actually expected income stream.

[9] Allais et al (2000) investigate empirically the ability of the consumption capital asset pricing model (C-CAPM) to solve this puzzle once assumed that consumption behavior presents habit formation. From the estimation of the model's parameters for the G-7 countries, and show that the consumption model with habit formation is able to account for financial asset returns with more reasonable preferences. See also Clerc, Harrison and Neiss (2001) and May, Larsen and Talbot (2002) for a discussion of the role of habits in explaining this puzzle in UK calibrated C-CAPM models.

As discussed in Fuhrer (2000), this simple habit formation specification is convenient because it neatly parameterises two key aspects of habit formation. First, the parameter γ measures the importance of habit formation in the utility function. If $\gamma = 0$, Hall's original REPIH model obtains. This implies a version of the optimising consumption equation as that used initially in optimising monetary models by Kerr and King (1996), Woodford (1997) and McCallum and Nelson (1999b). If $\gamma = 1$, utility then only depends on consumption relative to past consumption. γ is capped at 1 to ensure non-satiation in consumption. Second, as discussed in Fuhrer (2000), the parameter ρ measures the persistence or 'memory' in the habit formation reference level. If $\rho = 0$, then utility only depends on last period's consumption. For ρ between 0 and 1, the closer ρ gets to unity, the wider the historical time span over which the reference level is determined. σ measures the curvature of the utility function, but in the presence of habits ($\gamma \neq 0$) is no longer interpretable simply as the inverse of the intertemporal elasticity of substitution. For values of σ greater than one, the higher the expected growth in the reference habit level, the lower consumption is relative to income (i.e. the lower the consumption-to-income ratio).

Combining (5) and (6) with a standard time-varying interest rate budget constraint, and following the manipulation in Campbell and Mankiw (1989),[10] Fuhrer (2000) shows that it is possible to obtain the approximate log-linear consumption function:

$$c_t - y_t = \sum_{j=1}^{\infty} \mu^j E_t \left[\Delta y_{t+j} + a_1 \left(p_{t+j+1} - p_{t+j} \right) + a_2 \left(z_{t+j+1} - z_{t+j} \right) - \delta r_{t+j+1} \right] \tag{7}$$

with p_t defined as:

$$p_t \equiv \beta \rho E_t p_{t+1} + b_1 c_t - b_2 z_t \tag{8}$$

As shown in equation (8), p_t summarises the relationship of the marginal utility of current consumption with future consumption. This results from the fact that today's consumption choices impact future consumption reference levels, and is the origin of non-time separability in this model. In equation (7), r_t is the *ex ante* real interest rate. It is expressed as the discounted weighted average of model-consistent forecasts of short term real interest rates (*d* below being equal to *D*/(1+*D*) where *D* is, as in Fuhrer, 2000, the duration of the implicit long-term real bond, set equal to 40 quarters—ten years—in his and our paper) as follows:

[10] Campbell and Mankiw (1989) combine the Euler equation for consumption of the REPIH with the household's infinite horizon budget constraint to get a consumption function relating consumption, wealth, and expected future returns on wealth. They then move from the wealth-based consumption function to an income-based consumption function by expressing the market value of wealth in terms of future expected returns and the future expected income flows from wealth. Note that a model with an income-based consumption function would not capture wealth revaluations (due to shocks to technology shocks, for example) if dividends are not paid out—a point made to us by Francesco Giavazzi. However, this should presumably be less of an issue in modelling UK consumption as non-human wealth there is predominantly invested in housing stock, contrary to the US where equities constitute a larger portion of households' assets.

$$r_t \equiv (1-d)\sum_{i=1}^{\infty} d^i E_t\left(f_{t+i} - \pi_{t+i+1}\right) \quad (9)$$

Above, lower-case letters denote logs, y_t denotes disposable income, and the parameters a_1, a_2, and δ are non-linear functions of the deep parameters γ, σ, and β of the consumers' optimisation problem.[11] μ is the degree of forward-looking behaviour, and captures how much weight consumers attach to expectations of future variables driving their decision to consume. This is distinct from the discount factor, which instead governs the subjective preference of whether to consume today or in future periods, but is also bounded, such that $0 \leq \mu \leq 1$. If μ is unity, then consumers weight forecast information from time $t+1$ equally to information from time $t+n$, where $n > 1$. Finally, δ measures the impact of interest rates on consumption. *A priori* assumptions about how interest rates changes affect consumption, suggest that δ has a negative sign for all plausible values of the underlying utility parameters.

Because z_t is a function of lags of consumption (see equation (6)) consumption today depends on expected future and lagged consumption (see McCallum and Nelson, 1999a; and Batini, Harrison and Millard, 2001, for a derivation of the log-linear approximate consumption function under habits in the simpler case where $u(C_t, C_{t-1})$). This has the effect of making consumption 'sticky', thereby eliminating the 'frontloaded' response of consumption to income and interest rate shocks that features in Hall's original REPIH model.

2.3 'Rule-of-Thumb' Consumers

Equation (7) assumes that all consumers are identical, that they are all rational in intertemporally allocating their wealth on consumption, and that no credit restrictions apply. In practice, some consumers may be unable to borrow off their future labour income because of liquidity constraints. In this case, for some of them, consumption will simply equal current income, instead of the net present value of future income streams, in violation of the permanent income hypothesis. Is there evidence of liquidity constraints for UK consumers?

Jappelli and Pagano (1989), Campbell and Mankiw (1989, 1991), Muellbauer (1994), and Muellbauer and Murphy (1990, 1997) all find evidence that a proportion of consumers in the UK are credit constrained. In particular, Jappelli and Pagano (1989) find that these constraints have tightened since the late 1950s. Corroborative evidence on credit restrictions in the UK comes from Muellbauer (1983, 1994), Muellbauer and Lattimore (1995) and Bakhshi (2000),[12] who show that aggregate consumption in the UK is more sensitive to changes in human wealth (and labour income) than is predicted by the REPIH. The excess sensitivity of aggregate consumption to current income possibly indicates that some UK consumers are indeed credit-constrained. Likewise, Iacoviello and Minetti (2000) find evidence for several European countries, including the UK, that households' aggregate borrowing

[11] More specifically: $a_1 = ((\gamma(1-\sigma)(1-\mu))/\sigma)$, $a_2 = ((1-\sigma)\gamma)/\sigma$, $\delta = \beta[(-\gamma(1-\sigma)(1-\rho)-1)/\sigma]$. However, later in the estimation step, δ is not fully constrained. In our analysis, β, the subjective discount factor, is set equal to 0.99 throughout.

costs vary with aggregate balance sheet strength—a sign of liquidity constraints. Finally, by looking at a number of stylised facts, Aoki et al (2002) also infer that credit frictions may be an important element in British households consumption plans, and hence examine the direct impact of house prices on consumption via credit market effects.[13]

Allowing for the possibility of 'rule-of-thumb' consumers, that is consumers whose current consumption equals current income because of liquidity constraints, yields the following log-linear consumption function:

$$c_t - y_t = (1-\lambda)E_t\left(\sum_{j=1}^{\infty}\mu^j E_t\left[\Delta y_{t+j} + a_1\left(p_{t+j+1} - p_{t+j}\right) + a_2\left(z_{t+j+1} - z_{t+j}\right) - \delta r_{t+j+1}\right]\right) + \varepsilon_{ct} \tag{10}$$

Where λ, which lies between 0 and 1, is the proportion of rule-of-thumb consumers in the population who consume current income in each period. ε_{ct} is the structural innovation in the consumption equation, usually interpreted as the innovation to lifetime resources. When income is modelled explicitly as in Section 2 below, however, this innovation captures temporary changes in preference parameters.

Once more, as in Fuhrer (2000), equation (10) encompasses various attractive alternatives, including: Hall's basic REPIH model (for $\lambda = 0$, $\gamma = 0$); the basic REPIH model with a fraction of consumers whose current consumption equals current income ('rule-of-thumbers') ($\gamma = 0$); and the REPIH modified to allow for habit formation in spending patterns ($\gamma \neq 0$).

Two additional points are worth mentioning about equation (10).

First, allowing for the possibility of rule-of-thumb behaviour as in equation (10) implies that there are now two types of representative consumers ('forward-looking' and 'rule-of-thumb'). Thus, aggregate consumption can now be divided into the consumption of the forward-looking agents and consumption of the rule-of thumbers. This poses the question of whose consumption defines the habit reference level '*z*' for the forward-looking consumers, who plan their spending patterns according to equation (10). As specified in Fuhrer (2000) and in equation (6), *z* is a function of past per capita aggregate consumption. So, according to this specification, the reference level for the habit of forward-looking consumers is a function of everybody's past consumption, viz, of the spending of both forward-looking and rule-of-thumb consumers in the past. An alternative specification, not yet considered in the literature, is that forward-looking consumers form their habit using as a benchmark past average consumption of the forward-looking consumers alone, and ignore average consumption of the rule-of-thumbers. Although it does not imply that habits become purely "internal", this second

[12] See also surveys by Deaton (1992).
[13] Aoki et al (2002) point in particular to the fact that, in the UK, the spread of mortgage rates over the risk-free interest rate varies with the collateral position of each household, and unsecured borrowing rates, which are the marginal source of finance once collateral has been exhausted, are much higher than mortgage rates.

way of specifying the habit allows for the possibility that consumers are particularly concerned about "catching up" with the spending patterns of their peer group—namely forward-looking consumers—rather than catching up with anybody's consumption.

The simple way in which Fuhrer (2000) specifies rule-of-thumb behaviour allows us to recover the proportion of consumption consumed by the forward-looking agents, and therefore to re-specify the habit to allow for this consideration. The alternative, more "internal" habit formation model turns out to be:

$$Z_t = \rho\, Z_{t-1} + (1-\rho)[C_{t-1} - \lambda Y_{t-1}] \tag{11}$$

Equation (11) now suggests that forward-looking consumers wish to "catch up" with the past average consumption of other forward-looking consumers, but are indifferent towards past spending patterns of the rule-of-thumbers.

Second, it can be argued that equation (10)—irrespective of how habits are specified—is suited to capture consumption behaviour in an open economy like the UK. In fact, given our assumption that consumers are infinitely lived and that the discount factor of the representative agent is exogenously determined, the external asset position of the economy is irrelevant for consumption behaviour. The evidence indeed suggests that, at the business cycle frequency, the dynamics of consumption are generally not much changed by the introduction of these features (see Kollmann, 1991, and Kim and Kose, 2000). On the other hand, since openness makes imports a component of the consumer price index, the inclusion of a separate exchange rate term in the Phillips curve cannot be overlooked. We return to this issue when we estimate the unconstrained VAR that we use in conjunction to equation (10) to proxy for leads of the regressors of equation (10).

Below we estimate the modified model for consumption as in equation (10) and test whether habits and rule-of-thumb behaviour are important to model British consumers' behaviour. In doing so we present estimation results obtainined when we use both Fuhrer's (2000) and our more 'internal' habit assumption. In later sections we examine whether the best performing habit model among these two helps capture observed dynamics in UK data better than the basic REPIH model. Throughout we compare findings on UK data with Fuhrer's and/our own findings on US data.

3. Estimation results

We break the discussion of our results in three subsections. In Sub-section 3.1 we describe the methodology that we employ to estimate equation (10). We then review our empirical findings when we apply that methodology to UK data over a sample period that goes from 1970 Q1 to 2002 Q2. We compare these results with Fuhrer's (2000) results on US data. In Sub-section 2.2 we show how results change for both the UK and the US when we assume that habits are formed according to our more "internal" habit model in equation (11). In Sub-section 3.3 we illustrate how good is our best-fitting consumption model at capturing UK consumption dynamics.

3.1 Methodology and Maximum Likelihood Estimates on UK and US data

Throughout the paper we use the methodology in Fuhrer (2000). So we start by estimating an unrestricted VAR of the key elements driving consumption. Since the UK economy is open, we use an open-economy VAR throughout the analysis. More specifically, our VAR is estimated from 1970 Q1 to 2002 Q2 on quarterly data for inflation in the consumption deflator, the nominal two-week repo rate, the log of real consumption of non-durables and services, the log of non-consumption GDP, the log of real disposable income, and finally, the first difference in the log of the real effective exchange rate index (ERI). We detrend the consumption, income and non-consumption GDP data with a segmented linear trend with breaks in 1980, 1990 and 1992.[14]

To orthogonalise the innovations in the VAR we apply a Choleski decomposition, assuming that the variables follow the causal ordering: consumption of non-durables and services → RPIX inflation → real ERI → repo rate → detrended non-consumption GDP → real disposable income. This is in line with the ordering of the open-economy VAR in Batini and Nelson (2001), which allows the interest rate—but not the exchange rate—to respond contemporaneously to monetary policy innovations. And it follows Fuhrer (2000), by allowing the interest rate to react contemporaneously to inflation but not to non-consumption GDP or income.

As a second step, we then combine the consumption equation (10) with the definition equations for z (eq. (6)), p (eq. (8)) and the *ex ante* real interest rate r (eq. (9)) with the VAR equations for income, inflation and the short-term nominal interest rate into a linear rational-expectations model. We cast the model as a set of stochastic linear difference equations, solve for expectations in this model, and then re-express them in terms of current and lagged variables following the solution procedure of Anderson and Moore (AIM, 1985). This ensures that all rational-expectations restrictions implied by the consumption model are imposed in estimation; it also allows us to specify the system as a set of constrained decision rules in observable variables, where the original structural shocks are identified.

Finally, we set up the likelihood for this system, which we estimate via a numerical, derivative-based maximisation method. As Fuhrer (2000) points out, this method has the advantage that it starts off with an unconstrained linear VAR, which nests all other successive models, and progresses towards increasingly constrained linear models. Once we have estimated the deep parameters of equation (10), we can go back to the VAR and impose further restrictions to the initially unconstrained equation. In the end this delivers a monetary model, nested in the initial unrestricted VAR, on which we can assess the ability of the suggested consumption framework to successfully portray consumption dynamics observed in the UK.

[14] These dates seem sensible when inspecting the pattern of consumption since 1970. Indeed, the timing of these splits is supported by results from Chow breakpoint tests. Also, regressing the log of consumption on five lags of itself, a constant, plus intercept and slope dummies for these three dates, we can reject at the 5% confidence level the restriction of no structural change [F-statistic = 1.94, p–value = 0.051]. The restriction that the parameter non-constancy is confined to the equation's intercept is can also be rejected at that confidence level [F-statistic = 1.54, p–value = 0.16]. For a discussion of breaks in the UK GDP series see Nelson and Nikolov (2002).

Table 1 below shows Maximum Likelihood parameter estimates of the consumption model laid out above for both the UK and Fuhrer's (2000) estimates for the US, for comparison. Estimation samples are 1970 Q1–2002 Q2 and 1966 Q1–1995 Q4, respectively.

Table 1: US and UK ML parameter estimates

Coefficient	UK estimate	Standard error	US estimate	Standard error
γ	0.82	0.09	0.80	0.19
ρ	0.00057	0.17	0.0015	0.0039
λ	0.14	0.06	0.26	0.13
σ	5.23	0.38	6.11	1.81
μ	0.999	0.011	0.996	0.01
δ	0.77	0.14	28.49	5.17

Various important points emerge from Table 1.

First, the 'memory' in the habit reference level ρ is the only parameter not significantly different from zero at the 5% level, for both the UK and the US. This indicates that only last period's consumption (i.e. consumption at t–1) defines the habit level. Fuhrer (2000) gives a detailed discussion of why this might be the case. He notes that presumably habits are formed over a horizon longer than one quarter. However, since the detrended level of consumption displays significant autocorrelation, last period's consumption level contains information about consumption of many previous periods. Therefore, he argues, the reference level of the single lag in consumption may be sufficient to impart smoothness to the changes in consumption expenditure absent in the standard permanent income model where consumption depends on leads but not lags of itself. In the UK case, the finding that only the first lag of consumption is informative in predicting current consumption accords, for instance, with empirical estimates of the consumption function of the Bank of England's MTMM model.[15]

Second, habit persistence seems important in explaining both UK and US aggregate consumption data. More specifically, we find that also on UK data $\gamma > 0$, that is, not only today's consumption matters for British households' current consumption plans, but also the level of today's consumption relative to past consumption. Results in Table 1 indicate that the importance of today's consumption relative to past consumption in the utility function looks similar across the two countries.

Third, the proportion of 'rule-of-thumb' consumers appears to be sizeable not just in the US but also in the UK. Campbell and Mankiw (1991) estimate in their basic model, $\lambda = 0.351$ for the US and $\lambda = 0.203$ for the UK with seasonally adjusted data. Our estimates of the rule-of-thumb/habit formation model on UK data also suggest that the fraction of rule-of-thumb consumers is lower in the UK than in the US. However, we find that only one seventh (as opposed to Campbell and Mankiw's finding of

[15] See Bank of England (1999), *Economic Models at the Bank of England*, and (2000), *Economic Models at the Bank of England: September 2000 Update*.

one fifth) of consumers may consume all their current income in each period instead of smoothing their consumption intertemporally.

Fourth, out of the consumers who are not 'rule-of-thumbers', we find that the horizon over which consumers compute their forecasts is long, and it is longer in the UK (μ = 0.999) than in the US (μ = 0.996).

We also find that the estimates of σ and δ are quite different in magnitude between the UK and the US. Typically, σ is the coefficient of relative risk aversion and the inverse of the coefficient of intertemporal substitution in the standard REPIH model. However, as already pointed out, the introduction of economically significant habits breaks this explicit link. So σ here is just an index of the curvature of the utility function. Our estimates indicate that the utility function of the UK representative agent exhibits less curvature than that of the representative agent in the US. Yet for both countries, σ is greater than one, implying that the higher is expected growth in the habits reference level, *z,* the lower is the log consumption-to income-ratio in both countries.

With regard to δ, the expected level of future interest rates has a negative effect on time-*t* consumption as predicted (remember that in the consumption model in equation (10) δ is preceded by a negative sign). As Fuhrer (2000), we do not fully constrain the real interest rate in estimation. However, for the UK, the magnitude of the freely estimated δ is quite in line with the fully constrained coefficient given estimates of the constraint (δ = 0.77 relative to a contraint-implied value of 0.47). The opposite is true for the US, where the magnitude of the freely estimated δ is considerably larger than the fully constrained coefficient given estimates of the constraint (δ = 28 relative to a constraint-implied value of 0.5). This is an interesting result highlighting that consumption in the UK may be (much) less affected by expected discounted real interest rates than consumption in the US. A corollary of this finding is that monetary policy in the UK may work mainly by influencing directly inflation expectations and/or through the exchange rate channel—rather than strongly through the output gap channel as it seems possible in the US.

Nested tests of habit formation and 'rule-of-thumb' behaviour in our UK-estimated model confirm the importance of these two assumptions as modifications of the REPIH to capture consumer behaviour in the UK. For instance, the hypothesis that habits do not matter in decisions on private spending in the UK (i.e. the hypothesis that $\gamma = 0$) is overwhelmingly rejected by the data. The χ^2 likelihood ratio test for this single restriction takes the value of 114.19, with p-value 1.18×10^{-26}. Analogously, the χ^2 likelihood ratio test for the restriction that for no consumer consumption equals current income ($\lambda = 0$) takes the value 21.87, with p-value 2.92×10^{-6}. Crucially, the likelihood ratio test for the constrained baseline model, which embeds 24 zero and cross-equation restrictions as implied by the structure in equation (10) and by the assumption that a (1-λ) portion of consumers behaves rationally, takes the value of 46.1, not significant at even the 10 % level. This accords with results for the US in Fuhrer (2000), where the tests take the corresponding values of: $\gamma = 0 \Rightarrow$ LR= 21.4; p-value 4×10^{-6}; $\lambda = 0 \Rightarrow$ LR= 12.6; p-value 4×10^{-4}; all model restrictions$\Rightarrow$ LR= 32.8). In this sense, both the UK and US results are a infrequent example in which joint restrictions from an optimising model with rational agents cannot be rejected relative to the unconstrained model in which the restricted model is nested.

3.2 Estimates using the alternative, more "internal" habit model

In this section we re-estimate the consumption model of the previous sub-section, but assume that habits are formed according to the model in equation (11). In essence, equation (11) suggests that forward-looking consumers wish to "catch up" with past average consumption of other forward-looking consumers, but are indifferent towards past spending patterns of the rule-of-thumbers when indexing their habits.

Table 2 shows the parameter estimates that we obtain on both UK and US data once we introduce this modification over the same sample period as above:

Table 2: Parameter estimates from the pure internal habit model

Coefficient	UK estimate	Standard error	US estimate	Standard error
γ	0.83	0.21	0.88	0.34
ρ	0.08	0.14	0.0007	0.58
λ	0.055	0.06	0.11	0.01
σ	15.10	0.17	5.15	1.33
μ	0.998	0.01	0.991	0.01
δ	4.52	0.30	12.22	5.70

Modelling the habit formation process with habits defined as in equation (11) gives different estimates for some key parameters for both countries.

In particular, assuming that forward-looking consumers care of their own average past consumption but not of those of the rule-of-thumbers, provides that:

i. The estimated proportion of rule-of thumb consumers, λ, drops relative to the case when we assume purely "external" habits. In the UK the estimate is around 6% as opposed to 14% (one seventh) when using the original Fuhrer (2000) habit formation model. In the US the proportion of rule-of-thumbers also drops substantially (falling to around 11% from 25%).
ii. Parameter estimates obtained on UK data are more unstable across model specifications than it is the case for estimates obtained on US data. For example, the curvature of the utility function, σ, increases significantly in the UK case when we use the alternative, more "internal" habit model. This, in turn, reduces the implied equilibrium consumption-to-income ratio for the UK. Conversely, our estimates of σ on US data are statistically indistinguishable across models.
iii. In the UK case the coefficient on the *ex ante* interest rate, δ, is now much greater in the UK case than originally estimated in Table 1. However, the estimate of this coefficient is lower in the US case than that arrived at in Table 1.

On the other hand, for both specifications, estimates of the parameter indexing the importance of habits, γ, are similar to the original ones for both countries. In addition, both in the UK and in the US case, habits still seem to depend only on last period's consumption ($\rho \cong 0$) when we use the alternative habit model.

Overall, the consumption model obtained when we assume the alternative, more "internal" habit specification seems less good than Fuhrer's (2000) original model at replicating the dynamics exhibited by consumption in both impulse response functions and autocovariances for the UK. [16] This accords with the result that the log-likelihood (LL) of the system is lower under the alternative habit assumption presented here than under the original habit formation assumption in Fuhrer (2000) (LL = 3.1407×10^3 compared with LL = 3.1431×10^3 for the model with Fuhrer's, 2000, habits). This suggests that the alternative, more "internal" habit specification where consumers try to "catch up" with consumption of their own peer group alone is a poorer representation of UK consumption than that where consumers try to "catch up" with everybody's consumption.

Conversely, the model with more "internal" habits seems to slightly outperform the model where habits are formed relative to total past consumption when it comes to US consumption dynamics, as it emerges by looking at the impulse response functions of the alternative habits model estimated on US data.[17] In addition, although results from the autocovariances indicate there is little difference between the two models, the log-likelihood of the system is higher when we fit the model with the alternative, more "internal" habit assumption, than when we fit the model with the original habit assumption discussed in Fuhrer (2000) (estimates of the alternative, more "internal" habit model gives LL = 2.90488×10^3 compared with a log-likelihood of 2.90426×10^3 from the original habit specification). Therefore, on balance, it seems as if the alternative, more "internal" habits model may offer a better representation of the behaviour of US consumers, the opposite of what we find for the UK.

Understanding why the two habit formation models fit differently in the UK and the US requires a systematic analysis of the preferences of consumers in those two countries, as well an exploration of the psychology of spending across British and American consumer groups that plan looking forward in time. Such analyses are beyond the scope of this paper. However, possible causes that come to mind may be, *inter alia*: (i) the ability in both countries to observe consumption patterns of different peer groups. Factors like the lower density of population in the US relative to the UK, and the fact that there income groups tend to live in homogenous-income neighbourhoods more than it is perhaps the case in the UK may imply that consumption of non-peers is less easily and/or less frequently observed, and so less used as a benchmark for habit formation; (ii) the marketing of consumption goods and services may be more focussed to particular income and/or social groups in the US than in the UK, which could induce a stronger fragmentation of demand—possibly a consequence of the fact that US consumption takes place via catalogue orders, the Internet and via telesales more than it is the case in the UK, due to the geographical remoteness of suppliers.

[16] These are available from the authors on request.
[17] *Ibidem*.

Given that UK consumption seems better portrayed by a model with habits indexed on total—as opposed to forward-looking agents' only—consumption, in the rest of the paper we focus on this model alone. So, in what follows, when we refer to 'habits' or 'habit formation model' we mean the original "external" habits model discussed in Fuhrer (2000).

3.3 Do habits and rule-of-thumb behaviour help capture UK data?

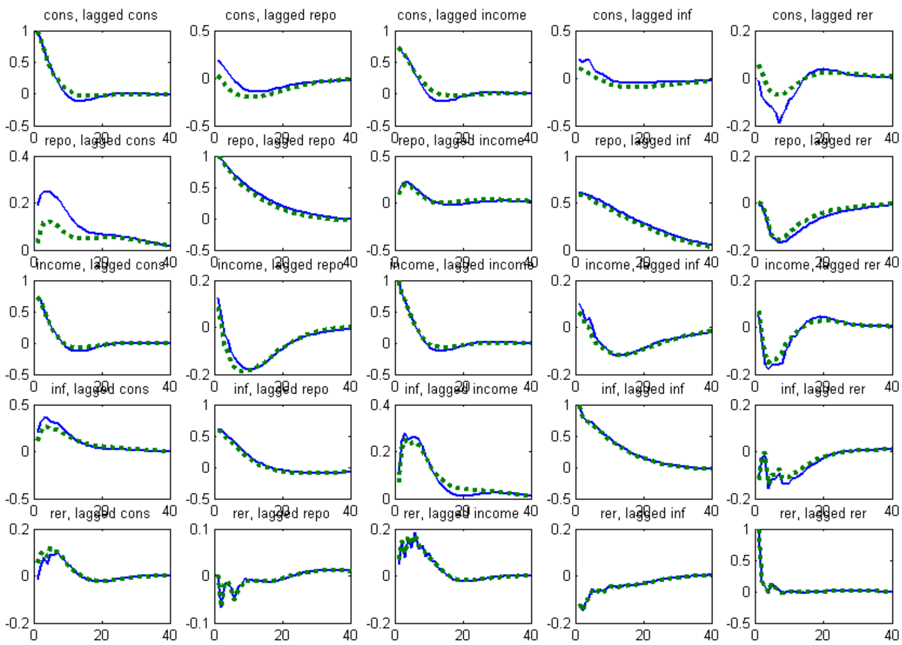
A comparison of the unrestricted VAR and habit formation model auto and cross-correlation functions estimated on UK data indicates that our model implies sensible data-consistent dynamic correlations. This is shown in Chart 2 below. The chart shows that the habit formation model captures well the autocorrelation in consumption suggested by the unrestricted VAR. The chart also shows that the model is capable of replicating the persistent dynamic correlations between consumption and interest rates, income and inflation observed in the VAR, without worsening the ability of the model to capture interactions of consumption with other variables.

Chart 3 provides further evidence that the parameter estimates that we get help obtaining a reliable model of consumption behaviour, one which can match reasonably well the hump-shaped response of consumption to a unit income shock. This contrast with typical results from the basic REPIH model, which is unable to replicate that response—as suggested by the 'excess smoothness' literature on UK consumption—and by the thin solid line in the chart, plotting the response of the basic REPIH model with no habits and no rule-of-thumb behaviour. Finally, Chart 4 illustrates how a model with habits and 'rule-of -thumb' behaviour helps matching the delayed and hump-shaped response of consumption spending to a nominal interest rate shock—although it suggests that consumption troughs following the shock sooner than what implied by the VAR—contrary to the basic REPIH model. This is consistent with previous findings in Batini, Harrison and Millard (2001), which indicate that augmenting a stochastic general equilibrium model calibrated on UK data to allow for habits in consumption helps capturing the hump-shaped response of the output gap to a monetary policy innovation observed in empirical models estimated on that data.

4. Constrained versus unconstrained VAR results

In Section 3 we have estimated the parameters of the consumption function with habits (eq. (10)), where habits are indexed to past per capita aggregate consumption. This model seemed to offer a superior fit than the alternative, more "internal" habits one. Focussing on the former model, we now add successive restrictions to the short-term nominal interest rate, inflation and the real exchange rate equations in the unrestricted vector autoregression of Section 3.

Chart 2: Auto and Cross-correlation functions–Habit Formation Model vs. VAR



Notes: X-axis: Lags in quarters, Y-axis: Correlation Function
Solid Blue Lines: Unrestricted VAR, Dotted Green Lines: Estimated Habit formation Model

Chart 3: Impulse response of consumption to a shock in real disposable income: model vs. VAR

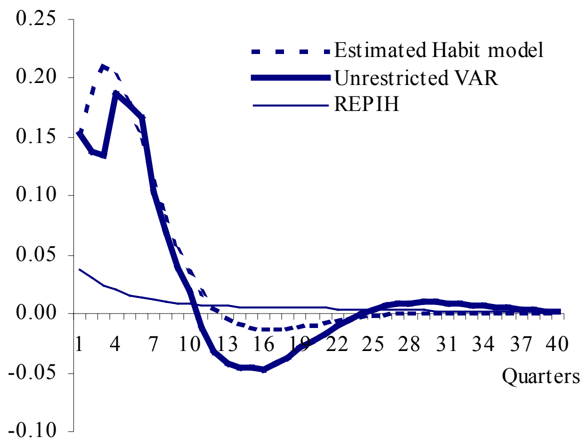
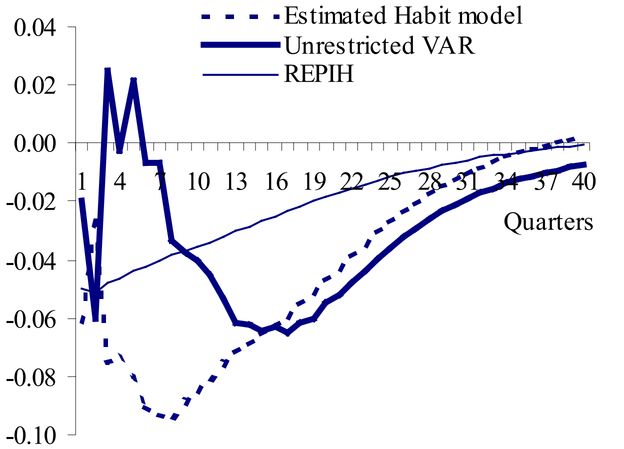


Chart 4: Impulse response of consumption to a shock of the repo rate: model vs. VAR



We start by imposing a short-term nominal interest rate, which follows a simple feedback rule as in Taylor (1993). This takes the form:

$$f_t = \left(1-\sum \alpha_{f,i}\right)\left(\bar{r}+\bar{\pi}\right)+\sum_{i=1}^{2}\alpha_{f,i}f_{t-i}+\sum_{j=0}^{2}\alpha_{\pi,j}\left(\pi_{t-j}-\bar{\pi}\right)+\sum_{k=0}^{2}\alpha_{y,k}y_{t-k}+\varepsilon_{ft} \quad (12)$$

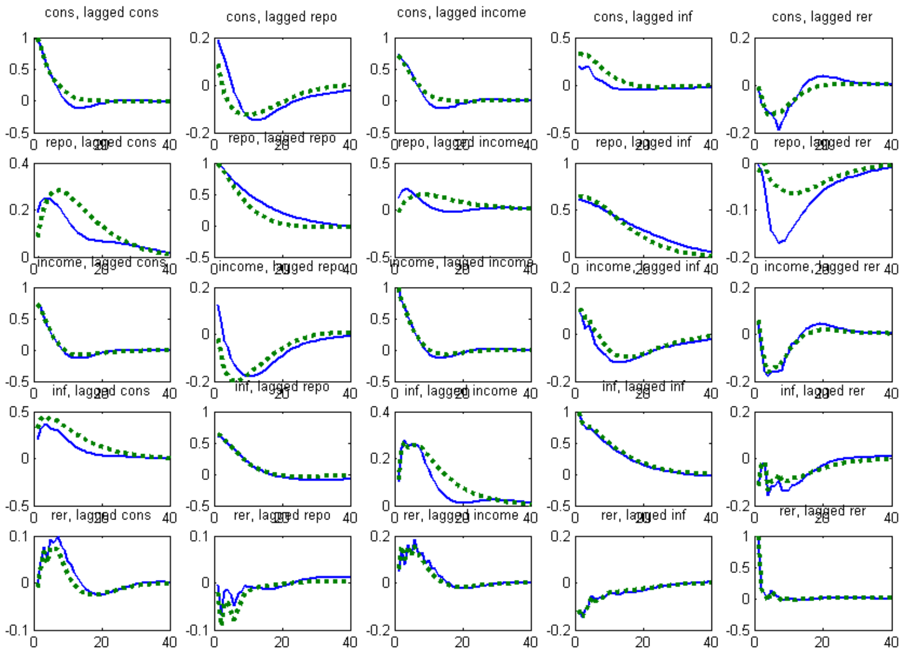
We estimate equation (12) from 1970 Q1 and 2002 Q2 using FIML. Estimates of the parameters are shown in the Results Appendix. Dynamic correlations of the habits model embedded in a VAR with this additional restriction vis a vis dynamic correlations of the unrestricted VAR are plotted in Chart 5 below.

As expected, the auto and cross-correlations of the repo rate with the other variables change somewhat. However, the chart indicates that differences between dynamic correlations of consumption for this model and the one without the Taylor rule restriction on the monetary reaction function are quantitatively small.

As a second restriction, we constrain the price process and impose an open-economy adaptation of the Fuhrer and Moore (1995) contracting process, similar to that derived in Batini and Haldane (1999). The difference with that equation is that here, as Fuhrer (2000), we use a longer lag-lead specification equal to the lag length of the unrestricted VAR. This implies that the equation for inflation under this specification takes the form:

$$\pi_t = (1/2k)\sum_{i=1}^{k}\left(\pi_{t+i}+\pi_{t-i}\right)+\theta\left(y_t+y_{t-1}\right)+\varpi\left[(1-\xi)\Delta q_t+\xi E_t\Delta q_{t+1}\right]+\varepsilon_{pt} \quad (13)$$

Chart 5:Auto and Cross-correlation Functions–Habit Model with Taylor Rule vs VAR



Notes: X-axis: Lags in quarters, Y-axis: Correlation Function
Solid Blue Lines: Unrestricted VAR, Dotted Green Lines: Estimated Habit formation model plus Taylor rule.

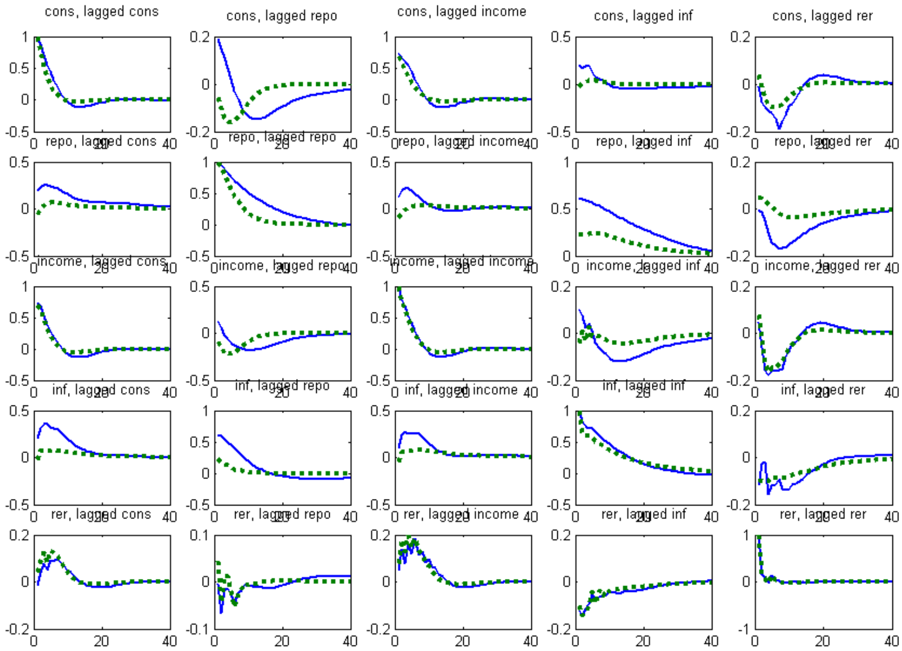
Where $k = 4$, π_t = inflation at time t, y_t is the output gap at time t and Δq_t is the change in the effective exchange rate between t and $t - 1$.

Equation (13) states that inflation at time t depends on expected inflation four quarters ahead, as well as inflation four quarters ago. It also depends on a two-period moving average of the output gap and on current and future expected changes in the real effective exchange rate, q_t—an implication of the direct price effect of changes in the exchange rate on consumer prices. Estimates of the parameters are shown in the Results Appendix.

Dynamic correlations of the habits model embedded in a VAR with this additional restriction versus dynamic correlations of the unrestricted VAR are plotted in Chart 6 below. As in the case of the previous restriction, the chart indicates that differences between dynamic correlations of consumption for this model and the one without the additional restriction on the Phillips curve are quantitatively small. However this chart points to a deterioration in the ability of the model with the extra restriction to capture the dynamic interactions between inflation and the other variables, relative to that of the unrestricted VAR and to that of the model with only habits embedded in the VAR.

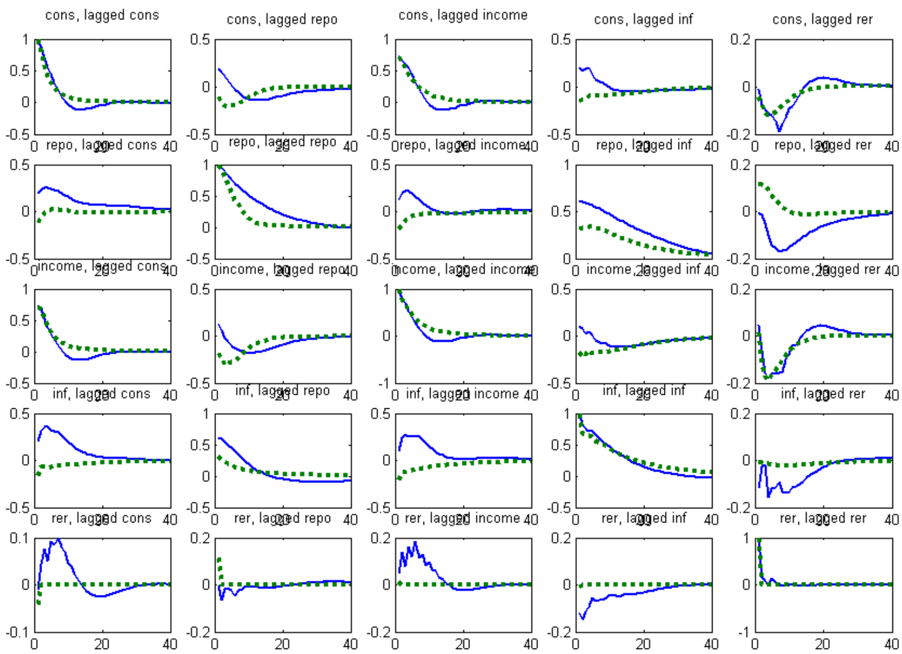
Our final restriction concerns the equation for changes in the real effective exchange rate in the VAR. We substitute this VAR equation with an equation, which assumes the real exchange rate in the UK follows a random walk. This is a much-used alternative exchange rate assumption utilised by the Bank of England's MPC when forecasting RPIX over the two-year-ahead horizon (see Bank of England, *Inflation Report*, various issues). Dynamic correlations of the habits model embedded in a VAR with this additional restriction vis a vis dynamic correlations of the unrestricted VAR are plotted in Chart 7 below. The chart indicates that the random walk assumption for the real exchange rate worsens the ability of the model to replicate many data-consistent interactions.

Chart 6: Auto and Cross-correlation Functions – Habit Model plus Taylor Rule plus Fuhrer-Moore Phillips Curve vs VAR



Notes: X-axis: Lags in quarters, Y-axis: Correlation Function
Solid Blue Lines: Unrestricted VAR, Dotted Green Lines: Estimated Habit formation model plus Taylor rule and Fuhrer-Moore Phillips curve

Chart 7: ACFs as in Chart 5 except real ERI modelled as a random walk.



Notes: X-axis: Lags in quarters, Y-axis: Correlation Function
Solid Blue Lines: Unrestricted VAR, Dotted Green Lines: Estimated Habit Formation Model plus Taylor rule, Fuhrer-Moore Phillips Curve and the real exchange rate following a random walk.

Taken together, these results suggest that the imposition of additional restrictions on top of the one imposed on the consumption equation may worsen, rather than improve, the ability of the model to match the dynamic correlations of the unrestricted VAR.

5. Implications of habit formation in consumption on output

In this section we examine what our findings on UK consumption imply for the dynamics of aggregate demand in the UK. One easy way to do this is shown in Rudebusch (2002). Following McCallum and Nelson (1999a) and Rudebusch (2002) we log-linearise the consumption Euler equation (7), which incorporates forward-looking behaviour as well as habits indexed to total consumption, to give an estimate of the New Keynesian output Euler equation. Rudebusch (2002) demonstrates that parameter estimates from Fuhrer (2000) imply a New Keynesian output Euler equation for the US like:

$$y_t = 0.323y_{t-1} + 0.677E_t y_{t+1} - 0.017r_t + \upsilon_{USt} \quad (14)$$

The corresponding output Euler equation for the UK, using our Maximum Likelihood estimates from Section 3, is reported below (equation (15)). The equation indicates that UK consumers are marginally more forward-looking in their consumption behaviour and marginally less sensitive to real interest rates than US consumers. In particular, equation (15) suggests that current consumption in the UK depends for about two-thirds on expected future consumption, and for about one-third on past consumption.

$$y_t = 0.281y_{t-1} + 0.718E_t y_{t+1} - 0.015r_t + \upsilon_{UK,t} \quad (15)$$

Rudebusch (2002) points out that it is not straightforward to interpret equations (14) and (15) as models that fit total real output. This is for three reasons. First, these equations only explain consumption of non-durables. This is a fraction, albeit large,[18] of total private consumption in the UK and the US, and so cannot comprehensively proxy for total consumption and, thus, total output. Second, in order to derive equations (14) and (15), Rudebusch (2002) (and us, following him) modelled the non-consumption components of output separately via an autoregressive process. This is not entirely satisfactory, and may bias upwards or downwards the actual behaviour of non-consumption GDP, which has implications for the reliability of the coefficients in equations (14) and (15). Finally, by construction, parameter estimates in equations (14) and (15) rule out rule-of-thumb behaviour, as the equations are derived by assuming that all consumers are forward-looking and nobody is credit constrained. From Fuhrer's (2000) and our estimates we know, however, that rule-of-thumb behaviour is an important determinant of consumption in the US and the UK.

To overcome these shortcomings, Rudebusch (2002) and Fuhrer and Rudebusch (2002) suggest estimating "hybrid" output Euler equations. These generalise the simple output Euler equation by capturing forward-looking behaviour (μ below), and habits ($\alpha_1 + \alpha_2$ below) in consumption and the

[18] In the UK, the fraction of non-durable and services consumption to total private consumption is 0.75. In terms of GDP, that fraction falls to just below 0.5 (0.48).

importance of longer-term interest rates (β below). Increasingly longer-term interest rates are captured by changing the duration (κ below) of the model consistent *ex ante* real interest rate. A "hybrid" model of this kind can be expressed as:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \mu E_t y_{t+1} - \beta E_t \left[\tfrac{1}{\kappa} \Sigma_{j=0}^{\kappa-1} (i_{t+j} - \pi_{t+j+1})\right] + v_t \qquad (16)$$

Fuhrer and Rudebusch (2002) find small sample bias when estimating these equations using GMM methods. They show that Full Information Maximum Likelihood (FIML) has better small sample properties and therefore opt for this estimation method in their investigation on US data. Here we follow their approach, and also use FIML to estimate the parameters on UK data.

At heart, the estimation methodology that we adopt to estimate output is identical to that used in Section 3 to estimate the consumption model with habits. So here as well we first estimate an unrestricted VAR in detrended output, inflation and the repo rate. We then replace the VAR equation for output with the structural model (16) and estimate the parameters using FIML. Since the estimates can be sensitive to the method used to detrend output, we experiment with a variety of detrending/filtering techniques. These include: (1) HP filtering output with a 1,600 smoothing parameter; (2) detrending output by subtracting from actual GDP values of a segmented linear trend;[19] and (3) detrending output by subtracting from actual GDP values an estimate of potential output based on a Cobb-Douglas production function, as described in, for example, Bank of England (1999, p.27). We refer to these different measures as "OHP", "OSLT", "OPF", respectively.

Table 3: Parameter estimates of 'hybrid' output Euler equations[(a), (b)]

	ML Estimates of OUTPUT EULER EQUATION									LR Tests [(c)]	
Trend	κ	α_1	$SE(\alpha_1)$	α_2	$SE(\alpha_2)$	μ	$SE(\mu)$	β	$SE(\beta)$	$\mu=0$	$\beta=0$
OHP	1	0.314	*(0.24)*	0.076	*(0.13)*	0.607**	*(0.08)*	2.60E-05	*(0.0011)*	0.681	0.681
OHP	4	0.166*	*(0.10)*	0.142**	*(0.02)*	0.691**	*(0.13)*	0.0011	*(0.0030)*	0.747	0.747
OHP	40	0.239	*(0.24)*	0.121	*(0.11)*	0.623**	*(0.23)*	0.012	*(0.1800)*	0.701	0.701
OSLT	1	0.266**	*(0.06)*	0.088	*(0.05)*	0.635**	*(0.03)*	9.19E-05	*(0.0088)*	0.968	0.976
OSLT	4	0.357**	*(0.10)*	0.103**	*(0.02)*	0.415**	*(0.16)*	0.0000	*(0.0004)*	0.956	1.000
OSLT	40	0.339**	*(0.05)*	0.1**	*(0.05)*	0.458**	*(0.07)*	0.0272*	*(0.0146)*	0.854	0.480
OPF	1	0.281**	*(0.00)*	0.122**	*(0.06)*	0.602**	*(0.03)*	0.00175**	*(0.0008)*	0.003	0.022
OPF	4	0.281**	*(0.06)*	0.122**	*(0.03)*	0.601**	*(0.03)*	0.00178**	*(0.0008)*	0.097	0.766
OPF	40	0.298	*(0.18)*	0.118	*(0.11)*	0.596**	*(0.07)*	0.0018**	*(0.0007)*	0.000	0.780

(a) OHP = output detrended with a HP filter, OSLT = output detrended with a segmented linear trend, OPF = Output detrended by Cobb-Douglas production function.
(b) A ** denotes significance at the 5%, * denotes significance at the 10% level.
(c) *P*–values.

Table 3 above shows the estimation results of equation (16) based on a sample of UK data going from 1970 Q1 to 2002 Q2. The first column of Table 3 indicates the method used to detrend output (OHP, OSLT or OPF). The second column indicates the duration of interest rates used when estimating the output Euler equation (16) (1, 4, or 40 quarters). The next 8 columns list the corresponding estimates of the parameters in equation (16). Finally, the two columns on the extreme right, denoted 'LR Tests', report *p*–values from Likelihood Ratio tests for individual restrictions that either the coefficient on expected output, μ, is zero; or that the *ex ante* model-consistent interest rate coefficient, β, is equal to zero.

Three key findings emerge from the table.

First, the split between backward and forward-looking components of output is roughly the same as that found in the simple derivation of the output equations coefficients from the previous estimates of the consumption Euler equation: two-thirds on the lead term and one-third on the lag terms.[20] Yet, overall, the output Euler estimated are slightly more backward-looking than predicted by the estimates of the corresponding consumption Euler equations.

Second, β, i.e. the coefficient on the real interest rate term, is tiny and generally insignificant, except when we detrend output using the OPF method, where it is one-tenth in magnitude of the corresponding estimate from the consumption Euler equation.

Third, and in line with the two findings above, a comparison to Fuhrer and Rudebusch (2002) results for the US again reveals that agents in the UK are more forward-looking and less interest-rate-sensitive than their US counterparts.

To assess the importance of these results for predicting output in the UK, we again computed Likelihood Ratio (LR) tests on our estimates. The last two columns of Table 3 separately test the restriction that the coefficient on the lead term of output equals zero ($\mu = 0$) and the restriction that the coefficient on the interest rate term equals zero, ($\beta = 0$). Results from these tests indicate that: (i) it is not possible to reject the hypothesis that the coefficient on the output lead term (μ) is equal to zero, except when we detrend output via the OPF method. This is in line with our intuition from the consumption model that agents look ahead when planning how much to consume; (ii) in general, it is not possible to reject the hypothesis that expected future interest rates have no effect on output, apart from the case where $\kappa = 1$ in the OPF model. This result is intriguing in the light of the conventional view of the transmission of monetary policy impulses. One possible explanation for it is that expected future consumption already captures the impact on current consumption of future interest rate expectations.

In the next section we turn to out-sample-forecasts to shed further light on the importance of expectations in predicting time-t UK consumption.

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[19] As defined for the consumption estimation in Section 3.

[20] In Table 2, μ, i.e. the coefficient on the forward-looking component of output, is significant in all specifications of equation (16), and the magnitudes for the different derivations of the output gap and interest rate duration are similar. Also, at least one coefficient on the lag term is significant, except in the case of two of the HP detrended output equations.

6. Pseudo out-of-sample forecast performance of estimated structural equations relative to unrestricted VARs

One interesting question to ask is whether the consumption and output models that we have estimated can outperform unrestricted VARs in forecasting consumption and output respectively. In this section we tests the relative forecast accuracy of the various models we have looked at. In particular, we compare the accuracy of our structural consumption and detrended output models relative to corresponding unrestricted VARs in (pseudo out-of-sample) forecasting consumption and output over the two-year horizon between 2000 Q2 to 2002 Q2. To do so we use structural and reduced-form models like those described in Section 3, but re-estimated using data available through 2000 Q1. Throughout, as a way of quantifying this accuracy, we compare Mean Squared Forecast Errors (MSFE. See Stock and Watson, 2000). Sub-section 5.1 below explains what is the MFSE. Sub-section 5.2 goes through the results.

6.1 The Mean Squared Forecast Error

As explained in Stock and Watson (2000, p. 8), a well-known and easy-to-interpret way to quantify pseudo out-of-sample forecast performance consists in deriving the mean squared error of a candidate forecast (forecast *i*) relative to a benchmark forecast (forecast 0). Here we follow this method and let the *h*-step ahead out-of-sample forecast from unrestricted VARs of Section 3, $\hat{Y}^{h}_{0,t+h|t}$, be our benchmark forecast; and the *h*-step ahead out-of-sample forecast from one of our structural models in turn (for example, the habits model embedded in the VAR) $\hat{Y}^{h}_{i,t+h|t}$ be our candidate forecast. We hence express the *h*-step ahead relative mean squared forecast error (MSFE) for each candidate model relative to the corresponding unrestricted VAR benchmark forecast as:

$$\textit{h-step relative}\, MSFE = \frac{\dfrac{1}{T_2 - T_1 - h + 1}\displaystyle\sum_{t=T_1}^{T_2-h}\left(Y^{h}_{t+h} - \hat{Y}^{h}_{i,t+h|t}\right)}{\dfrac{1}{T_2 - T_1 - h + 1}\displaystyle\sum_{t=T_1}^{T_2-h}\left(Y^{h}_{t+h} - \hat{Y}^{h}_{0,t+h|t}\right)}$$

Where Y^{h}_{t+h} are the actual data that we are trying to forecast and where the forecasts are computed starting from T_1 until $T_2 - h$, i.e. forecasts are made for the dates $t = T_1+h, \ldots, T_2$. As discussed in Stock and Watson (2000), if the candidate forecast model provides a better out-of-sample forecast than the benchmark VAR, the MSFE statistic is less than one. Conversely, if the candidate model performs worse than the benchmark model (the unrestricted VAR in our case), the MSFE statistic is greater than one.

6.2 Results

Table 3 below lists MSFE for the case where the benchmark model is the unrestricted VAR and the candidate model is the linear consumption function with habits of Section 3. It also provides *t*-statistics and *p*-values associated with each MSFE statistic.[21] We consider three alternative candidate models for consumption: (1) is the estimated forward-looking consumption function with habits; (2) the estimated forward-looking consumption function with habits plus the estimated Taylor rule; and (3), the estimated forward-looking consumption function with habits plus the estimated Taylor rule plus the open-economy Fuhrer-Moore Phillips curve. All these models are embedded in the unrestricted VAR, so Model 3 will have three restricted equations, Model 2 two and Model 1 one—the restriction on the equation for consumption.

Table 4: Out-of-sample forecasts of consumption - Q2 2000 to Q2 2002

Consumption:

Mean Squared Forecas Error Statistics

		Newey-West		OLS	
Model	**MSFE**	t-stat	p-value	t-stat	p-value
1	0.7122	*(-1.99)*	*0.0816*	*(-2.02)*	*0.0779*
2	0.7564	*(-0.78)*	*0.4581*	*(-0.97)*	*0.3621*
3	0.6894	*(-1.35)*	*0.2128*	*(-1.60)*	*0.1487*

1 = Consumption function with habits
2 = 1+ Estimated Taylor rule
3 = 2 + Fuhrer-Moore open economy Phillips curve

Note: (a) Newey-West HAC adjusted

The MSFE statistics indicate that the candidate models perform better than the benchmark VAR since each statistic is less than one. However, only Model (1) produces a forecast that is significantly better than the unrestricted VAR. Inclusion of the Taylor rule and open-economy Fuhrer-Moore Phillips curve renders the forecasts insignificantly better than the unrestricted VAR. This agrees with our earlier findings (cf. Section 3 and 4) comparing ACFs of increasingly restricted versus fully unrestricted VARs.

Table 5 repeats the analysis of Table 4 using candidate models for detrended output, instead of consumption. In particular, it compares the forecasts of output Euler equations relative to their respective VARs for the different definitions of the output gap, (OHP, OSLT and OPF) and different interest rate durations (1, 4, and 40 quarters). The *p*-values indicate that, at the 10% significance level,

[21] We obtained these by testing that the difference between the means of the forecast residuals (actual minus forecast) of the candidate (*u*, say) and benchmark (*v*, say) models is zero. That is, H0 is H0: $\sigma_u - \sigma_v = 0$. To do so we regressed the difference between the squares u(t)^(2)-v(t)^(2) on a constant and carried out a *t*-test that the coefficient is zero. The regression coefficient from this regression is, in fact, the difference : $\sigma_u - \sigma_v$. We also cross-checked the robustness of our results in case that the forecast errors were conditionally heteroskedastic or autocorrelated by using a robust Newey-West *t*-statistic. These results are shown in the last four columns of Table 3. We thank Kenneth West for this suggesting, among more complicated ones, this simple testing approach to us.

all the estimated forward-looking output Euler equations forecast significantly better that the respective unrestricted VARs, regardless of the method used to detrend output and regardless of the duration of interest rates used.

In short, in the majority of cases, the consumption and output models that we estimate forecast significantly better than unrestricted open-economy VARs. These results suggest that the introduction of forward-looking elements appears to improve our ability to forecast consumption and output out-of-sample over this sample period relative to an entirely backward-looking model like an unrestricted VAR. We infer from this that expectations of future consumption and output may be useful in predicting current consumption and output respectively, in the UK.

7. Conclusions and monetary policy implications

The empirical literature on consumption behaviour in the UK suggests evidence of near-rule-of-thumb behaviour, liquidity constraints and habits in spending decision of British households. In this paper we have investigated this issue by estimating via Maximum Likelihood a log-linear consumption function on UK data as suggested in Fuhrer (2000).

Table 5: Sensitivity analysis of pseudo out-of-sample forecasts for detrended output[(a)] —2000 Q2 to 2002 Q2

Output:

Mean Squared Forecast Error Statistics

			Newey-West		OLS	
Trend	κ	**MFSE**	t-stat	p-value	t-stat	p-value
OHP	1	0.1721	*(-2.58)*	*0.0324*	*(-3.80)*	*0.0053*
	4	0.1736	*(-2.45)*	*0.0402*	*(-3.60)*	*0.0070*
	40	0.1694	*(-2.54)*	*0.0346*	*(-3.73)*	*0.0057*
OSLT	1	0.4917	*(-2.08)*	*0.0716*	*(-3.06)*	*0.0155*
	4	0.4903	*(-2.07)*	*0.0718*	*(-3.06)*	*0.0156*
	40	0.4128	*(-1.97)*	*0.0841*	*(-2.90)*	*0.0198*
OPF	1	0.1301	*(-2.65)*	*0.0294*	*(-3.93)*	*0.0043*
	4	0.5592	*(-3.29)*	*0.0111*	*(-4.86)*	*0.0013*
	40	0.8283	*(-4.82)*	*0.0013*	*(-5.99)*	*0.0003*

Notes:
(a) OHP = output detrended with a HP filter, OSLT = output detrended with a segmented linear trend, OPF = Output detrended by Cobb-Douglas production function.
(b): Newey-West HAC adjusted

We have found that, in general, habit formation in consumption is an economically important determinant in the utility function of British households. This is consistent with previous findings in Batini, Harrison and Millard (2001), which indicate that augmenting a stochastic general equilibrium model calibrated on UK data to allow for habits in consumption helps capture the hump-shaped response of the output gap to a monetary policy innovation observed in empirical models estimated on that data.[22] With regard to different habits' assumptions, we show that for the UK a model of purely "external" habits as in Fuhrer (2000) fits the UK data remarkably well, and possibly in a superior way than US data, where consumers' habits look slightly more "internal" in that they appear indexed to past average consumption of only a subset of (peer) consumers in the economy, rather than total past per capita consumption. We have also found that for about one seventh of UK consumers, current consumption equals current income—a strong violation of the permanent income hypothesis.

The model that we have estimated with habits indexed to per capita past per capita aggregate consumption as in Fuhrer (2000) has many desirable properties: it explains most of the autocorrelation in UK consumption data; and when embedded in a sticky price-sticky inflation open-economy monetary model estimated on UK data, it helps capture the hump-shaped response of the output gap to income and interest rate shocks. Overall, our estimates suggest a level of habits and a curvature of the utility function that are similar to those found by Fuhrer (2000) for the US under an identical habit assumption. However, we have found a more muted response of the consumption–to–income ratio to real interest rates in the UK relative to the US, and one more in line with the constraints implied by the structural model. This may suggest that monetary policy in the UK works mainly by influencing inflation expectations and through the exchange rate channel—as opposed to the output gap channel.

Our estimates of output Euler equations confirm the result of a muted response of demand to interest rates in the UK. Although we find mixed results on the importance of lead terms in the output Euler equations from estimation, our out-of-sample forecasting exercise appears to confirm the evidence that expectations are an important determinant of output in the UK.

[22] As shown using US data by Abel (1990), Jermann (1998) and Campbell and Cochrane (1999), among others, models with generalised habit formation can go a long way in explaining the 'equity premium puzzle' that undermines the empirical consistency of consumption capital asset pricing model (C-CAPM). Clerc, Harrison and Neiss (2001) show that this puzzle is present in UK data as well, so our model may lend support to the presence of habit formation in the UK too.

References:

Abel, A. B. (1990). "Asset Prices under Habit Formation and Catching up with the Joneses." *American Economic Review,* 80: 38-42.

Allais, O., Cadiou, L. and Dees, S. (2000). "Consumption Habit and Equity Premium in the G7 Countries," CEPII Working Paper, 2000/19, 28.

Aoki, K., Proudman, J. and Vlieghe, G. (2002). "House prices, consumption, and monetary policy: a financial accelerator approach" Bank of England Working Paper 169.

Anderson, G.S. and Moore, G. R. (1985). "A Linear Algebraic Procedure for Solving Linear Perfect Foresight Models." *Economics Letters,* 17: 247-252.

Attanasio, O. P. and Low, H. (2000). "Estimating Euler Equations", NBER Technical Working Paper No 253.

Attanasio, O. P., Picci, L. and Scorcu, A. E. (2000). "Saving, Growth, and Investment: A Macroeconomic Analysis using a Panel of Countries." *The Review of Economics and Statistics,* 82(2): 182-211.

Attfield, C. L. F., Demery, D and Duck, N. W. (1990). "Saving and Rational Expectations: Evidence for the U.K." *The Economic Journal,* 100: 1269-1276.

Bakhshi, H. (2000), "The sensitivity of aggregate consumption to human wealth," Bank of England Working Paper 108.

Batini, N., Harrison, R. and Millard, S. P. (forthcoming), "Monetary Rules for an Open Economy," *Journal of Economic Dynamics and Control.*

Batini, N. and Haldane, A. (1999). "Forward Looking Rules for Monetary Policy," in Taylor, J. eds. *Monetary Policy Rules*, University of Chicago Press.

Batini, N. and Nelson, E. (2001). " Optimal Horizons for Inflation Targeting." *Journal of Economic Dynamics and Control,* 25: 891-910.

Campbell, J. Y. (1999). "Asset Pricing at the Millennium", *Journal of Finance,* 55: 1515-1567.

Campbell, J .Y. and Cochrane, J. H. (1999). "By Force of Habit: A Consumption-Based Explanation of Aggregate Stock Market Behaviour." *Journal of Political Economy,* 107: 205-251.

Campbell, J. Y. and Deaton, A. S. (1989). "Why is Consumption so Smooth?" *Review of Economic Studies,* 56: 357 –373.

Campbell, J. Y. and Mankiw, N. G. (1989). "Consumption, Income and Interest Rates: Reinterpreting the Time Series Evidence," in Olivier Blanchard and Stanley Fischer, eds., *NBER macroeconomics annual: 1989,* Cambridge, MA: MIT Press: 185-216.

Campbell, J. Y. and Mankiw, N. G. (1991). "Permanent Income, Current Income and Consumption: A Cross-Country Investigation." *European Economic Review,* 35: 723-756.

Carroll, C. D. (1992). "The Buffer-Stock Theory of Saving: Some Macroeconomic Evidence," *Brookings Papers on Economic Activity*, 1992(2), 61-156

Carroll, C. D. (1994). "How Does Future Income Affect Current Consumption?" *Quarterly Journal of Economics,* 109: 111-147.

Carroll, C. D. (2001). "Death to the Log-Linearised Consumption Euler Equation." mimeo, John Hopkins University, Baltimore.

Carroll, C. D., Overland, J. R and Weil, D. N. (2000). "Savings and Growth with Habit Formation." *American Economic Review,* 90: 341-355.

Christiano, L., Eichenbaum, M. and Evans, C. (2001). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." Mimeo.

Clerc, L,., Harrison, R. and Neiss, K. (2001). "A consumption-based measure of the risk free real interest rate." Mimeo.

Cochrane, J. H. (1989). "The Sensitivity of Test of the Intertemporal Allocation of Consumption to Near-Rational Alternatives." *American Economic Review,* 79: 319-337.

Constantinides, G. M. (1990). "Habit Formation: A Resolution of the Equity Premium Puzzle." *Journal of Political Economy,* 98: 519-543.

Darby, J. and Ireland, J. (1994). "Consumption, Forward Looking Behaviour and Financial Deregulation," University of Stirling, Department of Economics Working Paper 94/5.

Deaton, A. S. (1987). "Life Cycle models of consumption: Is the evidence consistent with the theory?" in T.F. Bewley, ed. *Advances in Econometrics, Fifth World Congress, Vol. 2.* Cambridge University Press, Cambridge MA.

Deaton, A. S. (1992). *Understanding Consumption*, Clarendon Press.

Duesenberry, J. S. (1949). *Income, saving and the theory of consumer behaviour.* New York: Oxford University Press.

Fernandez-Corrugedo, E. and Price, S. (2002). "The UK consumption ECM redux," mimeo, Bank of England.

Friedman, M. (1957). " A Theory of the Consumption Function." Princeton University Press, Princeton, N.J..

Fuhrer, J. C. (2000). "Habit Formation in Consumption and its Implications for Monetary Policy Models." *American Economic Review,* 90: 367-390.

Fuhrer, J. C. and Moore, G. R. (1995). " Inflation Persistence." *Quarterly Journal of Economics,* 110: 127-159.

Fuhrer, J.C., Moore, G. R. and Schuh, S. D. (1995). "Estimating the linear-quadratic inventory model. Maximium likelihood versus generalized methods of moments," *Journal of Monetary Economics*, 35: 115-157.

Fuhrer, J. C. and Rudebusch, G. D. (2002). "Estimating the Euler Equation from Output." Federal Reserve of Boston Working Paper: 02-3.

Hall, R. E., (1978). "Stochastic Implications of the Life-Cycle/Permanent Income Hypothesis: Theory and Evidence." *Journal of Political Economy,* 86: 971-987.

Hall,R. E., Mishkin, F. S. (1982). "The Sensitivity of Consumption to Transitory Income: Estimates from Panel Data on Households," *Econometrica*, 50(2): 461-81

Iacoviello, M. and Minetti, R. (2002). "The Credit Channel of Monetary Policy and the Housing Market: International Empirical Evidence," Boston College Working Paper: 541.

Jappelli, T. and Pagano, M, (1989). "Consumption and Capital Market Imperfections: An International Comparison," *American Economic Review*. 79(5): 1088-1105.

Jermann, U. J., (1998). "Asset Pricing in Production Economies," *Journal of Monetary Economics,* 41: 257-275.

Kerr, W. and King, R. (1996). "Limits on Interest Rate Rules in the IS Model" *Federal Reserve Bank of Richmond Economic Quarterly* 82(2): 47-75.

Kim, S. H. and Kose, A. (2003). "Dynamics of Open Economy Business Cycle Models: Understanding the Role of the Discount Factor," *Macroeconomic Dynamics* (forthcoming).

Kollmann, R. M. (1991), "Essays on International Business Cycles," Ph.D. University of Chicago 1991.

May, B., Larsen, J. and Talbot, J. (2002). "What do aggregate consumption data tell us about real interest rate?" Mimeo.

McCallum, B. T. and Nelson, E., (1999a). "Nominal income targeting in an open-economy optimizing model," *Journal of Monetary Economics* 43: 553-578.

McCallum, B. T. and Nelson, E., (1999b). "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis*,"* *Journal of Money, Credit, and Banking* 31: 296-316.

Modigliani, F. and Brumberg, R. (1954). "Utility analysis and the consumption function: An interpretation of cross-section data," in Kurihara. K. K., ed., *Post Keynesian Economics.* Rutgers University Press, New Brunswick, NJ.

Modigliani, F. and Brumberg, R. (1980). "Utility analysis and the consumption function: An attempt at integration," in Abel, A., ed., *The collected papers of Franco Modigliani,* vol 2., MIT Press, Cambridge, MA.

Muellbauer, J. N. J. (1983). "Surprises in the Consumption Function." *The Economic Journal,* 93: 34-50.

Muellbauer, J. N. J. (1994). "Consumption," *Oxford Review of Economic Policy,* 10(2): 1-41.

Muellbauer, J. N. J. and Lattimore, R. (1995). "The consumption function: A theoretical and empirical overview," in Pesaran, H. and Wickens, M. R., *Handbook of Applied Econometrics.*

Muellbauer, J. and Murphy, A. (1990). "Is the UK Balance of Payments Sustainable", *Economic Policy*, 11: 347-95.

Muellbauer, J. N. J. and Murphy, A. (1997). "Booms and Busts in the UK Housing Market", *The Economic Journal*, 107: 1720-1746.

Nelson, E. and Nikolov, K. (2002). "Monetary Policy and Stagflation in the UK," Bank of England Working Paper: 155.

Rudebusch, G. D. (2002). "Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty." *The Economic Journal,* 112: 402-432.

Smets, F. and Wouters, R. (2002). "An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area." European Central Bank Working Paper No: 171.

Stock, J. H. and Watson, M. W. (2000). "Forecasting Output and Inflation: The Role of Asset Prices," Mimeo.

Taylor, J. B. (1993). "Discretion Versus Policy Rules in Practice." *Carnegie-Rochester Conference Series on Public Policy,* 39: 195-214.

Wachter, J. A. (2002). "Habit formation and Returns on Bonds and Stocks," mimeo, New York University, New York.

Woodford, M. (1997) "Control of the Public Debt: A Requirement for Price Stability?" in G. Calvo and M. King, eds., The Debt Burden and Monetary Policy, London: Macmillan, [Published version is excerpted from NBER working paper no. 5684, July 1996.]

Results Appendix

- Taylor rule estimate:

$$f_t = 1.08f_{t-1} - 0.19f_{t-2} + 0.09\pi_t - 0.03\pi_{t-1} - 0.01\pi_{t-2} + 0.12(y_t^o + c_t) - 0.08(y_{t-1}^o + c_{t-1})$$

(0.033) (0.045) (0.046) (0.038) (0.025) (0.086) (0.065)

$$+ 0.03(y_{t-2}^o + c_{t-2}) + 0.007 \qquad \text{(A1)}$$

(0.039) (0.003)

Where, f_t is the repo rate, $\bar{r}$ and $\bar{\pi}$ are the equilibrium real interest rate and inflation target, y_t is the output gap, y_t^o is non-consumption GDP and c_t is consumption. Standard errors are in parenthesis.

- Estimate of the open economy Fuhrer-Moore Phillips curve:

$$\pi_t = (1/2k)\sum_{i=1}^{k}\left(\pi_{t+i} + \pi_{t-i}\right) + 0.03\left(y_t + y_{t-1}\right) + 0.13\left[(1-0.66)\Delta q_t + 0.66E_t\Delta q_{t+1}\right] + \varepsilon_{pt}$$

(0.02) (0.06) (0.8) (A2)

Where k = 4, π_t = inflation at time t, y_t is output at time t and Δq_t is the change in the effective exchange rate between t and t-1. Standard errors are in parenthesis.

Data Appendix

The UK data that we use are all quarterly and seasonally adjusted.

*Data used to estimate the consumption equa***tion** **(**1970 Q1 to 2002 Q2)

- Bank Rate (1970 Q1 to 1972 Q3)
- Minimum Lending Rate (1972 Q4 to 1981 Q2)
- Minimum Band 1 Dealing Rate (1981 Q3 to 1997 Q1)
- Repo Rate (1997 Q2 to 2002 Q2)
- Log per capita non-durable and services consumption at 1995 constant prices (ONS code UTIL + UTIP)
- Log per capita real household post-tax income at 1995 constant prices (ONS code see Economic Models at the Bank of England (2000))
- Log per capita nonconsumption of durables and services at 1995 constant prices (ONS code YBHH – (UTIL + UTIP)).
- Log change in the total final consumers expenditure deflator (1995 =1) (ONS code (ABJQ + HAYE)/(ABJR + HAYO)).

Fuhrer (2000) detrends US data on consumption, income and non-consumption GDP via a segmented linear trend with a break in 1974. We have also detrended the UK consumption, income and non-consumption GDP data data with a segmented linear trend with breaks in 1980, 1990 and 1992.

Data used to estimate the output Euler equation

- Gross domestic product at constant prices (1995=100). (ONS code YBHH)
- GDP deflator. (ONS code ln((YBHH/ABMI)*100))
- Repo rate defined as above
- Output is detrended using (1) a HP filter with the smoothing parameter set to 1600, (2) a segmented linear trend with the same breaks as described in Table 1A and (3) potential output based on a Cobb-Douglas production function, as described in Bank of England (1999, p. 27)