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Durable goods and consumer behavior with liquidity constraints

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Abstract

This paper presents an integrated model of intratemporal demand and intertemporal consumption, with allowance for durable goods and liquidity constraints. Demand equations for non-durable and durable goods with the user cost of durable goods are jointly estimated with a consumption Euler equation incorporating liquidity constraints for Norwegian consumers from 1978 to 2018. Results show that demand analyses ignoring durable goods lead to a significant bias in the elasticities of non-durable goods. Norwegian consumers are found to be impatient, with low risk aversion. There is weak evidence for liquidity constraints in consumption. No strong evidence exists for intertemporal substitution in consumption, but a considerable effect of uncertainty is found in durable consumption.

Keywords: Euler equation; indirect utility function; intertemporal substitution; risk aversion; user cost of durable goods

JEL classification: *D*12; *D*15; *E*21

1. Introduction

There is an increasingly large body of empirical work analyzing consumer behavior from both micro and macro perspectives. Traditionally, the two strands of the study of consumer behavior are conducted in isolation of each other. Demand analysis, which represents the micro study of consumer behavior, is typically concerned with optimal allocation of consumption expenditure across goods within periods, and thus demand functions are

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estimated conditional on total expenditure, which is usually treated as exogenously given and is left unexplained. However, to the extent that the consumer chooses expenditure to optimally allocate wealth across periods, which is a focus in consumption/saving analysis typifying the macro study of consumer behavior, consumption expenditure is not exogenously given, but is endogenously determined in the consumer's optimization problem. This implies that the consumer's intratemporal (within period) and intertemporal (across period) allocation decisions, though seemingly disjointed, are inextricably linked together and cannot be separated. In particular, time preference, the interest rate, and uncertainty, which determine the intertemporal consumption decision, indirectly influence the intratemporal allocation decision as represented by consumer demands. However, commodity prices as determinants of the intratemporal allocation decision also have an effect on the intertemporal consumption decision. This leads us to infer that the traditional approach to consumer behavior, based on separation of research on consumer demand and consumption, likely leads to biased results. Hence, a proper understanding of consumer behavior entails an integration of consumer demand and consumption studies in a unifying framework.

The purpose of this study is to present an integrated model of consumer demand and consumption, with allowance for durable goods and liquidity constraints, which is then estimated to provide new evidence from Norwegian consumers. The model is based on the idea of intertemporal two-stage budgeting that jointly accounts for the consumer's intratemporal and intertemporal choices (Kim and McLaren, 2023), with relative prices of non-durable goods and the user cost of durable goods. The integrated model of consumer behavior embeds micro analysis of consumer demand within an intertemporal optimization problem by endogenizing consumption expenditure, and provides the micro-foundational underpinnings to macro analysis of consumption by allowing for relative prices of non-durable goods. Our contribution lies in a coherent treatment of consumer behavior, analyzed separately in traditional demand and consumption studies, with more realism, by incorporating non-durable, as well as durable goods, with liquidity constraints. This will allow us to examine relevant issues in consumer demand and consumption, such as demand elasticities, risk aversion, intertemporal substitution, and precautionary saving, in a unifying framework with more reliable results than in the traditional approach to consumer behavior.

To achieve our goal of a joint analysis of consumer demand and consumption, we characterize consumer preferences by using an indirect utility function, specified as a function of total consumption on non-durable and durable goods, as well as of prices of these goods, with durable goods expressed in a stock form and their price represented by the user cost. We then derive the demand functions for non-durable and durable goods. We also generalize the traditional measure of risk aversion based on power, or CRRA utility, by utilizing the indirect utility function. Next, from the intertemporal optimization with the indirect utility function, we obtain a Euler equation governing intertemporal consumption behavior, with allowance for liquidity constraints. By taking a log-normal approximation of the Euler equation, we derive a log-linearized consumption growth equation that depends on the time preference rate, the interest rate, growth rates of non-durables prices, and user costs, conditional variance capturing uncertainty with precautionary savings, and liquidity constraints.

We conduct an empirical analysis of the integrated model of consumer behavior, using annual Norwegian data for 1978–2018 on eight disaggregate non-durable goods and an aggregate durable good. We employ a flexible specification of the indirect utility function that places minimal restrictions on consumer preferences with a rank 3 demand system. We jointly estimate the system of nine budget share equations, together with the Euler equation for consumption. Then, we present new evidence on demand and intertemporal consumption relative to previous studies on Norwegian consumer behavior.

We find that a joint analysis of intratemporal and intertemporal choices is essential for a proper understanding of consumer behavior. Ignoring durable goods leads to a significant bias in the elasticities of non-durable goods. Durable goods are largely found to be necessities, and are price-inelastic, like most non-durable goods. Norwegian consumers are, in general, impatient with low risk aversion. There is weak evidence for liquidity constraints, which does not have an important influence on consumption. No strong evidence exists for intertemporal substitution in the consumption of non-durable and durable goods, although there is a considerable effect of uncertainty. This suggests that increasing uncertainty causes consumers to reduce or defer current non-durable and durable spending, accompanied by an increase in precautionary savings, especially in times of economic weakness, as observed during the recent pandemic.

In contrast to our approach to analyzing consumer behavior that jointly accounts for the consumer's intratemporal and intertemporal allocation decisions, traditional studies fail to consider the interaction between the two allocation decisions with allowance for durable goods and liquidity constraints. In demand studies, durable goods are either ignored, tacitly assuming that non-durable goods are separable from durable goods (Deaton and Muellbauer, 1980b; Banks et al., 1997), or treated like non-durable goods, without recognizing the inherent differences between the two classes of goods (see Clements et al., 2020). Both approaches are not satisfactory. While most studies of consumption focus on non-durable consumption (e.g., Hall, 1978; Hansen and Singleton, 1983; Ludvigson and Paxson, 2001), there are studies analyzing non-durable consumption by incorporating durable goods with the user cost (e.g., Mankiw, 1985; Ogaki and Reinhart, 1998; Pakoš, 2011). These studies, however, employ restrictive utility functions to represent consumer preferences, and are highly aggregated with no due regard to the components of non-durable consumption, which leaves unexplained the role of relative prices of non-durable goods in determining consumption. This can be justified under the assumption that consumer preferences are homothetic in non-durable goods with unitary expenditure elasticities, which is found to be inconsistent with observed consumer behavior (Deaton and Muellbauer, 1980b; Banks et al., 1997). Our model, based on the indirect utility function, is non-homothetic and imposes no *a priori* restrictions on consumer preferences. There are also studies on durable goods in consumption with liquidity constraints, but they fail to account for the intratemporal allocation problem of consumption (Chah et al., 1995; Alessie et al., 1997). Moreover, there are studies employing intertemporal two-stage budgeting, but they assume that capital markets are perfect, and do not allow for durable goods (Blundell et al., 1994). Kim et al. (2021) generalize the intertemporal two-stage budgeting, but do not utilize the user cost of durable goods, and thus the demand for durable goods is not explicitly analyzed.

There are also studies on consumer behavior for Norway that estimate demand functions, as well as consumption functions (see the detailed literature review presented in Online Appendix A). However, virtually none of these studies incorporates durable goods, and they fail to allow for the interplay between the consumer's intratemporal and intertemporal allocation decisions. As such, they are limited in scope and analysis to address broad issues in consumer behavior in a unifying framework.

2. Data and preliminary analysis

In this section, we discuss the construction of data used in our study and present a brief descriptive analysis to motivate the formulation of the model in the next section. This is necessary because the requisite data are not readily available and, more importantly, because of the nature of durable goods, which is a main contribution of our analysis.

2.1. Data

We use data, obtained from Eurostat online, on the consumption expenditure of households in Norway for the period 1978–2018. The data come from the "Economy and Finance" statistics (code "nama_10_co3_p3"), where household consumption is classified in terms of the COICOP (classification of individual consumption purpose) three-digit classification. It contains information on consumption expenditure in current prices (million euros), percentage of total consumption, and the price index (2010 = 100), among others, for a range of European countries.[1]

We have constructed eight expenditure groups for non-durable goods and services, and an aggregate durable good. The eight non-durable goods and services are: (1) food and non-alcoholic beverages; (2) alcoholic beverages, tobacco, and narcotics; (3) clothing and footwear; (4) housing services; (5) water and fuels; (6) health services; (7) transport services; and (8) other non-durables and services. Durable goods include items such as furnishings, household equipment, appliances and equipment, vehicles, telephone and telefax equipment, and audiovisual, photographic, and information-processing equipment.

The aggregate price indices for each category of non-durable goods and services, and for an aggregate durable good, are constructed as weighted averages of the component price indices, with expenditure shares for each component good serving as weights. Then, the quantity indices for non-durable and durable goods are obtained by dividing their respective current expenditure by the associated price index, which measures real expenditure for non-durable and durable goods.

Unlike non-durable goods, consumers do not derive utility directly from spending on durable goods in the current period, but rather from the flow of services they provide over time, which is assumed to be proportional to the stock of these goods. This indicates that durable goods should be specified in a stock form, rather than as a quantity. To construct durables stock,[2] we use the following durables stock accumulation equation,

$$k_s = (1 - \delta)k_{s-1} + q_s^k \quad \text{for all} \;\; s \geq t, \tag{1}$$

where k_s is the stock of durable goods at the end of time s, δ is the depreciation rate at time s assumed constant, and q_s^k is an aggregate quantity of durable goods at time s. To begin the recursive process, we use the initial value of durables stock, k_0, calculated by utilizing the formula, $k_0 = q_0^k/(g + \delta)$, where q_0^k is real durables expenditure in the first year of the sample period, and g is the average geometric growth rate for the real durable expenditure in the sample; see Casselli and Feyrer (2007) to construct capital stock in the production context. For the depreciation rate, we use $\delta = 0.20$ (20 percent per year; Mankiw, 1985).

[1] See https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_co3_p3&lang=en.

[2] We have aggregated the durable items into one specific good. However, not all durable goods share the same property, and relative prices among durable goods have changed dramatically. Thus, it might be desirable to disaggregate them into several categories. We will explore that in a future work.

With consumers deriving utility from the service flow of durable goods, the relevant price of durable goods, which measures the opportunity cost of these goods, is the cost of using durables services (i.e., the user cost r_t^k), not the purchase price, of these goods. It is defined at time t as (Deaton and Muellbauer, 1980a, Chapter 13)

$$r_t^k = p_t^k - \frac{1-\delta}{1+r_{t+1}} p_{t+1}^k, \tag{2}$$

where p_t^k is the aggregate price of durable goods, and r_{t+1} is the interest rate at time $t+1$. Given a re-sale or second-hand market with no transaction cost, the user cost of durable goods equals the net expense of buying a unit of durable goods in one period, using it in the same period, and selling it at the discounted depreciated price in the next period. Assuming that p_t^k grows by $\Delta \ln p_{t+1}^k$ and approximating equation (2), the user cost of durable goods is considered the rental equivalent price, that is,

$$r_t^k \approx p_t^k \left(r_{t+1} + \delta - \Delta \ln p_{t+1}^k \right),$$

where $\Delta \ln p_{t+1}^k$ is the expected rate of inflation of durable goods.[3] For the interest rate, the three-month interest rate on short-term government bonds is used. It is often believed that a lack of a second-hand market for durable goods causes the irreversibility of durables purchases, which means that uncertainty about future shocks makes consumers hesitant (i.e., a “wait-and-see” attitude) to purchase new durable goods (Knotek and Kahn, 2011; Gudmundsson and Natvik, 2012). There is, however, a prevalence of a second-hand market for many durable goods.

Given the user cost and durables stock, the relevant expenditure for durable goods is not the expenditure, as for non-durable goods, but the value of durables services or the rental value of durables stock (i.e.,$r_t^k k_t$).[4] Then total consumption expenditure M_t is the sum of nominal expenditure on non-durables and services C_t and nominal expenditure on durables stock, $r_t^k k_t$ (i.e., $M_t = C_t + r_t^k k_t$). Non-durable expenditure accounts for about 79 percent, and durables stock expenditure for about 21 percent, of total consumption expenditure in Norway. We consider disposable income in our analysis. Expenditure and disposable income are expressed in per capita terms. Total real consumption expenditure is total current consumption expenditure divided by its price index.

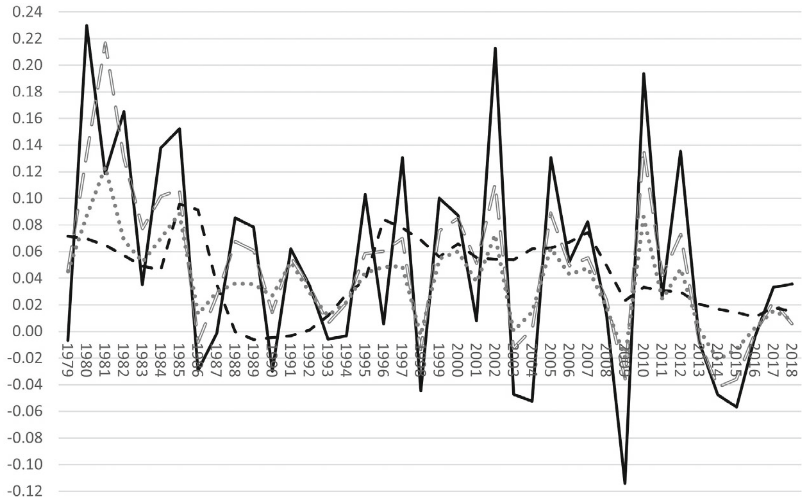
[3]Substituting $p_{t+1}^k = p_t^k (1 + \ln p_{t+1}^k)$ into equation (1), we have $r_t^k = p_t^k \{1 - [(1-\delta)/(1+r_{t+1})](1 + \ln p_{t+1}^k)\}$, which can be approximated as $p_t^k (r_{t+1} + \delta - \Delta \ln p_{t+1}^k)$.

[4]Obtaining a consistent and precise measure of household consumption is often difficult. Fagereng and Halvorsen (2017) provide a method for imputing consumption from administrative registry records of income and wealth information, for tax purposes, for Norway.

2.2. Descriptive analysis

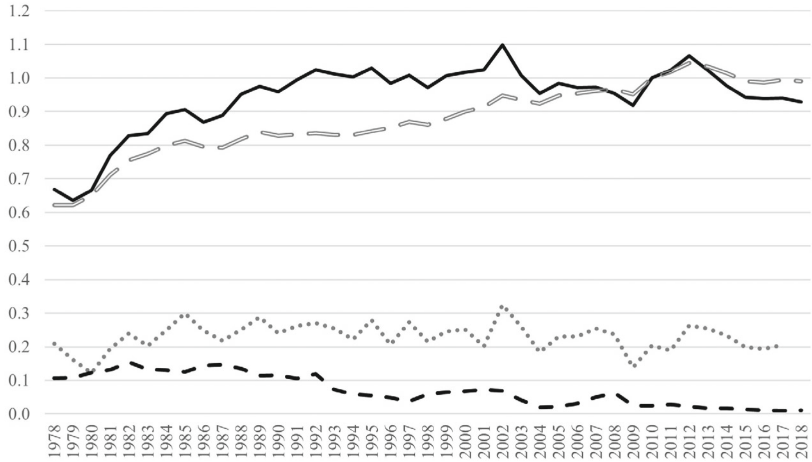
Demand analysis is concerned with the intratemporal allocation of consumption expenditure to non-durable and durable goods. In intertemporal analysis, the focus is on the allocation of consumption expenditure between present and future, so we examine the growth rates of these variables and seek to identify relevant variables determining them, though the interest rate is known to be a key variable (see Section 3.1.4 for a detailed discussion). Figure 1 shows the time series plots of annual percentage changes in nominal and real non-durable expenditures, as well as annual percentage changes in durables stock and in total consumption (the growth rate of a variable is measured by a log change in two adjacent time periods). It is interesting to note that nominal total consumption and nominal and real non-durable consumption exhibit almost the same cyclical patterns. The nominal non-durable spending shows an average growth rate of 4.6 percent per year with the standard deviation of 5.1 percent, whereas the rate for durables stock is 4.6 percent per year with the standard deviation of 7.5 percent. Total expenditure exhibits an average growth rate of almost 4.6 percent per year with the standard deviation of 5.3 percent. The real growth rate of non-durable consumption shows an average rate of 2.8 percent, which is somewhat lower than that corresponding to the nominal rate of non-durable consumption. It is clear that during recessions, all series are falling.

Figure 1. Annual growth rates of consumption and durables stock



Notes: The black solid line denotes the nominal growth rate of M_t (total consumption), the gray long-dashed line denotes the nominal growth rate of C_t (non-durable consumption), the gray dotted line denotes the real growth rate of C_t (non-durable consumption), and the black dashed line denotes the growth rate of k_t (durables stock).

Figure 2. Movements of price indices, user cost, and interest rate over time



Notes: The black solid line denotes the price index of non-durable goods, the gray long-dashed line denotes the price index of durable goods, the gray dotted line denotes the user cost of durable goods (calculated using equation (2)), and the black dashed line denotes the interest rate.

Figure 2 displays the time series plots of the price indices of non-durable and durable goods, as well as the user cost of durables stock and the interest rate. The price index of non-durable goods has a stable upward trend over time, whereas the price index of durable goods shows a fluctuating pattern during the sample period. It is steadily rising with a peak occurring in 2002, followed by a steady fall until 2009, and then rising until 2012 followed by a fall until the end of the sample period. It is interesting to note that the user cost of durable goods shows almost the same pattern as the price index of durable goods, though with fewer fluctuations. The interest rate shows a slightly decreasing trend over the years. It was above 10 percent during 1979–1992, but it has been falling since then, from the value of 7.265 percent in 1993 to 2.236 percent in 2012. It has remained below 2 percent since then until the end of the sample period.

The recent COVID-19 pandemic created a particularly important uncertainty, which has evidently impinged on the consumption patterns of non-durable and durable goods. We take this into account in our analysis for a better understanding of consumption behavior. While the standard deviation or variance tells us about the variability of a variable, the time-varying or conditional variance is a relevant measure of uncertainty about the future (Ballie and Bollerslev, 1992). Conditional variances for total consumption, non-durable consumption, and durables stock growth are given by $\sigma^2_{M_{t+1}} = E_t[(\Delta \ln M_{t+1})^2]$, $\sigma^2_{C_{t+1}} = E_t[(\Delta \ln C_{t+1})^2]$, and $\sigma^2_{k_{t+1}} = E_t[(\Delta \ln k_{t+1})^2]$, assuming that $E_t[\Delta \ln M_{t+1}] = 0$, $E_t[\Delta \ln C_{t+1}] = 0$, and $E_t[\Delta \ln k_{t+1}] = 0$, where E_t is the expectation operator conditional on information available at period t. They are also obtained by a second-order Taylor series expansion of a Euler equation with CRRA utility for M_t, C_t, and k_t (Dynan, 1993; Ludvigson and Paxson, 2001), but are not directly observable. What we observe, instead, are the realized values $(\Delta \ln M_{t+1})^2$, $(\Delta \ln C_{t+1})^2$, and $(\Delta \ln k_{t+1})^2$. Under rational expectations, we can take the realized values by instrumenting them with lagged values. Gudmundsson and Natvik (2012) recognized the importance of uncertainty in consumption in Norway. They looked at three components of household consumption (i.e., non-durables, durables, and services) to examine the effects of uncertainty on them. For durables consumption, expenditure is used without considering the user cost. In contrast to our measures of uncertainty, they utilized two alternative measures of uncertainty: volatility indices from financial markets, and the frequency with which economic uncertainty is mentioned in the Norwegian press.

Table 1 contains the summary statistics for the relevant variables to be considered in the empirical analysis. Looking at growth rates of non-durable

Table 1. Summary statistics

Variable	Mean (%)	Std dev.	Minimum	Maximum
$\Delta \ln M$	4.61	7.82	−12.14	20.71
$\Delta \ln C$	4.74	5.13	−4.26	19.61
$\Delta \ln k$	4.17	2.73	−0.63	9.15
$\Delta \ln p_1$	2.56	5.19	−4.20	22.05
$\Delta \ln p_2$	4.65	6.46	−5.28	31.33
$\Delta \ln p_3$	−0.27	6.28	−17.65	17.56
$\Delta \ln p_4$	3.21	5.22	−6.39	17.60
$\Delta \ln p_5$	4.55	8.63	−11.07	22.50
$\Delta \ln p_6$	4.33	4.91	−4.25	16.12
$\Delta \ln p_7$	4.10	6.42	−10.21	23.39
$\Delta \ln p_8$	2.09	6.82	−9.53	19.83
$\Delta \ln r^k$	−0.05	22.79	−53.35	47.31
r	7.13	4.66	0.89	15.37
$\Delta \ln Y^d$	5.69	11.25	−22.11	35.97
σ_M^2	0.81	1.07	0.00	4.29
σ_C^2	0.48	0.71	0.00	3.85
σ_k^2	0.25	0.23	0.00	0.84

Notes: M = total expenditure, C = non-durable consumption, k = durables stock, p_1 = price of food and non-alcoholic beverages, p_2 = price of alcoholic beverages, tobacco, and narcotics, p_3 = price of clothing and footwear, p_4 = price of housing services, p_5 = price of water and fuels, p_6 = price of health services, p_7 = price of transport services, p_8 = price of other non-durables and services, r^k = user cost of durable goods, r = interest rate, Y^d = disposable income, σ_M^2 = conditional variance of total expenditure measured by its realized value $(\Delta \ln M)^2$, σ_C^2 = conditional variance of non-durable consumption measured by its realized value $(\Delta \ln C)^2$, and σ_k^2 = conditional variance of durable goods measured by its realized value $(\Delta \ln k)^2$.

prices, goods experiencing high growth rates during the sample period are alcoholic beverages, tobacco, and narcotics at 4.65 percent, followed by water and fuels (4.55 percent), and health services (4.33 percent). Clothing and footwear exhibit a negative growth rate of prices (−0.27 percent). Looking at standard deviations and minimum and maximum values of the variables, there is good evidence for the prevalence of intertemporal variations in the relevant variables. In particular, water and fuels had the highest standard deviation of 8.63, and clothing and footwear has a negative price growth rate but a wide variation (6.28). The user cost of durable goods experienced a negative growth rate of 0.05 percent, but has a high standard deviation of 22.79. The interest rate during the sample period was 7 percent, on average, but with some variation. Regarding conditional variance, there is more uncertainty in non-durables consumption with more variability than in durables consumption. These results have an important implication for the intertemporal analysis of consumption because the underlying assumption of this model is that intertemporal or temporary variations in prices and the interest rate trigger intertemporal variations in consumption (see Section 3.1.4).

3. The model

3.1. Theoretical framework

We consider a representative consumer who faces an optimal consumption problem of non-durable and durable goods over time.[5] This problem can be solved in two stages via intertemporal two-stage budgeting (Kim, 1993; Kim and McLaren, 2023). In the first stage, the level of consumption expenditure is chosen by optimally allocating wealth across periods. Then, in the second stage, each period's optimal allocation of consumption expenditure is distributed across non-durable and durable goods. The consumer, however, faces borrowing or liquidity constraints because of limited opportunities to borrow against future labor income to finance current consumption expenditure. The solution to the above budgeting procedure can be found by reversing the order of the two stages: first, solve the second-stage problem, and then solve the first-stage problem.

3.1.1. Indirect utility function and demands for non-durable and durable goods. Let $\boldsymbol{q}_t$ be an n quantity vector at period t of non-durable and durable goods, which consists of eight non-durable goods and an aggregate durable

[5]We assume that durable goods are costlessly adjusted in a given period to facilitate the analysis. The use of annual data can provide a justification for such an assumption. Kim et al. (2021) found an insignificant effect of adjustment costs for durable goods in consumption. Notably, this result is consistent with Hall (2004), who found relatively strong evidence against substantial adjustment costs for capital that has similar features of durable goods.

good by taking $q_{nt} \equiv k_t$. Given a direct utility function, $u(\boldsymbol{q}_t)$, which is continuous, increasing, and quasi-concave in $\boldsymbol{q}_t$, the consumer's second-stage optimization problem is summarized by the indirect utility function, $v(M_t, \boldsymbol{p}_t)$, defined as

$$v(M_t, \boldsymbol{p}_t) \equiv \max_{\boldsymbol{q}_t} \left\{ u(\boldsymbol{q}_t) | \boldsymbol{p}_t \cdot \boldsymbol{q}_t \leq M_t \right\}, \tag{3}$$

where M_t is consumption expenditure to be allocated among non-durable and durable goods at period t (i.e., $M_t = C_t + r_t^k k_t$), and $\boldsymbol{p}_t$ is an n price vector at period t of non-durable and durable goods with $p_{nt} \equiv r_t^k$. The above indirect utility function is well defined as a description of the consumer's within-period preferences under the following regularity conditions: it is continuous, increasing in M_t, decreasing in $\boldsymbol{p}_t$, homogeneous of degree zero in M_t and $\boldsymbol{p}_t$, and quasi-convex in $\boldsymbol{p}_t$ (Deaton and Muellbauer, 1980a).

Application of Roy's identity to the indirect utility function (3) yields the system of non-durable and durable demand functions,

$$q_{it} = g_i(M_t, \boldsymbol{p}_t) = -\frac{\partial v(M_t, \boldsymbol{p}_t)/\partial p_{it}}{\partial v(M_t, \boldsymbol{p}_t)/\partial M_t}, \quad i = 1, \ldots, n, \tag{4}$$

which consists of eight ordinary or Marshallian demand functions for non-durable goods and an aggregate ordinary demand function for durable goods. The properties of the demand functions are well known, with consumption expenditure loosely referred to as income (Deaton and Muellbauer, 1980a). It should be noted, however, that the demand functions for non-durable and durable goods in equation (4) are conceptually different from the traditional demand functions incorporating durable goods that are treated as non-durable goods (Clements et al., 2020). In traditional demand analysis, the demand for durable goods is specified in a flow form (i.e., the quantity q_t^k of these goods, with the purchase price p_t^k). In our analysis, it is specified in a stock form (i.e., durables stock k_t with the user cost r_t^k). Further, in traditional demand analysis, durables expenditure is given by $p_t^k q_t^k$, and total expenditure M_t is defined as $M_t = C_t + p_t^k q_t^k$. In our analysis, durables expenditure is given by $r_t^k k_t$, and total expenditure is defined as $M_t = C_t + r_t^k k_t$. These results suggest that traditional demand analysis with durable goods likely leads to a bias in demand elasticities for non-durable and durable goods.

3.1.2. Intertemporal optimization and the consumption Euler equation.

The above second-stage optimization problem is derived under the assumption that the consumer takes, as given, consumption expenditure M_t. The first-stage problem of intertemporal two-stage budgeting allows us to determine it endogenously in the consumer's intertemporal optimization decision. In particular, the consumer faces an intertemporal finance or budget constraint,

$$A_s = (1 + r_{s-1})A_{s-1} + Y_s - M_s \quad \text{for all } \; s \geq t, \tag{5}$$

where A_s is the value of financial assets at the end of period s to be carried into the next period, r_{s-1} is the nominal interest rate on assets that can be both bought and sold between periods $s-1$ and s,[6] and Y_s is labor income at period s.[7] If the consumer faces a borrowing or liquidity constraint, debt cannot exceed the total current value of assets. The liquidity constraint is specified by

$$A_s \geq -L_s \quad \text{for all } \; s \geq t, \tag{6}$$

where L_s is the limit on net indebtedness at period s with $L_s \geq 0$, for all $s \geq t$.[8] If $L_s = 0$, the consumer cannot borrow or incur debt at all, but can save and earn interest from assets.

In formulating an intertemporal optimization problem by endogenizing consumption expenditure, it is important to note that the direct, and hence indirect, utility function in equation (3) is ordinal. Thus, the intratemporal allocation of consumption across goods as captured by the demand function (4) is invariant to a monotonic transformation of the utility function (3). However, the intertemporal allocation of consumption is invariant with respect to a linear transformation of the utility function, but not to other transformations of this function. For intertemporal preferences, we therefore take a Box–Cox form for $\nu(M_t, \boldsymbol{p}_t)$:

$$U_t = \frac{\nu(M_t, \boldsymbol{p}_t)^{1-\zeta} - 1}{1-\zeta}. \tag{7}$$

Here, ζ is a Box–Cox parameter, with the marginal utility of M_t given by

$$U_M(M_t, \boldsymbol{p}_t) \equiv \frac{\partial U_t}{\partial M_t} = \nu(M_t, \boldsymbol{p}_t)^{-\zeta} \nu_M(M_t, \boldsymbol{p}_t), \tag{8}$$

[6]It is common to specify the intertemporal budget constraint (5) with the interest rate r_s, the interest rate between periods s and $s+1$. To be consistent with the usual definition – and for easy interpretation – of the elasticity of intertemporal substitution (EIS), we instead specify it with r_{s-1}, the interest rate between periods $s-1$ and s (Zeldes, 1989). This yields the Euler equation expressed with r_t (equation (11)), which allows us to define the EIS with the interest rate measured at the current rate r_t (Hall, 1988) – see also Section 3.1.4 for a detailed discussion – rather than at the future rate r_{t+1}, as is done in most studies (e.g., Gourinchas and Parker, 2001; Havranek, 2015; Thimme, 2017).

[7]We consider leisure or labor supply as fixed and treat labor income as exogenous to the consumer's choice.

[8]We can treat L_s as a function of durables stock, meaning that durable goods can be used as collateral for borrowing (Chah et al., 1995; Alessie et al., 1997). See also Section 3.2 for a related discussion.

where $\nu_M(M_t, \boldsymbol{p}_t) \equiv \partial \nu(M_t, \boldsymbol{p}_t)/\partial M_t$. A Box–Cox transformation on consumption alone would give plain vanilla CRRA utility (see Section 3.1.3). The Box–Cox transformation with the parameter ζ allows the indirect utility function (3) to be cardinal under intertemporal separability of preferences. It also allows for an additional degree of flexibility in measuring the intertemporal properties of this function. While the indirect utility function (3) as a representation of within-period preferences is well defined with its regularity conditions discussed above, we assume that the Box–Cox utility function (7) is continuous, increasing, and, more importantly, strictly concave in M_t for a given $\boldsymbol{p}_t$. The concavity condition ensures the existence of a solution to the intertemporal optimization problem, and implies that the necessary conditions are indeed sufficient.

Now, with the transformation of the indirect utility function, the consumer's first-stage optimization problem is to choose M_s for $s \geq t$ so as to maximize expected lifetime utility

$$E_t \left[\sum_{s=t}^{\infty} (1+\rho)^{-(s-t)} \left(\frac{\nu(M_s, \boldsymbol{p}_s)^{1-\zeta} - 1}{1-\zeta} \right) \right], \tag{9}$$

where ρ is the constant rate of the consumer's time preference, subject to the intertemporal budget constraint (5), the liquidity constraint (6), and the appropriate transversality condition for assets. The expectation operator E_t is taken over future variables, using information available at the beginning of period t. We assume that the consumer replans continuously when solving the above stochastic dynamic control problem (Lluch, 1973). The consumer, therefore, updates their plans continuously by reoptimizing the intertemporal problem at every period s, $s \geq t$, with the new information they have. This means that the calendar time τ solution for M should be the successive time t solution of this optimization problem as τ evolves through time, with the present always being time t. This idea satisfies dynamic consistency, in the sense that, provided expectations are realized, the optimal solutions for M_s derived at time t will coincide with the time t solutions derived beginning at time s. Then, we can assume that the observed M and $\boldsymbol{q}$ values at t correspond to the initial time period of successive solutions of the optimization problem (9) together with equation (4). At each point in time t, the consumer observes current wealth and the variables r_{s-1} and $\boldsymbol{p}_t$. On the basis of this information and the assumed distributions of future values of stochastic variables, the consumer chooses optimal values for M_t and, hence, values of $\boldsymbol{q}_t$ via equation (4), and planned decision rules to determine the stochastic variables M_s, $s > t$, to satisfy the intertemporal optimization conditions (see equations (10) and (11)).

For estimation and data analysis then, only the first-order conditions necessary for the above intertemporal optimization problem at the initial point in time ($s = t$) are relevant. Utilizing the Lagrange method, they are given by

$$M_t : v(M_t, \boldsymbol{p}_t)^{-\zeta} v_M(M_t, \boldsymbol{p}_t) = \lambda_t \tag{10}$$

and

$$A_t : \lambda_t - \phi_t = E_t \left[\frac{1 + r_t}{1 + \rho} \lambda_{t+1} \right], \tag{11}$$

where λ_t is the Lagrange multiplier associated with the asset accumulation constraint (5) known at time t, which measures the marginal utility of wealth, and ϕ_t is the Lagrange multiplier for the liquidity constraint (6) known at period t, which measures the shadow price of borrowing. ϕ_t will be positive when the liquidity constraint is binding and zero when it is not.[9] Equation (10) indicates that the marginal utility of wealth is equated, at the optimum, to the marginal utility of consumption. This is a property implied by the intertemporal separability of preferences that underlies intertemporal two-stage budgeting. Equation (11) is the standard Euler equation for consumption derived with the indirect utility function (3) adjusted for the presence of a liquidity constraint. It is important to note that, according to equation (11), the marginal utility of consumption in equation (10), which depends on consumption and commodity prices, is a forward-looking variable capturing the influence of future variables, and links the intratemporal and intertemporal decisions in the consumer's optimization problem with allowance for the liquidity constraint. For empirical analysis, it is convenient to work with equation (11) in a ratio form represented by

$$E_t \left[\left(\frac{1 + r_t}{1 + \rho} \right) \frac{\lambda_{t+1}}{\lambda_t} \right] = 1 - \hat{\phi}_t, \tag{12}$$

where $\hat{\phi}_t \equiv \phi_t / \lambda_t$; see Section 3.1.4 for a further discussion.

3.1.3. Risk aversion under non-homothetic preferences. In the presence of uncertainty, consumers' attitudes toward risk, measured by the degree of risk aversion, determine their decisions about occupation, asset allocation, health-related conduct, and moving and changing jobs (Guiso and Paiella, 2008). The degree of relative risk aversion (RRA) is typically measured using the well-known power or CRRA utility function,

$$u(c_t) = \frac{c_t^{1-\zeta} - 1}{1 - \zeta},$$

[9]This describes the complementary slackness condition $\phi_t \geq 0$ and $(A_t + L_t)\phi_t = 0$.

with c_t real non-durable consumption, which gives RRA = ζ (Hansen and Singleton, 1983; Mehra and Prescott, 1985). This measure of RRA hinges on restrictive preferences with real consumption under homothetic preferences, and its value is constant. We generalize this risk-aversion measure under non-homothetic preferences with allowance for relative prices in consumption.

The well-known measures of risk aversion following Arrow (1965) and Pratt (1964) are, essentially, a static concept constructed under the assumption that initial wealth is non-random or the consumer has full access to the capital market.[10] Because the consumer cares about consumption, which is directly related to wealth, the indirect utility function (3) can be deployed to construct operational measures of risk aversion (Deschamps, 1973). However, while the demand functions are determined by an ordinary utility function, a risk-aversion function is determined by a cardinal utility function. To allow for this, we take a Box–Cox transformation of the indirect utility function given in equation (7) with the marginal utility of consumption given in equation (8). The coefficient of RRA is then defined as

$$RRA(M_t, \boldsymbol{p}_t) = -\frac{M_t U_{MM}(M_t, \boldsymbol{p}_t)}{U_M(M_t, \boldsymbol{p}_t)} \equiv -\frac{\partial \ln U_M(M_t, \boldsymbol{p}_t)}{\partial \ln M_t}, \tag{13}$$

where

$$U_{MM}(M_t, \boldsymbol{p}_t) \equiv \frac{\partial U_M(M_t, \boldsymbol{p}_t)}{\partial M_t} = \frac{\nu_{MM}(M_t, \boldsymbol{p}_t)}{\nu(M_t, \boldsymbol{p}_t)^{\zeta}} - \zeta \frac{[\nu_M(M_t, \boldsymbol{p}_t)]^2}{\nu(M_t, \boldsymbol{p}_t)^{\zeta+1}}.$$

The concavity of the intertemporal utility function with respect to M_t implies that $U_{MM}(M_t, \boldsymbol{p}_t) < 0$ and hence $RRA(M_t, \boldsymbol{p}_t) \geq 0$.

3.1.4. Intertemporal allocation of consumption: consumption growth equation. In the intertemporal optimization problem (9), consumption expenditure M_t is a choice variable to be endogenously determined by solving simultaneously the first-order conditions given by equations (10) and (11), along with the intertemporal budget constraint (5) over time. In general, it is not feasible to obtain a structural or closed-form of this function from the intertemporal optimization problem, even for simple utility functions, when the environment is stochastic. To circumvent this problem, it is instead a common practice to work with the Euler equation in studies on consumption

[10]Recent studies show that attitudes towards risk can be affected by the prospect of being liquidity-constrained and by the presence of additional uninsurable, non-diversifiable risks; see Guiso and Paiella (2008) for a discussion with evidence).

and saving (e.g., Hall, 1978; Ludvigson and Paxson, 2001), which is adopted here. To do so, we use the Euler equation for consumption (12) and exploit a lognormal property (Hansen and Singleton, 1983; Kim et al., 2021). Assuming that the quantity $(\lambda_{t+1}/\lambda_t)$ has a lognormal distribution and taking logs on both sides of equation (12), we have

$$\ln\left(\frac{1+r_t}{1+\rho}\right) + E_t(\Delta \ln \lambda_{t+1}) + \frac{1}{2}\mathrm{var}_t(\Delta \ln \lambda_{t+1}) = \ln(1-\hat{\phi}_t),$$

where $\Delta \ln \lambda_{t+1} \equiv \ln(\lambda_{t+1}/\lambda_t)$, the growth rate of the marginal utility of consumption. Rearranging this equation gives

$$\Delta \ln \lambda_{t+1} = -\ln\left(\frac{1+r_t}{1+\rho}\right) - \frac{1}{2}\sigma^2_{t+1} + \ln(1-\hat{\phi}_t) + e_{t+1}, \tag{14}$$

where $\sigma^2_{t+1} \equiv \mathrm{var}_t(\Delta \ln \lambda_{t+1})$ is the conditional variance of marginal utility growth of consumption, and e_{t+1} is an expectation error at time $t+1$ that is uncorrelated with variables known at time t.

To evaluate equation (14), we need an expression for $\Delta \ln \lambda_{t+1}$. Logarithmically, totally differentiating the marginal utility of consumption λ_t in equation (10), whose arguments are M_t and $\boldsymbol{p}_t$, with respect to time, and taking a discrete approximation of log changes, we obtain

$$\Delta \ln \lambda_{t+1} \approx b_{Mt}\Delta \ln M_{t+1} + \sum_{j=1}^{n} b_{jt}\Delta \ln p_{jt+1}, \tag{15}$$

where

$$b_{Mt} \equiv \frac{\partial \ln \lambda_t}{\partial \ln M_t} = -\zeta\frac{\partial \ln v(M_t,\boldsymbol{p}_t)}{\partial \ln M_t} + \frac{\partial \ln v_M(M_t,\boldsymbol{p}_t)}{\partial \ln M_t}$$

and

$$b_{jt} \equiv \frac{\partial \ln \lambda_t}{\partial \ln p_{jt}} = -\zeta\frac{\partial \ln v(M_t,\boldsymbol{p}_t)}{\partial \ln p_{jt}} + \frac{\partial \ln v_M(M_t,\boldsymbol{p}_t)}{\partial \ln p_{jt}},$$

$j = 1$ to n. Because the marginal utility of consumption is decreasing in M_t and p_{jt}, we expect that b_{Mt} and b_{jt} are negative. Substituting equation (15) into equation (14) and solving for $\Delta \ln M_{t+1}$, we obtain a log-linearized Euler equation for consumption growth:

$$\Delta \ln M_{t+1} = d_{rt}\ln\left(\frac{1+r_t}{1+\rho}\right) + \sum_{j=1}^{n} d_{jt}\Delta \ln p_{it+1} + d_{\sigma t}\sigma_2^{t+1} + d_{\phi t}\ln(1-\hat{\phi}_t) + u_{t+1}, \tag{16}$$

where $d_{rt} \equiv -1/b_{Mt}$, $d_{jt} \equiv -b_{jt}/b_{Mt}$, $j = 1, \ldots, n$, $d_{\sigma t} \equiv -1/(2b_{Mt})$, $d_{\phi t} \equiv 1/b_{Mt}$, and $u_{t+1} = e_{t+1}/b_{Mt}$.

Equation (16) identifies the variables governing the intertemporal allocation of consumption. This equation, unlike previous studies on consumption based on real non-durable consumption with no durable goods (Hall, 1988; Ludvigson and Paxson, 2001), is expressed with nominal total consumption by incorporating the growth rates of individual prices of non-durable goods and of the user cost of durable goods. Hence, it accounts for a change in the composition and the relative prices of goods in the consumption basket. The variables of focal interest are the time preference rate, the interest rate, liquidity constraints, and conditional variance. *Ceteris paribus*, a higher time preference rate implies a higher propensity to consume now rather than in the future with less saving, resulting in negative consumption growth. A change in the interest rate has the opposite effect of the time preference rate. In particular, the elasticity of intertemporal substitution (EIS) for consumption measures the response of expected consumption growth to changes in the current interest rate. In equation (16), the coefficient d_{rt} identities the EIS, that is, $d_{rt} = \partial\Delta \ln M_{t+1}/\partial \ln(1 + r_t)$. Given the EIS, *ceteris paribus*, the relation between the time preference rate and the interest rate determines the growth of consumption, with the result that a high interest rate relative to the time preference rate increases consumption growth.

For additively separable preferences across states and time periods, it is well known that the EIS equals the reciprocal of the coefficient of RRA, so RRA $\times$ EIS = 1. For power or CRRA utility, the EIS is given by $1/\zeta$. Given this property, it is easy to infer RRA from the estimated coefficient on the interest rate d_{rt} in the log-linearized consumption growth equation (16), that is, RRA = $1/d_{rt}$ (Hansen and Singleton, 1983). Hall (1988), however, argues that this coefficient should be interpreted as the EIS and can only be informative about the degree of risk aversion under restrictive assumptions.[11] This is the position we take in this paper by separately estimating RRA and EIS.

It is, however, worth noting that a change in the interest rate usually induces substitution as well as wealth effects on consumption. In evaluating these effects, it is important to distinguish between permanent and temporary changes in the interest rate because consumers react differently to these changes. A temporary change in the interest rate is a change in the current interest rate, with all other future interest rates held constant. A permanent change in the interest rate, however, alters current as well as all future interest rates. In general, a permanent change in the interest rate lasts for long periods of time, while a temporary change lasts for only short periods.

[11] Epstein and Zin (1991) proposed a non-expected or recursive utility function to separate risk aversion and intertemporal substitution. However, this framework is based on power utility and gives constant RRA. It is useful in consumption, but not in demand, analysis because it does not allow for the interplay between intratemporal and intertemporal choices.

When a change in the interest rate is temporary, a mediate change in wealth, defined to be the sum of asset income and the present discounted value of future labor incomes, is considered small enough to be ignored, thereby inducing an intertemporal substitution effect only; see Mankiw et al. (1985) in a different context. A permanent change in the interest rate induces a non-trivial wealth effect but does not bring about an intertemporal substitution effect, because consumers adjust current, as well as future consumption, in the same direction in response to such a change in wealth. In essence, a temporary change in the interest rate does not affect future interest rates and wealth, but a permanent change does. Hence, a temporary change in the interest rate effectively controls for the wealth effect, which allows us to properly identify the EIS. This has not received due attention in the literature on intertemporal substitution in consumption (Havranek, 2015; Thimme, 2017).

The variable $\hat{\phi}$ in equation (16) refers to the degree of liquidity constraints. A binding constraint implies that $\hat{\phi} > 0$. To see the effect of the liquidity constraint on consumption growth, the term $\ln(1 - \hat{\phi})$ can be approximated by $-\hat{\phi}$. Because $b_{Mt} < 0$ and thus $d_{\phi t} > 0$, this implies a positive relation between liquidity constraints and consumption growth. An increase in liquidity constraints means that the consumer's ability to borrow is reduced, leading to a lower current consumption and thus increased consumption growth.

The variable σ^2_{t+1} is the conditional variance of consumption, which is a measure of uncertainty of consumption. The coefficient $d_{\sigma t}$ captures the effect of uncertainty on consumption. In the absence of insurance or risk-sharing opportunities, uncertainty, in general, motivates consumers to engage in precautionary saving in the form of safe or liquid assets to guard against falling consumption or income in the future (Dynan, 1993; Gourinchas and Parker, 2001). This leads them to decrease current consumption in exchange for an increase in future consumption, resulting in higher expected consumption growth. Durables spending is particularly sensitive to uncertainty because purchase decisions are costly to reverse. In such a situation, uncertainty induces consumers to postpone these decisions rather than taking them immediately (Knotek and Kahn, 2011).

3.2. Empirical specification

In the integrated model of consumer behavior, the indirect utility function (3) is a vehicle that allows a joint analysis of consumer demands and intertemporal consumption in a coherent way. For empirical analysis, the specification of an appropriate functional form for this function is essential to obtain reasonable results. To properly characterize consumer behavior, however, the chosen functional form should be flexible while satisfying the requisite regularity conditions for within-period as well as intertemporal preferences.

The price-independent generalized logarithmic (PIGLOG) form, popularized by the almost ideal demand system (AIDS) of Deaton and Muellbauer (1980b), is widely used in applied demand analysis. Despite some drawbacks with this system, Blundell et al. (1994) utilized it to analyze consumer behavior in the context of intertemporal two-stage budgeting with no durable goods. We note, however, that when there are substantial changes in real income or consumption, the implied budget share equations for AIDS violate the required monotonicity and curvature conditions.

In this study, we have extended the modified PIGLOG (MPIGLOG) form of Cooper and McLaren (1992) as a functional representation of the indirect utility function (3). The extended MPIGLOG form is a composite indirect utility function of rank 3 (McLaren and Wong, 2009). Thus, it is more flexible than the PIGLOG and MPIGLOG forms based on rank 2, while it allows easier imposition of regularity conditions in the form of effective global regularity (Cooper and McLaren, 1996; McLaren and Wong, 2009).

With the extended MPIGLOG specification, the indirect utility function (3) is given by

$$v(M_t, \boldsymbol{p}_t) = \left\{ \frac{[M_t / P_A(\boldsymbol{p}_t)]^{\mu} - 1}{\mu} \right\} \frac{M_t^{\eta} / P_B(\boldsymbol{p}_t)}{1 + [P_C(\boldsymbol{p}_t)/M_t]}, \tag{17}$$

where μ and η are parameters, and $P_A(\boldsymbol{p}_t)$, $P_B(\boldsymbol{p}_t)$, and $P_C(\boldsymbol{p}_t)$ are price indices that are positive, increasing, and concave in $\boldsymbol{p}_t$. We assume that the price indices take the forms,

$$P_A(\boldsymbol{p}_t) \equiv \left(\sum_{j=1}^{n} \alpha_j p_{jt}^{\rho_A} \right)^{1/\tau_A}, \quad P_B(\boldsymbol{p}_t) = \Pi_{j=1}^{n} p_j^{\beta_j},$$
$$\sum_{j=1}^{n} \beta_j = \eta, \quad \text{and} \quad P_C(\boldsymbol{p}_t) = \sum_{j=1}^{n} \gamma_j p_j, \tag{18}$$

where $P_A(\boldsymbol{p}_t)$ is a constant elasticity of substitution (CES) function, $P_A(\boldsymbol{p}_t)$ is a Cobb–Douglas function, and $P_C(\boldsymbol{p}_t)$ is a linear function of prices. These price indices are of different forms with different parameter values to reflect the relative importance of each index, and they form a rank 3 demand system. We use these forms of price indices to capture regularity of the indirect utility function (Cooper and McLaren, 1996).

Given equation (17) together with associated price indices in equation (18), we obtain the following derivatives:

$$\frac{\partial v(M_t, \boldsymbol{p}_t)}{\partial M_t} = \left[\frac{M_t^{\eta} / P_B(\boldsymbol{p}_t)}{M_t + P_C(\boldsymbol{p}_t)} \right] [1 + (\mu + \eta + RP_{C_s}) R_t], \tag{19}$$

$$\frac{\partial v(M_t,\boldsymbol{p}_t)}{\partial p_{it}} = -\left[\frac{M_t^{\eta-1}/P_B(\boldsymbol{p}_t)}{M_t + P_C(\boldsymbol{p}_t)}\right]\left[\frac{(1+\mu R_t)E_{Ait} + \beta_i R_t}{p_{it}} + \frac{\gamma_i R_t}{M_t + P_C(\boldsymbol{p}_t)}\right], \quad i = 1, \ldots, n, \tag{20}$$

and

$$\frac{\partial^2 v(M_t,\boldsymbol{p}_t)}{\partial M_t^2} = \left\{(\mu+\eta+RP_{C_t})(1+\mu R_t) - RP_{C_t}(1-RP_{C_t})R_t + [\eta - (1-RP_{C_t})][1+(\mu+\eta+RP_{C_t})R_t]\right\} \times \left[\frac{M_t^{\eta-1}/P_B(\boldsymbol{p}_t)}{M_t + P_C(\boldsymbol{p}_t)}\right], \tag{21}$$

where

$$R_t = \frac{[M_t/P_A(\boldsymbol{p}_t)]^\mu - 1}{\mu}, \quad RP_{C_t} = \frac{P_C(\boldsymbol{p}_t)}{M_t + P_C(\boldsymbol{p}_t)},$$

and

$$E_{Ait} = \frac{\partial \ln(P_A)}{\partial \ln(p_{it})} = \frac{\alpha_i p_{it}^{\tau_A}}{\sum_j \alpha_j p_{jt}^{\tau_A}}.$$

Expressions (19) and (20) can be used to derive the demand functions for non-durable and durable goods via Roy's identity (4). In a budget or expenditure share form, we have

$$S_{it} = -\left[\frac{\partial v(M_t,\boldsymbol{p}_t)/\partial p_{it}}{\partial v(M_t,\boldsymbol{p}_t)/\partial M_t}\right]\frac{p_{it}}{M_t} = \frac{(1+\mu R_t)E_{Ait} + \beta_i R_t + [(\gamma_i p_{it} R_t)/M_t + P_C(\boldsymbol{p}_t)]}{1+(\mu+\eta+RP_{C_t})R_t}, \quad i = 1, \ldots, n, \tag{22}$$

where $S_{it} \equiv p_{it}q_{it}/M_t$ is the share of the ith ($i = 1, \ldots, n$) good in total expenditure, with $\sum_{i=1}^n S_{it} = 1$. A more detailed discussion of the budget share equations (22) is provided in Online Appendix B with the derivation of price and income elasticities.

The coefficient of RRA (13) is derived as

$$RRA(M_t,\boldsymbol{p}_t) = \xi\frac{\partial \ln v(M_t,\boldsymbol{p}_t)}{\partial \ln M_t} - \frac{\partial \ln v_M(M_t,\boldsymbol{p}_t)}{\partial \ln M_t}, \tag{23}$$

where

$$\frac{\partial \ln v(M_t, \boldsymbol{p}_t)}{\partial \ln M_t} = \frac{1}{R_t} + (\mu + \eta + RP_{C_t})$$

and

$$\frac{\partial \ln v_M(M_t, \boldsymbol{p}_t)}{\partial \ln M_t} = \frac{(\mu + \eta + RP_{C_t})(1 + \mu R_t) - RP_{C_t}(1 - RP_{C_t})R_t}{1 + (\mu + \eta + RP_{C_t})R_t} + \eta - (1 - RP_{C_t}).$$

Moreover, the Euler equation in equation (12) can be written as

$$\frac{(1 + r_t)}{(1 + \rho)} \frac{\lambda_{t+1}}{\lambda_t} + \frac{\Phi_t}{\lambda_t} = 1 + \varepsilon_{t+1}, \tag{24}$$

where

$$\lambda_{t+s} = v(M_{t+s}, \boldsymbol{p}_{t+s})^{-\xi} \frac{\partial v(M_{t+s}, \boldsymbol{p}_{t+s})}{\partial M_{t+s}},$$

for $s = 0$ and 1, and ε_{t+1} is an expectation error, with $v(M_{t+s}, \boldsymbol{p}_{t+s})$ and $\partial v(M_{t+s}, \boldsymbol{p}_{t+s})/\partial M_{t+s}$ given by equations (17) and (19).

Estimation of the Euler equation (24) requires the solution for the Lagrange multiplier or shadow price for borrowing or liquidity constraints ϕ_t. This variable is a non-differentiable function of many variables, which is difficult to derive analytically. As a result, previous studies deal with this difficulty either by using some proxy for liquidity constraints, or by splitting the sample by some indicator, such as wealth, to identify households who are likely to be liquidity-constrained (Zeldes, 1989; Wakabayashi and Horioka, 2005). In this paper, we take a different approach to detect the presence or absence of liquidity constraints. When consumers face liquidity constraints, their ability to adjust current consumption is limited in response to a future increase in income; hence, their optimal consumption is constrained by current income. If consumers are liquidity-constrained and their disposable income increases in the current period, the constraint will be relaxed and therefore ϕ_t will fall, suggesting a negative relation between ϕ_t and disposable income (Zeldes, 1989). Moreover, because of their unit value and longer lifetime, some durable goods can be used as collateral, which makes consumers easier to finance using credit (Chah et al., 1995; Alessie et al., 1997). We can then expect a negative relation between ϕ_t and durables stock. Therefore, we use disposable income and durables stock as measures of liquidity constraints, and express ϕ_t as a function of these variables,

$$\phi_t = \phi_0 + \phi_1 \ln Y_t^d + \phi_2 \ln k_t, \tag{25}$$

where Y_t^d is disposable income at period t, and ϕ_1 and ϕ_2 are parameters with the restriction that $\phi_1 < 0$ and $\phi_2 < 0$ if the consumer is liquidity-constrained.

4. Estimation and results

The empirical investigation was carried out using annual consumption expenditure data for Norway, as discussed in Section 2.1, with eight non-durable goods and an aggregate durable good spanning the period 1979–2018. In this section, we discuss the estimation procedures of the empirical model and then present estimation results.

4.1. Estimation methods

To obtain the values of parameters in the extended MPIGLOG indirect utility function (17) together with the Box–Cox parameter ξ, the time preference rate ρ appearing in the intertemporal optimization problem (9), and the liquidity constraint parameters in equation (25), we jointly estimate the budget share equations for eight non-durable goods and an aggregate durable good in equation (22), together with the Euler equation for total consumption in equation (24). Although the Euler equation contains all information to identify the parameters, it is not efficient to use only this equation, because it neglects the information given in the budget share equations. In estimation, it should be noted that total consumption M_t is not exogenous, but is endogenously determined in the consumer's optimization problem and hence is correlated with the error terms. Also, current prices $\boldsymbol{p}_t$ and the interest rate r_t might not be strictly exogenous. Moreover, there are variables dated $t + 1$ that need to be properly treated in estimation. The use of the realized values causes them to be correlated with the error terms. These facts suggest an instrumental variables (IV) approach to estimate the model.

We employ nonlinear three-stage least-squares (3SLS) to jointly estimate the system of nine budget share equations (22) with the Euler equation (24).[12]

[12]Kim et al. (2013) provided a good discussion of the joint estimation framework in the context of the generalized method of moments (GMM). However, they do not allow for durable goods and fail to account for the interplay between intratemporal and intertemporal decisions. We adapt their estimation method to our analysis. However, in estimation, we experienced some identification problems with the GMM, and so we employ nonlinear 3SLS. The GMM reduces to 3SLS when the errors are conditionally homoskedastic. We make this assumption for simplicity, although estimation of the demand functions in a budget form of equation (22) rather than equation (2), as well as the Euler equation in a ratio form of equation (24) rather than equation (11), should provide a more favorable disposition toward homoskedastic errors.

We assume that the budget share equations are stochastic, due to errors of optimization or taste shocks. The error in the Euler equation is, by the nature of the first-order condition (12), uncorrelated with all information dated at time t. We use as instruments a set of variables that does not include any current variables appearing in the equation system.[13] Serial correlation is a common issue in estimation of the budget share equations. To accommodate evidence of significant positive serial correlation in the budget share equations revealed in the initial estimation, we use the correction for autoregressive errors proposed by Moschini and Moro (1994). The parameters of equations (22) and (24) are identified by imposition of multiple cross-equation parameter restrictions in the nine equations, with one share equation deleted because of the adding up condition.

In an IV regression, it is important to see if the chosen instruments are valid. This can be done with the J-test that examines whether the instruments used in estimation are exogenous, satisfying the moment conditions with the overidentifying restrictions, as required by the theory. It has a χ^2 distribution with the degrees of freedom, df (= number of overidentifying restrictions, 74 in our model) equal to $L - K$, where L is the number of equations in the system (nine in our model) × the number of instruments (13 in our model), and K is the number of independent estimated parameters in the system (43 in our model).[14]

To estimate the consumption growth equation (16), we assume that all explanatory variables may not be strictly exogenous. Hence, we pursue an IV method, using as instruments one-period lags of all regressors.[15] For conditional variance of total consumption, we can take the realized values by using instruments under rational expectations (see the discussion in Section 2.2).

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[13]We used the following instruments: constant, time trend, time trend squared, non-durable price indices and the user cost lagged one period, disposable income lagged by one period, and the interest rate lagged by one period. It is common to use laggard variables as instruments for aggregate time series data in consumption studies. In this case, the weak instrument problem can arise if lagged variables have low correlations with current endogenous variables (Stock and Wright, 2000). To check the strength of our instruments, we examined the autocorrelation coefficient of these variables (except constant and time trend), and found that almost all of them exhibit strong autocorrelation. This implies that the weak instrument problem caused by the use of their lagged values as instruments appears not to be a problem. In addition, we tried several different sets of other instruments but found some violations of the regularity conditions. Our chosen instruments satisfy the regularity conditions and the overidentifying restrictions are not rejected (see Table 2).

[14]Because of the adding up condition, there are eight budget share equations, giving nine estimated equations with 34 parameters estimated. In addition, there nine autocorrelation coefficients, giving the total number of 43 estimated parameters.

[15]We used the following instruments: constant, time trend (t), t^2, $\Delta \ln(p_{it-1})$, ($i = 1 - -8$), $\Delta \ln r^k_{t-1}$, $\ln[(1 + r_{t-1})/(1 + \rho)]$, $\ln(1 - \hat{\phi}_{t-1})$, and $\Delta \ln(Y^d_{t-1})$.

Table 2. Constrained joint estimation results: budget share system and Euler equation (*t* ratios in parentheses)

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
α_1	0.095	β_1	0.043	γ_1	0.131
	(5.712)		(3.118)		(3.130)
α_2	0.012	β_2	0.018	γ_2	0.010
	(1.698)		(3.915)		(0.741)
α_3	0.012	β_3	0.028	γ_3	0.000
	(1.758)		(6.242)		–
α_4	0.212	β_4	0.044	γ_4	0.261
	(27.971)		(3.464)		(5.409)
α_5	0.102	β_5	0.031	γ_5	0.061
	(6.187)		(2.811)		(2.699)
α_6	0.024	β_6	0.003	γ_6	0.029
	(4.545)		(1.032)		(3.352)
α_7	0.095	β_7	0.007	γ_7	0.201
	(7.195)		(0.510)		(5.192)
α_8	0.035	β_8	0.066	γ_8	0.087
	(2.183)		(3.651)		(1.972)
α_9	0.413	β_9	0.087	γ_9	1.220
	(12.705)		(6.704)		(16.894)
τ_A	0.796	η	0.327	ϕ_0	0.021
	(19.417)		(12.870)		(3.894)
ρ	0.074	ξ	0.030	ϕ_1	−0.015
	(3.802)		(22.776)		(−3.840)
		μ	−2.200	ϕ_2	−0.011
			(−9.826)		(−2.494)

Notes: Log-likelihood value: 1628.24. J-test of overidentifying restrictions: χ^2 test statistic (df =74) = 81.784, p-value = 0.768.

4.2. Parameter estimates

Tables 2 and 3 report estimation results for the empirical model based on joint estimation of the nine budget shares along with the Euler equation for consumption. The following comments are in order. The model is highly nonlinear with many parameters, and to ensure that the requisite within-period and intertemporal regularity conditions are satisfied, we imposed a parameter restriction in estimation by setting $\gamma_3 = 0$ in the extended MPIGLOG indirect utility function (17).[16] With this restriction, all of the regularity conditions are

[16]The 3SLS estimation process starts from a set of starting values of the parameters and progressively adjusts them iteratively until the fit between the likelihood model and the observed data does not improve beyond a threshold value. We adopt the methodology of

satisfied at every sample period.[17] The J-test for overidentifying restrictions cannot reject the null hypothesis that the moment conditions for instruments are valid, providing evidence for the relevance of the chosen instruments in our estimation. Moreover, as can be seen in Table 3, the general fit of the budget share system, indicated by the R^2 values, calculated as the generalized R^2 for instrumental variables regressions (see Pesaran and Smith, 1994), is quite good. Autocorrelation diagnostics revealed in the Durbin–Watson and Box–Pierce χ^2 statistics suggest that serial correlation in the error terms is no longer severely pathological.

While these results lend some validity to our estimated model, there are some estimated parameters that are of particular interest in our analysis. The estimated ξ (0.030) is significantly different from zero, substantiating the relevance of the Box–Cox transformation of the indirect utility function (17). The liquidity constraint parameters ϕ_1 (−0.015) and ϕ_2 (−0.011) have expected negative signs and are significant at conventional significance levels. Thus, disposable income and durables stock affect the liquidity constraint, but their effects are rather small. The value of ϕ_0 is also small but significant. Using equation (25), the degree of liquidity constraint is evaluated at the sample means of disposable income and durables stock, which gives the estimated ϕ_t value of 0.0062 with the t ratio of 2.6209. This clearly suggests weak evidence for liquidity constraints.

Finally, the estimated time preference rate ρ of 0.074 means that consumers discount the utility of future consumption at an annual rate of 7.4 percent with the discount factor $(1/(1+\rho))$ of 0.93. The intertemporal stability condition for consumers with a fixed interest rate requires that the interest rate is

Cranfield et al. (2000) to resolve the problem of convergence; that is, the parameters for the "rich" (α_i) begin at the mean budget shares for the ith good across the sample, while the parameters for the "poor" (γ_i) begin at half the minimum observed consumption levels in the sample. Given these initial values, convergence is achieved after 13 iterations.

[17]When the model is estimated with γ_3 set to be free or unconstrained (see Table C1 in Online Appendix C), the value of γ_3 is found to be −0.006, which is marginally below the limiting value of 0. An inspection of the eigenvalues of the implied Slutsky matrix of the extended MPIGLOG form with $\gamma_3 = -0.006$ reveals a violation of the curvature condition for some observations in the sample period. This condition, though, has to be satisfied for our model to be well behaved, and this can be done by setting γ_3 equal to 0. With this restriction, the required monotonicity and curvature conditions are satisfied at every sample period. It is, however, important to note that the Wald test statistic of the restriction $\gamma_3 = 0$ is only 0.323, which is below the critical value for χ^2 of 3.84 for the 5 percent significance level, suggesting that γ_3 is not significantly different from 0. Nevertheless, and perhaps more importantly, a comparison of the constrained estimated model (Table 2) with the unconstrained model (Table C1) shows that the constrained and unconstrained parameter estimates are very comparable, with the same sign and similar orders of magnitude. Thus, it appears that imposing the restriction $\gamma_3 = 0$ does not have much impact on the results.

Table 3. Estimated model summary statistics

Commodities	R^2	DW statistic	Box–Pierce χ^2 statistic ($\chi^2_{2.5\%,6}$ = 14.45)
q_1	0.989	1.089	12.900
q_2	0.884	2.094	5.000
q_3	0.958	1.621	5.860
q_4	0.826	1.178	6.080
q_5	0.719	2.045	4.360
q_6	0.943	0.988	8.730
q_7	0.900	1.575	4.770
q_8	0.989	1.461	6.050
k	0.958	0.602	31.800

Notes: q_1 = food and non-alcoholic beverages, q_2 = alcoholic beverages, tobacco, and narcotics, q_3 = clothing and footwear, q_4 = housing services, q_5 = water and fuels, q_6 = health services, q_7 = transport services, q_8 = other non-durables and services, and k = durables stock. R^2 is calculated as the generalized R^2 for IV regressions (Pesaran and Smith, 1994). DW = Durbin–Watson statistic. Estimation is based on the nine budget share equations (22) and the Euler equation (24) using nonlinear 3SLS.

greater than the time preference rate for a growing economy (Kim, 2017). During the sample period, the average annual interest rate was 7.13 percent. However, this average rate is misleading when used to represent the behavior of the interest rate during the sample period (see Table 1). The interest rate was above 10 percent during 1979–1992, but it has been falling since then, from the value of 7.265 percent in 1993 to 2.236 percent in 2012; and it remained below 2 percent for 2013–2018. Thus, the time preference rate was greater than the interest rate for most of the sample period. This implies that Norwegian consumers, to a large extent, appear to be impatient, in the sense that they have a high time preference for present consumption relative to the risk-free interest rate.[18] This likely led to the absence of a sustained rise in consumption (see the related discussion in Section 3.1.4), accompanied by the lack of households' wealth accumulation in the Norwegian economy during the sample period; see the consumption growth pattern in Figure 1.

4.3. Estimated demand elasticities and relative risk aversion

Price and income or expenditure elasticities of goods and services are important summary measures characterizing consumer behavior. Table 4 displays mean

[18] Fagereng et al. (2021) estimated a buffer stock model of consumption/saving with aggregate consumption for Norway. With the interest rate set at 0.0406, equal to the average excess return on illiquid assets in Norway between 2005 and 2015, they found the discount factor of 0.902, which gives the time preference rate of 0.1086. Although their interest rate and the time preference rate are different from ours, the fact that the time preference rate is higher than the interest rate corroborates our finding and resulting implications.

Table 4. Estimation results: expenditure and price elasticities and relative risk aversion (t ratios in parentheses)

Commodities	Mean budget shares		Expenditure elasticities		Own price elasticities	
	With durables	Without durables	With durables	Without durables	With durables	Without durables
q_1	0.150	0.189	0.675	0.566	−0.407	−0.514
	(6.193)	(5.807)	(7.950)	(5.313)	(−4.900)	(−5.134)
q_2	0.045	0.057	1.375	1.070	−0.690	−1.305
	(14.901)	(15.230)	(5.179)	(2.252)	(−5.512)	(−2.783)
q_3	0.061	0.077	1.370	−6.714	−0.782	−0.204
	(6.807)	(6.260)	(8.648)	(−0.002)	(−19.645)	(−1.154)
q_4	0.161	0.204	0.367	0.404	−0.257	−0.521
	(20.145)	(25.549)	(7.100)	(4.650)	(−4.879)	(−5.964)
q_5	0.052	0.065	0.386	0.232	−0.383	−0.057
	(12.283)	(14.211)	(5.693)	(1.160)	(−6.349)	(−0.358)
q_6	0.014	0.018	0.261	0.331	−0.253	−0.512
	(4.744)	(5.057)	(2.696)	(2.002)	(−2.449)	(−2.358)
q_7	0.093	0.117	0.366	0.373	−0.161	−0.121
	(17.029)	(22.834)	(4.552)	(2.690)	(−1.856)	(−0.978)
q_8	0.215	0.272	1.407	0.580	−0.640	−0.476
	(6.347)	(6.877)	(8.489)	(6.618)	(−6.585)	(−18.244)
k	0.209	–	0.685	–	−0.332	–
	(8.809)	–	(20.056)	–	(−19.873)	–

Notes: Coefficient of RRA: with durables, 1.001 (22.211); without durables, 0.894 (6.349). q_1 = food and non-alcoholic beverages, q_2 = alcoholic beverages, tobacco, and narcotics, q_3 = clothing and footwear, q_4 = housing services, q_5 = water and fuels, q_6 = health services, q_7 = transport services, q_8 = other non-durables and services, and k = durables stock. Estimation is based on the elasticities for non-durable and durable goods derived in Online Appendix B along with estimates of RRA using equation (23) evaluated at the sample means of the variables.

budget shares for commodities and estimated expenditure and price elasticities for non-durable and durable goods derived in Online Appendix B, along with estimates of RRA using equation (23) evaluated at the sample means of the variables. To see the bias resulting from ignoring durable goods, using non-durable goods only, two sets of estimates with and without durable goods are presented. Looking at the mean budget shares without durable goods, a substantial portion of expenditure on non-durable goods and services, except for other goods, is spent on housing services (20.4 percent), followed by food and non-alcoholic beverages (18.9 percent), and transport services (11.7 percent). When durable goods are included, it is important to note that durables expenditure is measured based on durables stock, not expenditure. With durable goods, a major portion of total consumption expenditure except for other goods is spent for durable goods (20.9 percent), followed by housing services (16.1 percent), and food and non-alcoholic beverages (15 percent).

As can be seen, ignoring durable goods leads to a significant bias in expenditure and price elasticities, underscoring the importance of accounting for durable goods. In particular, when durable goods are not considered, clothing and footwear has an incorrect sign for the expenditure elasticity. Most non-durable goods are income-inelastic and can be classified as necessities. However, alcoholic beverages, tobacco, and narcotics, and clothing and footwear are income-elastic, though clothing and footwear are not strictly non-durable, but semi-durable. Durable goods are also found to be a necessity, like most non-durable goods.

This result is markedly different from previous studies finding that durable goods are luxuries (see Clements et al., 2020). This is because traditional demand studies estimate the demand for durable goods in a flow form, but our analysis is based on a stock form. There are also studies for the United States based on a stock form finding durable goods as luxuries, but they are limited in scope and analysis with restrictive utility functions (Mankiw, 1985). There might be some expensive or large durable goods that are luxuries, but most of them are small and can be treated as necessities.

Estimated price elasticities also reveal an appreciable difference with and without durable goods. When durable goods are considered, all non-durable goods are price-inelastic, and durable goods are also found to be price-inelastic. There are studies estimating income and price elasticities of demand for Norwegian consumers (see Online Appendix A for a literature review). However, they do not consider durable goods and use different groupings of non-durable goods, and thus are not comparable to our results.

There has been a dramatic rise in the share of income spent on health expenditures in many countries, including Norway, and it is believed that this is a consequence of rising income or living standards (Hall and Jones, 2007). This would be the case if health care is a luxury. Acemoglu et al. (2013) investigated this issue by estimating the income elasticity of health care for the United States, and found that the estimate is much less than unity. This led them to conclude that rising income is unlikely to be a major driver of the rising health expenditure share of GDP. It has often been suggested, without evidence, that the invention of new and expensive medical technologies causes health spending to rise over time (Hall and Jones, 2007).

The question that remains is, what is behind the notable trend in the rising health share of income? Our analysis provides some answer to this question for Norway. In particular, the estimated expenditure elasticity of health services when durable goods are included is 0.261, which is less than all other goods, meaning that health services are more necessary than other goods. Thus, the evidence is clear to reject that health care is a luxury; it can instead be considered a necessity. More importantly, we have an expenditure share equation for health care estimated in conjunction with other commodities (see equation (22)), with an average of 1.4 percent of total consumption spent on health care. From this equation, we can estimate the health share elasticities of income and prices, which are directly related to the income and price elasticities of health services, in Table 4. From the estimated expenditure elasticity of health services, we get a health share elasticity of income of −0.739 with the t-value of −2.696. This means that rising income has a negative effect on the health share of income, in direct contradiction to the conventional view (Hall and Jones, 2007). The estimated price elasticity of health services is −0.253, yielding a health share elasticity of the health services price of 0.747, with the t-value of 2.449. Accordingly, we can conclude that the rise in the health expenditure share of GDP in Norway has been driven by rising health care prices or costs rather than by rising income. To a certain extent, this validates technological change as an explanation for the rising health share of income, because the invention of new and expensive medical technologies raises the costs of providing health care.[19]

Table 4 also provides the estimates of RRA with and without durable goods. We find that there is no significant difference in its value with and without durable goods. The RRA value with durable goods is lower than the usual *a priori* values considered reasonable for relative risk aversion ($1 < RRA < 5$; Cochrane, 2005). To further examine the behavior of RRA over time, Figure 3 presents a plot of RRA estimated with durable goods during the sample period. As can be seen, the degree of RRA has been decreasing over time. This implies that Norwegian consumers are, in general, not considered risk-averse and have been less risk-averse over the years.[20] This runs counter to any attempt to explain the observed equity premium with an implausibly high level of risk aversion (Mehra and Prescott, 1985; Kocherlakota, 1996).

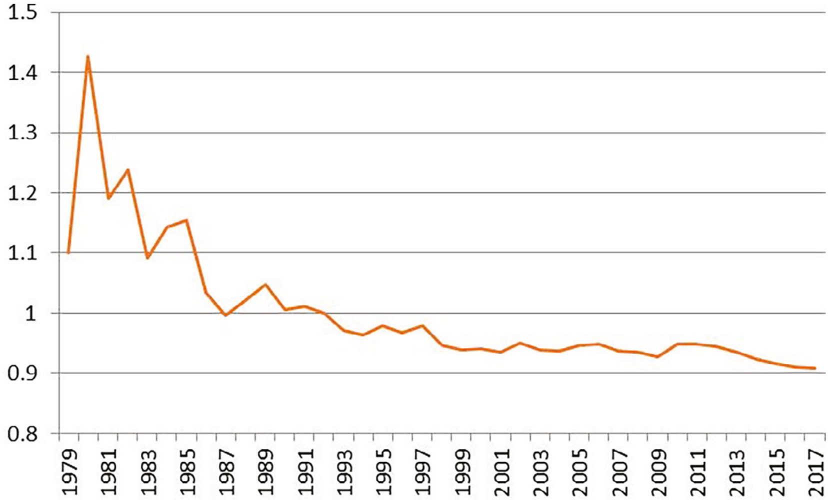
4.4. Estimated consumption growth equations

Table 5 presents results of estimating consumption growth equations based on total consumption (M_t), non-durable consumption (C_t), and durables stock (k_t). Two sets of results are presented in nominal and real specifications. For each specification, a growth equation is estimated for M_t using equation (16), and for C_t and k_t. For the C_t and k_t growth equations, we estimate them by

[19]It is possible that the apparent increase in health care prices is spurious and caused by rapid progress in medical technology, leading to a higher quality of health care. Perhaps quality-adjusted prices have not risen by as much. We were not able to investigate this possibility.

[20]It is found that 70 percent of Norwegians above the age of 18 gambled in 2012, through the services of fully state-owned companies (see Fagereng et al., 2021). To the extent that gambling is negatively associated with risk aversion, this result is consistent with our finding of low risk aversion.

Figure 3. Movement of RRA over time



Notes: The coefficient of RRA is calculated using equation (23).

assuming that the two equations are independent and jointly related. For ρ and $\hat{\phi}$, we use their estimated values (see Section 4.2). All growth equations are estimated by an IV approach, assuming that all explanatory variables may not be strictly exogenous.

The general fit of all growth equations, as indicated by R^2, is quite good. The Durbin–Watson statistic shows that serial correlation is not a serious problem. The J-test reveals that our chosen instruments are valid at conventional significance levels for most of the growth equations. These results appear to indicate the relevance of the estimated growth equations.

Looking at the nominal specification for total consumption, there are significant price effects, with the largest being p_1 (price of food and non-alcoholic beverages) with the value of −0.716, followed by p_7 (price of transport services) with the value of 0.611, and p_2 (price of alcoholic beverages, tobacco, and narcotics) with the value of 0.540. Most of the non-durables price changes have positive effects on total consumption growth. The user cost of durable goods (r^k) has a positive and significant value of 0.235. However, the interest rate has a rather modest effect on total consumption growth with the value of 0.193, but it is not significant. The liquidity constraint has a greater effect than the interest rate on total consumption growth, but it is insignificant. Remarkably, however, conditional variance has a large and significant effect on total consumption growth.

When total consumption is broken into non-durable and durable consumption, the effects are different. Non-joint and joint estimation also

Table 5. Estimation results: consumption and durables stock growth equations – nominal specification (*t* ratios in parentheses)

Regressors		Non-joint estimation		Joint estimation	
	$\Delta \ln M_{t+1}$	$\Delta \ln C_{t+1}$	$\Delta \ln k_{t+1}$	$\Delta \ln C_{t+1}$	$\Delta \ln k_{t+1}$
Constant	0.028	0.030	0.007	0.020	0.029
	(1.954)	(3.445)	(2.040)	(0.792)	(3.272)
$\Delta \ln p_{1t+1}$	−0.716	−0.543	–	−0.434	−0.288
	(−2.269)	(−2.916)	–	(−0.508)	(−0.919)
$\Delta \ln p_{2t+1}$	0.540	0.130	–	0.206	0.053
	(3.311)	(1.064)	–	(0.252)	(0.306)
$\Delta \ln p_{3t+1}$	−0.014	−0.023	–	−0.330	0.045
	(−0.101)	(−0.248)	–	(−0.806)	(0.339)
$\Delta \ln p_{4t+1}$	−0.502	−0.047	–	−0.213	−0.535
	(−2.077)	(−0.265)	–	(−0.438)	(−2.291)
$\Delta \ln p_{5t+1}$	0.038	−0.006	–	0.040	0.070
	(0.621)	(−0.137)	–	(0.185)	(0.988)
$\Delta \ln p_{6t+1}$	−0.408	−0.038	–	−0.065	0.149
	(−1.794)	(−0.292)	–	(−0.119)	(1.106)
$\Delta \ln p_{7t+1}$	0.611	0.345	–	0.500	0.183
	(3.724)	(3.185)	–	(1.542)	(1.325)
$\Delta \ln p_{8t+1}$	0.216	0.110	–	0.197	0.332
	(1.777)	(1.475)	–	(0.608)	(3.796)
$\Delta \ln r^k_{t+1}$	0.235	–	0.005	0.074	0.005
	(7.271)	–	(1.240)	(4.772)	(1.253)
$\ln[(1+r_t)/(1+\rho)]$	0.193	0.079	−0.096	0.411	−0.073
	(1.124)	(0.626)	(−3.129)	(1.086)	(−0.551)
$\ln(1-\hat{\phi}_t)$	0.320	0.349	0.033	0.136	0.236
	(1.269)	(1.824)	(0.684)	(0.275)	(1.704)
$\sigma^2_{M_{t+1}}$	2.766	–	–	–	–
	(4.959)	–	–	–	–
$\sigma^2_{C_{t+1}}$	–	4.836	–	4.126	–
	–	(11.049)	–	(2.372)	–
$\sigma^2_{k_{t+1}}$	–	–	9.006	–	9.121
-	–	–	(17.256)	–	(5.118)
R^2	0.899	0.971	0.910	0.892	0.970
DW	2.009	1.493	0.809	1.367	1.181
J-test					
χ^2 test statistic	3.524	1.127	1.089	8.835	
Degrees of freedom	2	2	1	4	
p-value	0.172	0.569	0.297	0.065	

Table 5. (Continued)

Regressors		Non-joint estimation		Joint estimation	
	$\Delta \ln M_{t+1}$	$\Delta \ln C_{t+1}$	$\Delta \ln k_{t+1}$	$\Delta \ln C_{t+1}$	$\Delta \ln k_{t+1}$
Wald test					
χ^2 test statistic	134.364	75.740	–	183.783	
Degrees of freedom	8	8	–	16	
p-value	0.000	0.000	–	0.000	

Notes: M = total expenditure, C = non-durable consumption, k = durables stock, p_1 = price of food and non-alcoholic beverages, p_2 = price of alcoholic beverages, tobacco, and narcotics, p_3 = price of clothing and footwear, p_4 = price of housing services, p_5 = price of water and fuels, p_6 = price of health services, p_7 = price of transport services, p_8 = price of other non-durables and services, r^k = user cost of durable goods, r = interest rate, ρ = time preference rate, $\hat{\phi}$ = degree of liquidity constraints, Y^d = disposable income, σ^2_M = conditional variance of total expenditure measured by its realized value $(\Delta \ln M)^2$, σ^2_C = conditional variance of non-durable consumption measured by its realized value $(\Delta \ln C)^2$, and σ^2_k = conditional variance of durable goods measured by its realized value $(\Delta \ln k)^2$). R^2 is calculated as the generalized R^2 for IV regressions (Pesaran and Smith, 1994). DW = Durbin–Watson statistic. The J-test is a test of overidentifying restrictions (with df = degree of freedom), and the Wald test is χ^2 ($\chi^2_{2.5\%,8}$ =17.53) for the test of the null hypothesis that all the coefficients of $\Delta \ln p_i$ ($i = 1, \ldots, 8$) are set to be zero. Estimation is based on the consumption growth equation (16) using IV regressions.

give different results. Looking at joint estimation results, most non-durables prices turn out to be insignificant for non-durable consumption and durables stock growth. The user cost has a small effect on non-durable consumption and durables stock growth, although it is significant for non-durable consumption growth. The interest rate has a large, though insignificant, effect on non-durable consumption, but it has a wrong sign for durable goods. The liquidity constraint has an insignificant effect on non-durable and durable consumption. However, conditional variance has large and significant effects on both non-durable and durable consumption, with this being especially so for durable consumption.

Our analysis is predicated on the premise that relative prices of non-durable goods play an important role in consumer demand as well as in consumption. To examine this, we conducted a Wald test, which has a χ^2 distribution, for the null hypothesis that all the coefficients for non-durables prices are zero. The p-values show that the null hypothesis is decisively rejected at conventional significance levels, suggesting strong evidence for the relative price effects of non-durable goods in consumption. To further examine the relative price effects of consumption, Table 6 presents the results of estimating total consumption, non-durable consumption, and durables stock growth equations specified in real variables. These results do not account for relative prices of non-durable goods in consumption, and are based on homothetic preferences for non-durable goods with unitary expenditure elasticities, which was rejected (see Table 4). Unlike the nominal specification, the estimated coefficients have different values and signs for the user cost, the interest rate, and the liquidity

Table 6. Estimation results: consumption and durables stock growth equations – real specification (t ratios in parentheses)

Regressors		Non-joint estimation		Joint estimation	
	$\Delta \ln M_{t+1}$	$\Delta \ln C_{t+1}$	$\Delta \ln k_{t+1}$	$\Delta \ln C_{t+1}$	$\Delta \ln k_{t+1}$
Constant	0.256	0.043	0.009	0.115	0.005
	(3.020)	(4.654)	(0.869)	(3.967)	(0.543)
$\Delta \ln r^k_{t+1}$	0.180	–	−0.001	0.053	−0.002
	(3.138)	–	(−0.085)	(2.689)	(−0.240)
$\ln[(1+r_t)/(1+\rho)]$	0.156	−0.074	−0.101	−0.104	−0.093
	(0.831)	(−0.800)	(−3.004)	(−1.087)	(−2.796)
$\ln(1-\hat{\phi}_t)$	−0.366	4.091	0.057	0.327	0.033
	(−1.147)	(5.080)	(1.124)	(1.763)	(0.671)
$\sigma^2_{M_{t+1}}$	3.962	–	–	–	–
	(7.532)	–	–	–	–
$\sigma^2_{C_{t+1}}$	–	0.426	–	4.180	–
	–	(2.220)	–	(6.499)	–
$\sigma^2_{k_{t+1}}$	–	–	8.467	–	9.076
	–	–	(18.891)	–	(18.042)
R^2	0.769	0.699	0.959	0.692	0.956
DW	1.457	1.620	0.821	1.258	0.731
J-test					
χ^2 test statistic	0.106	5.927	0.782	7.813	
Degrees of freedom	1	1	1	2	
p-value	0.745	0.015	0.377	0.020	

Notes: M = total expenditure, C = non-durable consumption, k = durables stock, r^k = user cost of durable goods, r = interest rate, ρ = time preference rate, $\hat{\phi}$ = degree of liquidity constraints, σ^2_M = conditional variance of total expenditure measured by its realized value $(\Delta \ln M)^2$, σ^2_C = conditional variance of non-durable consumption measured by its realized value $(\Delta \ln C)^2$, and σ^2_k = conditional variance of durable goods measured by its realized value $(\Delta \ln k)^2$). R^2 is calculated as the generalized R^2 for IV regressions (Pesaran and Smith, 1994). DW = Durbin–Watson statistic. The J-test is a test of overidentifying restrictions (with df = degree of freedom). Estimation is based on the consumption growth equation (16)) specified in real values by excluding individual prices, using IV regressions.

constraint. This clearly underscores the importance of accounting for the relative price effects of non-durable consumption.

From the above discussion, we find it important to analyze total consumption growth, together with non-durable consumption and durables stock growths, in order to fully understand the consumer's intertemporal consumption behavior. There are, in general, relative price effects in consumption. With the weak evidence of liquidity constraints (see Table 2), we find that liquidity constraints do not have an important influence for Norwegian consumption. However, there is a considerable effect of uncertainty on non-durable and durable consumption. Although there is more uncertainty found in non-durable consumption than in durable consumption (see Table 1, with a discussion in Section 2.1), durable consumption is more sensitive than non-durable consumption to uncertainty. This provides precautionary savings affecting all consumption goods and additional wait-and-see effects for durable consumption (Gudmundsson and Natvik, 2012). Precautionary saving under uncertainty is particularly relevant in times of economic weakness, as is observed during the COVID-19 pandemic that began at the end of 2019; see Smith (2020) for evidence in the United States.

It is, however, important to note that the EIS for total consumption, as well as non-durable consumption and durable goods, is low and insignificant. This is not unexpected and is consistent with the assertion by Hall (1988), according to which non-durable consumption growth is completely insensitive to changes in interest rates. Hence, the EIS is very close to zero. Kaplan and Violante (2018) also argue that the EIS is very close to zero because changes in the interest rate do not have much effect on the consumption of hand-to-mouth, poor and rich, consumers representing a sizable portion of the population (Kaplan et al., 2014). Almost all studies of intertemporal substitution in consumption are based on the use of non-durable goods and exclude durable goods. The evidence is mixed, but most estimates in previous studies are, by and large, much larger than zero; see Havranek (2015) and Thimme (2017) for surveys. The absence of intertemporal substitution that we find for durable goods is rather surprising, because durable goods are widely considered to be very sensitive to changes in the interest rate. While this might be true for large durable good items, such as automobiles or housing, it might not be the case for most other durable good items. For these goods, the interest rate might not be an important factor determining the consumer's purchase decision. Further, housing is excluded in durable goods in our database, Eurostat.

Importantly, however, the EIS measures the response of consumption growth to temporary changes in the interest rate.[21] The negligible value of this elasticity is largely attributed to a lack of sufficient intertemporal variations, or year-to-year temporary fluctuations in the interest rate (see Table 1). To the extent that this lack of variation can be interpreted as some evidence for the presence of permanent changes in the interest rate, the absence of intertemporal substitution in non-durable consumption and durable goods is expected. This is because the interest rate changes infrequently and its change can be perceived as permanent by consumers, in the sense that it will last for

[21] Best et al. (2020) use mortgage notches in Britain as a measure of the interest rate to estimate the EIS. To the extent that mortgage notches capture temporary changes in the interest rate, their estimates of the EIS are more reliable.

many periods.[22] This permanent change in the interest rate does not induce an intertemporal substitution effect, but a temporary change that lasts for short periods does (see Section 3.1.4 for a discussion). Then, with no intertemporal substitution effects, the observed fall in non-durable and durable spending subsequent to a rise in the interest rate can be explained by viewing this rise as permanent by consumers, with a negative wealth effect. When we treat consumers as net borrowers, a permanent rise in the interest rate decreases their wealth, thereby causing them to decrease non-durable and durable spending (this is also true for stockholders, because a permanent increase in the interest rate lowers the present discount value of their stocks).

There are studies on consumption behavior for Norwegian consumers (see Online Appendix A for a literature review). They estimate consumption functions by including income, wealth, the interest rate, and other variables. It is well known, however, that estimation of a consumption function suffers from some fundamental problems (Hall, 1978), and the Euler equation is a common framework in modern analysis of consumption (see Section 3.1.4), which is adopted in our study. Although studies on Norwegian consumption fail to allow for many relevant issues examined in our analysis, there are studies accounting for uncertainty for Norwegian consumers (Gudmundsson and Natvik, 2012; Jansen, 2015; Fagereng and Halvorsen, 2016). Notably, Gudmundsson and Natvik (2012) employed a structural VAR framework with two different measures of uncertainty: volatility indices from financial markets and the frequency with which economic uncertainty is mentioned in the Norwegian press. They found a considerable response to uncertainty of non-durable and, in particular, durable consumption. This is certainly consistent with our finding about uncertainty. Andersen et al. (2016) contended that stricter credit conditions and household's precautionary behavior have been the dominant causes of stagnant consumption growth in Norway since 2008. This is also compatible, although not strongly, with our analysis, because stricter credit conditions imply tighter liquidity constraints, which lead to reduced current consumption, together with precautionary saving. Aastveit et al. (2020) examined the effects of debit card transactions on consumption for Norwegian households, and found that pandemic-induced uncertainty greatly reduced their consumption. The reduced consumption is likely accompanied by an increase in savings. Although we have found no formal study in Norway for this possibility (see Smith, 2020 for evidence in the US), a Google search for Norway, indeed, reveals that "savings in equity funds in Norway more than doubled since the start of the pandemic". This is, of course, what is expected from our analysis of uncertainty.

[22] Although changes in the interest rate are temporary, insofar as they are persistent, such changes can be viewed as permanent by consumers.

5. Summary and conclusion

While there are many studies on consumer demand and consumption, they are conventionally conducted independently of each other. The tenor of this study is that the consumer's intratemporal and intertemporal consumption decisions cannot be separated, and, hence, consumer demand and consumption cannot be studied in isolation. To address this point, we have presented and estimated an integrated model of consumer behavior for Norwegian consumers for 1978–2018, with allowance for durable goods and liquidity constraints. We find that traditional demand analyses ignoring durable goods lead to a significant bias in the elasticities of non-durable goods. Although most non-durable goods, including health services, are necessities, alcoholic beverages, tobacco and narcotics, and clothing and footwear are found to be income-elastic. Durable goods are also found to be necessities and price-inelastic, like most non-durable goods. Norwegian consumers are, in general, impatient, with high time preference for present consumption relative to the risk-free interest rate. They are not risk-averse and have been less risk-averse over time. There is weak evidence for liquidity constraints, which have no important influence on consumption. No strong evidence exists for intertemporal substitution in the consumption of non-durable and durable goods. However, there is a considerable effect of uncertainty on non-durable consumption and, particularly, durable goods, inducing an increase in precautionary saving with reduced consumption, as is observed during the recent COVID-19 pandemic.

These results are informative to understand Norwegian consumer behavior relative to previous studies. However, to draw firm conclusions about consumer demand and consumption, more empirical work might be in order, with a possibly refined empirical model and better use of the data. In particular, we have used eight non-durable goods with the aim to offer more detailed information about the characteristics and properties of the goods. We could use fewer non-durable goods, but then the information would be more limited.

Although we have analyzed the consumer behavior of Norwegian consumers, the proposed model is general enough to apply it to investigate consumer behavior in other countries as well. Most importantly, our analysis indicates the relevance of the integrated model of consumer behavior that can be exploited to improve traditional micro studies on consumer demand, as well as macro studies on consumption/saving.

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Supporting information

Additional supporting information can be found online in the supporting information section at the end of the article.

Online appendices
Replication files

References

Aastveit, K. A., Fastvo, T. M., Granziera, E. A., Paulsen, K. S., and Torstensen, K. N. (2020), Nowcasting Norwegian household consumption with debit card transaction data, Norges Bank Research Working Paper 17/2020.

Acemoglu, D., Finkelstein, A., and Notowidigdo, M. J. (2013), Income and Health spending: evidence from oil price shocks, *Review of Economics and Statistics 95*, 1079–1095.

Alessie, R., Devereux, M. P., and Weber, G. (1997), Intertemporal consumption, durables, and liquidity constraints: a cohort analysis, *European Economic Review 41*, 37–59.

Andersen, H., Husabø, E., and Walle, M. A. (2016), *Hva Påvirker Husholdningenes Etterspørsel Etter Varer og Tjenester?*, Norges Bank Staff Memo 2016/4, Oslo.

Arrow, K. (1965), The theory of risk aversion, in *Aspects of the Theory of Risk-Bearing*, Yrjö Jansson Foundation, Helsinki, 28–44.

Ballie, R. T. and Bollerslev, T. (1992), Prediction in dynamic models with time-dependent conditional variances, *Journal of Econometrics 52*, 91–113.

Banks, J., Blundell, R., and Lewbel, A. (1997), Quadratic Engel curves and consumer demand, *Review of Economics and Statistics 79*, 527–539.

Best, M. C., Cloyne, J. S., Ilzetzki, E., and Kleven, H. J. (2020), Estimating the elasticity of intertemporal substitution using mortgage notches, *Review of Economic Studies 87*, 676–690.

Blundell, R., Browning, M., and Meghir. C. (1994), Consumer demand and the life-cycle allocation of household expenditures, *Review of Economic Studies 61*, 57–80.

Casselli, F. and Feyrer. J. (2007), The marginal product of capital, *Quarterly Journal of Economics 122*, 535–568.

Chah, E. Y., Ramey, V. A., and Starr, R. M. (1995), Liquidity constraints and intertemporal consumer optimization: theory and evidence from durable goods, *Journal of Money, Credit, and Banking 27*, 272–287.

Clements, K. W., Si, J., Selvanathan, E. A., and Selvanathan, S. (2020), Demand elasticities for 9 goods in 37 countries, *Applied Economics 52*, 2636–2655.

Cochrane, J. H. (2005), *Asset Pricing*, revised edition, Princeton University Press, Princeton, NJ.

Cooper, R. J. and McLaren, K. R. (1992), An empirically oriented demand system with improved regularity properties, *Canadian Journal of Economics 25*, 652–668.

Cooper, R. J. and McLaren, K. R. (1996), A System of demand equations satisfying effectively global regularity conditions, *Review of Economics and Statistics 78*, 359–364.

Cranfield, J. A. L., Preckel P. V., Eales J., and Hertel, T. W. (2000), On the estimation of an “implicitly additive demand system”, *Applied Economics 32*, 1907–1915.

Deaton, A. and Muellbauer, J. (1980a), *Economics and Consumer Behavior*, Cambridge University Press, Cambridge.

Deaton, A. and Muellbauer, J. (1980b), An almost ideal demand system, *American Economic Review 70* (3), 312–326.

Deschamps, R. (1973), Risk aversion and demand functions, *Econometrica 41*, 455–465.

Dynan, K. E. (1993), How prudent are consumers?, *Journal of Political Economy 101*, 1104–1113.

Epstein, L. G. and Zin, S. E. (1991), Substitution, risk aversion and the temporal behavior of consumption and asset return: an empirical analysis, *Journal of Political Economy 99*, 263–286.

Fagereng, A. and Halvorsen, E. (2016), Debt and household consumption responses, Norges Bank Staff memo, 2016/1, Oslo.

Fagereng, A. and Halvorsen, E. (2017), Imputing consumption from Norwegian income and wealth registry data, *Journal of Economic and Social Measurement 42*, 67–100.

Fagereng, A., Holm, M. B., and Natvik, G. J. (2021), MPC heterogeneity and household balance sheets, *American Economic Journal: Macroeconomics 3* (4), 1–54.

Gourinchas, P. O. and Parker, J. A. (2001), The empirical importance of precautionary saving, *American Economic Review 91* (2), 406–412.

Gudmundsson, J. and Natvik, G. J. (2012), That uncertain feeling – how consumption responds to economic uncertainty in Norway, Norges Bank Staff Memo No. 23/2012, Oslo.

Guiso, L. and Paiella, M. (2008), Risk aversion, wealth, and background risk, *Journal of the European Economic Association 6*, 1109–1150.

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. (1988), Intertemporal substitution in consumption, *Journal of Political Economy 96*, 339–357.

Hall, R. E. (2004), Measuring factor adjustment costs, *Quarterly Journal of Economics 119*, 899–927.

Hall, R. E. and Jones, C. (2007), The value of life and the rise in health spending, *Quarterly Journal of Economics 122*, 39–72.

Hansen, L. P. and Singleton, K. J. (1983), Stochastic consumption, risk aversion, and the temporal behavior of asset returns, *Journal of Political Economy 91*, 249–265.

Havranek, T. (2015), Measuring intertemporal substitution: the importance of method choices and selective reporting, *Journal of the European Economic Association 13*, 1180–1204.

Jansen, E. S. (2015), The beak in the macro-consumption function, unpublished presentation for the Ministry of Finance, Statistics Norway, Oslo.

Kaplan, G. and Violante, G. L. (2018), Microeconomic hetrogeneity and macroeconomic shocks, *Journal of Economic Perspectives 32* (3), 167–194.

Kaplan, G., Violante, G. L., and Weidner, J. (2014), The wealthy hand-to-mouth, *Brookings Papers on Economic Activity 45* (Spring), 77–153.

Kim, H. Y. (1993), Frisch demand functions and intertemporal substitution in consumption, *Journal of Money, Credit, and Banking 25*, 445–454.

Kim, H. Y. (2017), The permanent income hypothesis, transitional dynamics, and excess sensitivity of consumption, *Structural Change and Economic Dynamics 40*, 10–25.

Kim, H. Y. and McLaren, K. R. (2023), Intertemporal two-stage budgeting: implications for consumer demands and consumption, Working Paper, Western Kentucky University.

Kim, H. Y., McLaren, K. R., and Wong, K. K. G. (2013), Empirical demand systems incorporating intertemporal consumption dynamics, *Empirical Economics 45*, 349–370.

Kim, H. Y., McLaren, K. R., and Wong, K. K. G. (2021), Consumer demand, consumption, and asset pricing: an integrated analysis with intertemporal two-stage budgeting, *Macroeconomic Dynamics 25*, 379–425.

Knotek, E. S. and Kahn, S. (2011), How do households respond to uncertainty shocks?, *Federal Reserve Bank of Kansas City, Economic Review 96* (Q II), 5–34.

Kocherlakota, N. (1996), The equity premium: it's still a puzzle, *Journal of Economic Literature 34*, 42–71.

Landsem, J. (2016), An investigation of the Norwegian consumption function: income distribution and wealth effects, Notater Document 20, Statistics Norway.

Lluch, C. (1973), The extended linear expenditure system, *European Economic Review 4*, 2132.

Ludvigson, S. and Paxson, C. H. (2001), Approximation bias in linearized Euler equations, *Review of Economics and Statistics 83*, 242–256.

McLaren, K. R. and Wong, K. K. G. (2009), Effective global regularity and empirical modelling of direct, inverse, and mixed demand systems, *Canadian Journal of Economics 42*, 749770.

Magnussen, K. and Moum, K. (1992), Is Eilev Jansen wrong all the same?, *Sosialokonomen 46*, 12–18.

Mankiw, N. G. (1985), Consumer durables and the real interest rate, *Review of Economics and Statistics 67*, 353–362.

Mankiw, N. G., Rotemberg, J. J., and Summers, L. H. (1985), Intertemporal substitution in macroeconomics, *Quarterly Journal of Economics 100*, 225–251.

Mehra, R. and Prescott, E. C. (1985), The equity premium: a puzzle, *Journal of Monetary Economics 15*, 145–161.

Moschini, G. and Moro, D. (1994), Autocorrelation specification in singular equation systems, *Economic Letters 46*, 303–309.

Ogaki, M. and Reinhart, C. M. (1998), Measuring intertemporal substitution: the role of durable goods, *Journal of Political Economy 106*, 1078–1098.

Pakoš, M. (2011), Estimating intertemporal and intratemporal substitutions when both income and substitution effects are present: the role of durable goods, *Journal of Business & Economic Statistics 29*, 439–454.

Pesaran, M. H. and Smith, R. J. (1994), A generalized R^2 criterion for regression models estimated by instrumental variables method, *Econometrica 62*, 705–710.

Pratt, J. W. (1964), Risk aversion in the small and in the large, *Econometrica 32*, 122–36.

Smith, A. L. (2020), Why are Americans saving so much of their income?, *Economic Bulletin, Federal Reserve Bank of Kansas City 4* (December), 1–4.

Stock, J. H. and Wright, J. H. (2000), GMM with weak identification, *Econometrica 68*,10551096.

Thimme, J. (2017), Intertemporal substitution in consumption: a literature review, *Journal of Economic Surveys 31*, 226–257.

Wakabayashi, M. and Horioka, C. Y. (2005), Borrowing constraints and consumption behavior in Japan, NBER Working Paper 11560.

Zeldes, S. P. (1989), Consumption and liquidity constraints: an empirical analysis, *Journal of Political Economy 97*, 305–346.

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