Consumer panel data and rational chocie based theories of myopic habit formation: an empirical analysis

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CONSUMER PANEL DATA AND RATIONAL CHOICE BASED THEORIES OF MYOPIC HABIT FORMATION. AN EMPIRICAL ANALYSIS

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1. Introduction

No one doubts the existence of habits. We can observe habits daily in the behaviour. Addictions (i.e., particularly strong habits) cause many social problems. In commercial market research a household's last purchase is used as a predictor for the next purchase, assuming some sort of inertia in consumer behaviour.

There are some theories about the formation and persistence of habits. They usually ascribe three main properties to habits:

- Habits are the stronger the longer they already exists. This is the case, e. g., with old people, who often have habits that seem inappropriate today. But the history of successful practices in the past let the habit persist.
- Habits are the stronger the more frequent the behaviour is repeated. We observe this in everyday life. Habits exist very often with behaviour that is repeated frequently, e. g., having breakfast at eight' o 'clock, eating the same flavour of yogurt, having a cup of coffee at ten, and so on.
- Habits simplify specific actions, economize on resources, and reduce complexity. For example having found once a sufficiently tasty and low-priced yogurt, we will not search for every new purchase the whole market for yogurt again.[1]

These three aspects of habits correspond to the following three questions that a theory of habit formation should be able to answer to provide a satisfying theoretical model.

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1 Carrying on this last point it is often assumed that habits are characterised as unconscious and automatic behaviour, say reflexes. This phenomenon, e. g., is known to every driving learner. While in the beginning, steering, changing gears, and braking takes the whole attention (and sometimes even more), after some practice one is able to do these things automatically (and, e. g., to talk with a passenger simultaneously).

- Under what conditions does a habit develop?
- How does a habit persist?
- Under what conditions is a habit given up?

Especially the first and the last question are of crucial interest. While it is not to difficult to give reasons for the persistence of habits, it is not trivial to determine endogenously how a habit is started, or how it is given up.[2]

Based on these three questions, theories of habit formation roughly can be divided into two classes. One type especially makes use of the first two properties of habits and therefore models the role of time in habit formation. These theories are well suited to answer the first and last question. I call these dynamical theories of habit formation. The other type is based on the third quality presented and therefore considers a habit as a static concept.[3]

In this article I will deal with dynamic theories of habit formation for the following reasons: First, it is obvious to analyse habits as dynamic phenomena. Second, it can be shown that static theories have great problems in explaining habit formation in a theoretically consistent way.[4] Third, consumer panel data are very well suited for the empirical test of dynamic habit formation theories.

Hence, the goal of this analysis is to test empirically the basic conclusions of dynamic habit formation theories.

2. Theory: Dynamic models of habit formation

Dynamic theories of habit formation may be classified into two types. One is grounded in psychological research about behaviour in time.[5] I will be concentrate on the other type of habit formation theory, the Rational Choice Models. The latter are based on neoclassical economics. In short their common assumptions can be described as follows: Actors

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2 The reader may have noticed that classical behaviouristic learning theories are occupied exactly with the same three questions. This is not accidentally for these theories can be looked upon as theories of habit formation, too. (see below and especially footnote 5).

3 An example are framing theories as presented by Esser (1990).

4 See, e.g., Etzrodt (2000).

5 The best known example of theses theories is the so called matching-law (see e.g. Loewenstein and Elster, 1992).

maximize their utility under the given restrictions.[6] To model habit formation according to these principles specific elements are introduced into the utility function.

2.1 Rational choice models of myopic habit formation

Several authors present models of rational habit formation. Most of them are very sophisticated models (see e. g. Muellbauer 1988, Orphanides and Zervos 1998, Spinnewyn 1976) and draw on advanced mathematical analysis. I will not introduce these models in detail, because their formal analyses do not add much. Instead we will just present the basic elements of the models.

Dynamic models, and therefore also models of rational habit formation make two main assumptions. The strength of a habit is determined by (a) its frequency and (b) its duration.[7]

In order to define the relation between frequency and duration and their respective effects on habit formation it is assumed that all specific actions (like eating yogurt, spending vacancies in a special place, driving a car etc.) build up a capital stock. Hence this stock becomes bigger the more often the action has been repeated, and the longer the habit persists. In order to take into account the frequency of habit-repetition the habit stock is discounted with the time lag between two consecutive habitual actions. This aspect is based on the following argument: The larger the time interval since the habitual action has occurred for the last time, the smaller is its effect on the present action. In fact the habit stock is modelled analogous to an investment stock that is depreciated, and refreshed by new investments. Formally this can be put as follows:

$$\dot{S}(t) = -\tau S(t) + c(t) \qquad \text{with } S(0) = 0) \quad (1)$$

where $S(t)$ is the habit stock at time t, $c(t)$ is consumption of a habitual good at time t, and τ is the depreciation rate of the habit stock. This habit stock is introduced into a standard economic utility function as follows: If U_c denotes marginal utility with respect to *c* then

$$U_c = f(p_c, c, y, S_c) \quad (2)$$

6 I will not point out the theory. Because the crucial points for our analysis can easily be caught by intuition. For an introduction see e. g. Becker (1976).

7 ctually there is no need to explain these assumptions in detail. If we look at the model as an as-if explanation any assumption can be made as long as the resulting hypothesis prove to be empirically correct. In addition the assumptions seem very plausible. Yet if we like these assumption can be grounded on e. g. neurophysiological and psychological theories (see e. g. Leshner (1997)).

This means that the marginal utility is a function of the consumption c, the relative price p_c, the income y, and of the habit stock S_c.

We neglect a further formal discussion of the utility function and assumptions, but rely exclusively on an intuitive interpretation which will be accessible to most readers. [8]Formal analysis yields, among other things, the following implications: To consume more of a distinct good is always better than to consume less. An increase of the relative price decreases the amount of consumption, while an increase of income will raise consumption. Of course, these statements are standard in economic consumer theory.

The crucial relationship that is to be tested empirically here reads as follows: An increase of the habit stock for a distinct good raises consumption of that good.[9]

In the foolowing we speak of myopic habits because the actor just takes into account his past actions (i.e., consumption acts). He is myopic - not looking into the future - and does not calculate the future effects of his present behaviour. If he would act with taking into account the future effects of current behaviour, we would speak of a fully rational actor and therefore of a fully rational model of habit formation. Then the utility function would contain the future consumption and future price or its expectation of the actor. This extended version of rational habit formation is not analysed here. We restrict our attention to the model to the myopic maximizing actor.

For the interpretation of the model the following aspects are of particular importance:

- The habit stock can be interpreted as an endogenous change of preferences in time.[10]
- The rationality of the model is defined by the maximizing behaviour of the actor, i. e., the household makes choices *as if* he would maximize its consumption. This is the crucial difference to other models of habit formation (especially static models) which assume that habitual actors do not chose or maximize anything but just repeat past behaviour.

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8 The problem here is one of dynamical maximization under the given restriction with respect to the consumption. For a broader and exact discussion see, for example, Becker and Murphy (1988)

9 By that it is not stated that there are no other influences on the actors utility. Of course there are, but first the above stated relations are used routinely in utility theory, second their theoretical effect is clear, undoubted and very well confirmed, third these variables are all easy to measure and included in the used data sample and fourth the model is kept easy to survey in order to determine exactly the effects of habit.

10 But note that this is not necessary. Becker (see e. g. 1996) does not interpret habits as a change in preferences. Nevertheless this interpretation neither changes anything in the formal treatment nor in the empirical results.

- Therefore the above theoretical model can answer all three questions that were presented in the introduction as desiderata of any habit formation theory. Any actor forms a habit and therefore changes his preferences, as soon as he has chosen the same action more than once. Of course this is the case with almost every action. Therefore habits are an important factor in the formation of preferences. The habit will be maintained as long as the changes in the restrictions, i. e. relative price increases and decreases of income do not outweigh the additional utility by the habit. Therefore a habit will be given up if the increase in relative price of an action and/or the decrease in income is larger than the additional utility from maintaining the action.

- This provides us with a theoretically grounded relation between past and present actions or consumption acts. One may object that there is no need to produce a complicated theoretical model, just to state the more or less trivial assumption that the present action is somehow dependent on the past. This is not correct for the following reasons:

The first counterargument refers to the formulation of "somehow". In contrast to a purely exploratory procedure, which is often pursued in commercial market research, an explicitly formulated theoretical model provides us with several instruments to forecast future behaviour. The use of standard economic utility theory allows us, e. g., to calculate stock elasticities of demand, which are powerful instruments for predicting future market developments.[11] Second, from a scientific point of view, it is preferable to specify precisely how time works on habit formation and to embed this into an explicit action theory, instead of just stating some relation between past and present action.[12] Third, consumer panel research provides us with very rich data. To make use of this amount of information it seems meaningful to use an appropriate theory.

To test the theory we state the following testable hypotheses:

H_1: The more often a habitual action is chosen and the longer this habit already persist, i. e., the higher the habit stock S, the higher will be the chosen quantity of consumption c.

This is our main hypothesis. The following two hypothesis are well confirmed hypotheses of classic economic demand theory. Actually, they are just used to control for these standard variables.

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11 We will analyse this procedure further on in the empirical section.

12 Besides, very often in time series analysis this point is also neglected and theory building is replaced by pure empirical work.

H_2: The higher the relative price of consumption c, the smaller will be the chosen quantity of c.

H_3: The higher the income y, the higher will be the chosen quantity of action c.

In the next section the hypotheses are put to a test.

3. Data, Analysis, Results

3.1 Data

In using the available ZUMA data set of the GfK consumer panel data we take those variables that are most exactly measured and provide information on a true interval level. This is the amount of a commodity purchased, its price, the time periods between two consecutive purchases, and the self-estimated income. Therefore, validity and reliability of the data are hardly in question.

3.2 Operationalization

The theory of habit formation is formulated above in a general form, so that it includes all sorts of consumptions and costs. To test the theory we have to define a specific set of the variables.

The actor is one household or, more precisely, the person in the household which makes the household purchases. However the habit to be analysed actually is one of a household and not of a single actor. If one wants to avoid this assumption one could select just one-person-households, where actor and household coincide. Yet a short test has shown that these estimation do not differ from those using all the households. We will assume that the whole amount of the good will be consumed between two consecutive purchases in time. This means that there is no storage of the good and no giving away. Furthermore we assume that the whole amount of the good is consumed on the day it is purchased. In the absence of further information about the exact consumption pattern this seems to be an adequate approximation.[13]

13 This operationalization of actor and action follows from the assumption that the consumption of a good is the benefiting action. If one wants to avoid this assumptions without any theoretical changes the benefit of the action can be ascribed to the purchase of a good, and not the consumption. For commercial market research this seems even more appropriate, because there the explanandum is the purchase and not the consumption.

As equation (1) shows, it is necessary to determine a depreciation factor τ to calculate the habit stock. In the absence of empirical knowledge and of empirical knowledge and theoretical guidelines we have to rely on some plausible guesses to determine the size of τ.

Estimations are done with five different factors corresponding to a half-life period of the habit stock of one day, one week, one month, half a year and one year. A half-period of a week means that after one week the habit stock has diminished to the half and so has its habit-generating effect. Common sense tells us that the true value of τ probably will lie between a half-life period of a week and half a year. A half-life period of a day or year represent the outer bounds of τ which probably will not be crossed.

At last we have to choose distinct products out of the list of all possible goods provided by the panel. Due to reasons of practicability not all possible products can be taken for estimation. Three products are chosen, namely yogurt, roasted coffee, and beer[14]. By choosing these three products we try to cover another property of habits that has not been mentioned yet, but is obvious: Not every good or action forms habit of the same strength. Of course we will expect beer, or the alcohol in it, to generate stronger habits, or even addiction, than yogurt. For coffee, respectively caffeine, we would expect a habit strength in between the habit strength of those two commodities. Note that all three commodities can be expected to be purchased frequently. This aspect is important because the observation period is limited to one year. Because we expect the habit to stem from repeated consumption, it is necessary to observe as much purchases as possible to estimate the habitual effect of it.

3.3 Functional specification

To estimate empirically the functional specification must be determined. As it is often the case there are only few theoretical guidelines about the functional specification of the estimation equation. However theory (e.g. Becker and Murphy 1988) tells us that there is a linear relation between the size of the stock and the amount of the good consumed. We will choose a logarithmic specification for price and income for the following reasons. First, this is the function routinely chosen in econometrics and has been proven to be a good estimator in most cases. Secondly, it seems plausible that not absolute values of price and income have the strongest effect on consumption but differences. Third, at least distributions of price of yogurt and coffee are slightly right hand skewed and therefore will better fit the assumptions of OLS-estimation when a logarithmic transformation is used. The same argument holds for income. Moreover, metric income is calculated by

14 Corresponding to the product categories number 12 (coffee), 33 (beer) and 78 (yogurt).

replacing ordinal group numbers by the means of the group range. Hence the last group is an open category and the respective mean tend to underestimate the true values and distorts the OLS-regression. By raising the income to the logarithm this distortion is diminished. And fourth, estimating the logarithmic specification will generate directly the respective elasticities of demand that are very useful for interpretation.

This leads to the following estimating equation:

$$c = e^{\alpha + \beta S_c} p_c^{\gamma} y^{\delta} \qquad (4)$$

or in the linearized transformation

$$\ln(c) = \alpha + \beta S_c + \gamma \ln(p_c) + \delta \ln(y) \qquad (5)$$

This last expresion can directly be estimated with standard OLS-estimation.

3.4 Results

To show the effect of the habit stock S_c the model is estimated in two steps. In the first step we just estimate a bivariate regression with c and S_c, i. e., e following equation

$$\ln(c) = \alpha + \beta S_c \qquad (6)$$

As table 1 shows, the main hypothesis (H_1) is confirmed. The habit stock has a positive effect on the quantity consumed independently of the good and of the discount factor τ (i.e., the corresponding half-life period)[15].

Moreover the coefficients are fairly robust, no matter which depreciation rate is chosen.

Therefore the depreciation rate can be considered as a multiplying factor, which does not change the relative weights in the regression.

Besides, one month seems to be the best approximation for all three commodities for the half-life period of the habit stock.

By estimating equation (4) we take hypothesis (H_2) and (H_3) into account and control this relationship for price and income. This yields the following results (see table 2a to 2c).

15 The depreciation factors corresponding to a half-life period of one day and one year are not presented in order to keep the tables easy to survey and because, as expected, they generate the worst results.

Table 1: OLS-regression to logarithmic quantity of consumed good (for beer, coffee and yogurt) on habit stock for depreciation factors corresponding to the half-life periods of habit stock of one week, one month and half a year.

	half-life period	b	std. error	t-value	R^2	n[16]
Beer	one week	$2.241\ 10^{-5}$	$3.102\ 10^{-7}$	72.2	0.043	117153
	one month	$8.084\ 10^{-6}$	$7.962\ 10^{-8}$	101.5	0.077	123601
	half a year	$2.002\ 10^{-6}$	$2.164\ 10^{-8}$	92.5	0.064	123760
Coffee	one week	$1.630\ 10^{-4}$	$2.620\ 10^{-6}$	62.2	0.03	127058
	one month	$6.461\ 10^{-5}$	$8.739\ 10^{-7}$	73.9	0.04	134624
	half a year	$1.799\ 10^{-5}$	$2.486\ 10^{-7}$	72,4	0.037	134737
Yogurt	one week	$1.315\ 10^{-4}$	$1.492\ 10^{-6}$	88,2	0.065	112603
	one month	$4.482\ 10^{-5}$	$4.101\ 10^{-7}$	109,3	0.094	115196
	half a year	$1.179\ 10^{-5}$	$1.215\ 10^{-7}$	97.1	0.076	115241

Again all three hypothesis can be fully confirmed. Independently of the specification, all variables show always the correct sign. Higher habit stocks still lead to increased demand for the good. The standardised coefficients are slightly decreased by the additional variables but show about the same size. As expected, higher income raises the demand for the good, while higher prices reduce demand. Estimators for price and income are also robust and not affected by changes in the depreciation rate. One month still seems to be the appropriate half-life period of the habit stock.

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16 The number of cases is slightly changing for the different depreciation rates. This stems from the following estimation procedure: All cases that have a habit stock equalling zero are excluded from the estimation.The reason is simple: If we accept the most probable assumption that in each household the product has been consumed already once before the observation period (1995) a stock value of zero is in any case a wrong estimator, because the stock cannot become zero once it was higher. And there is an additional problem. Rounding procedures of the computing program (SPSS) now lead to zero values of the habit stock when this is actually not the case. Imagine for example a household that consumes one bottle of beer on January first 1995 and one bottle on New Year's Eve 1995. Then the habit stock of beer for this specific household is zero for all depreciation rates on January first, because of the lack of past observation to calculate a stock. Assuming a half-life period of a week at New Year's Eve the beer stock will be approximately zero (to be exact 0.5^{52}). Even for a half-life period of a month the stock will hardly differ from zero ($S=0.5^{12}$), but for a half-life period of a half year the stock will be 0.25.
Taking zero-values to into the estimation does not alter the parameters of the regression except for a smaller explained variance (see also section 3.5 for the problem).

Table 2a: OLS-regression of logarithmic quantity of consumed beer for depreciation factors corresponding to the half-life periods of habit stock of one week, one month and half a year on the habit stock, logarithmic price and the logarithmic income.

Beer	half-life period	std. b	std. error	t-value	adj. R^2	N
habit stock S		0.118	$3.880\ 10^{-7}$	48.0	0.094	60720
price p	one week	-0.195	0.014	-35.0	0.094	60720
income y		0.195	0.009	51.9	0.094	60720
habit stock S		0.243	9.870 10-8	65.1	0.119	63984
price p	one month	-0.118	0.0136	-31.5	0.119	63984
income y		0.202	0.008	54.2	0.119	63984
habit stock S		0.217	$2.616\ 10^{-8}$	57.9	0,107	64077
price p	half a year	-0.125	0.014	-33.4	0,107	64077
income y		0.204	0.008	54.5	0,107	64077

Table 2b: OLS-regression of logarithmic quantity of consumed coffee for depreciation factors corresponding to the half-life periods of habit stock of one week, one month and half a year on the habit stock, logarithmic price and the logarithmic income.

Coffee	half-life period	std. b	std error	t-value	adj. R^2	N
habit stock S		0.152	$3.664\ 10^{-6}$	40.6	0,105	64713
price p	one week	-0.273	0.010	73.4	0,105	64713
income y		0.054	0.004	14.6	0,105	64713
habit stock S		0.160	$1.260\ 10^{-6}$	44.1	0.111	68581
price p	one month	-0.270	0.010	-74.5	0.111	68581
income y		0.053	0.004	14.7	0.111	68581
habit stock S		0.137	$3.644\ 10^{-7}$	37.1	0.103	68637
price p	half a year	-0.260	0.010	-70.8	0.103	68637
income y		0.056	0.004	15.5	0.103	68637

Table 2c: OLS-regression of logarithmic quantity of consumed yogurt for depreciation factors corresponding to the half-life periods of habit stock of one week, one month and half a year on the habit stock, logarithmic price and the logarithmic income. [17]

Yogurt	half-life period	std. b	std. error	t-value	adj. R^2	N
habit stock S	one week	0.255	$1.471\ 10^{-6}$	89.7	0,091	112603
price p		-0.162	0.006	-57.0	0,091	112603
habit stock S	one month	0.303	$4.049\ 10^{-7}$	109.3	0.117	115196
price p		-0.152	0.005	-55.1	0.117	115196
habit stock S	half a year	0.271	$1.200\ 10^{-7}$	96.8	0,099	115241
price p		-0.153	0.005	-54.6	0,099	115241

Just looking at the best estimation, we see that for explaining the chosen quantity of c the habit stock statistically is at least as important as is price. Nevertheless we should not stress this fact to much. The reason is the small variance of price especially for beer and yogurt. For these two commodities prices are about the same for a wide range of different brands. By raising the price to logarithm we even reduces range. This could be a reason for the relatively small proportion of explained variance by beer and yogurt prices. This view is confirmed by the estimation of the demand for coffee. There, the price range is much bigger and so a greater proportion of variance is explained by price.[18]

Yet standardised b is a difficult to interpret measure for the effect of habits on demand. But we can calculate the respective elasticities of demand for all three explaining variables. Because we used the double-logarithmic functional specification for price and income the respective elasticities of demand just correspond to the unstandardised b coefficients. For the habit stock we applied a logarithmic-linear functional specification

17 The variable "income" is not available for all households in the consumer panel. And it is totally missing yogirt and partly for beer and coffee. Hence for yogurt the estimation had to be done without the variable. Due to missing income data the number of cases for the analysis of beer and coffee consumption is greatly reduced.

18 A test with alcoholic beverages ("spirits") for which price vary in a wide range also confirms this explanation. Though no one would doubt the strongly addictive character of alcoholic beverages, most of the demand is explained not by the habit stock but by the price of spirits.

so that the elasticity is not constant for every size of the stock. As a consequence elasticity increases linear with habit stock and so does the reaction of the actor to changes in the stock. [19]

For matters of simplicity the results are just shown for the half-life period of the habit stock of one month (see table 3a to 3c).

Table 3a: Elasticities of beer demand for habit stock, price and income (half life period of one month).

Beer	mean	median	Mode
habit stock S	0.206	0.144	0.064
price p	-0.428	-0.428	-0.428
income y	0.453	0.453	0.453

Table 3b: Elasticities of coffee demand for habit stock, price and income (half life period of one month).

Coffee	mean	median	Mode
habit stock S	0.100	0.056	0.028
price p	-0.74	-0.74	-0.74
income y	0.055	0.055	0.055

Table 3c: Elasticities of yogurt demand for habit stock, price and income (half life period of one month).

Yogurt	mean	median	Mode
Habit stock S	0.218	0.155	0.013
Price p	-0.297	-0.297	-0.297

19 The elasticity is defined as follows: $\varepsilon = \beta S$ (see e. g. Braun, et al 2001).

For the chosen functional specification the respective elasticities of demand for price and income are constants. For all three commodities price and income elasticity of demand is below unity. In standard economic terms this is called inelastic demand and the goods are necessary goods. Nevertheless, again one should be careful with overinterpreting this results. First, as stated above, the variance of the price for beer and yogurt is very small. Therefore the reaction of demand on price variety is confined to a small range which leads to underestimation of price elasticity. Second, we did not spend to much effort on finding the true functional specification. Though we have good reason to choose a double logarithmic, this is not necessarily the true specification. Further analysis eventually would lead to different functional specifications and hence to different elasticities. The same argument is true for income elasticity.

The opposite situation is given for the stock demand elasticity of demand. There, variance is very high, and we have theoretical reasons for the chosen logarithmic-linear functional specification. Hence we can conclude the following: The habit stock elasticity of demand for beer is a linear increasing function with an extremely flat slope of $6.423\ 10^{-6}$ (coffee: $5.555\ 10^{-5}$, yogurt: $4.427\ 10^{-5}$).[20]

The habit stock elasticities of demand of all there goods are fairly small and lie distinctly below price elasticity of demand. This can be interpreted as follows: The habits of consuming beer, coffee and yogurt seem to be just slightly addictive. A one percent increase of the stock[21] generates an increase of demand in the next period of 0.084% (coffee) to 0.16% (yogurt). For heavy consumers this rate increases linearly in their respective stock. This means that frequent consumption for a long time leads to stronger habits. But as we would expect it, habits turn out to be fairly persistent, too. Splitting the stock into two halves after one month reduces demand just about 8% for yogurt (beer: 6.8%, coffee: 4.2%). We could therefore conclude that yogurt is the least addictive good, while coffee (in contrary to what we expected) is the most addictive of the three goods.[22]

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20 Again this numeric results are almost the same if we use another half-life period of stock.

21 Translating this to the measures of everyday life yields the following results: For an average consumer (measured at the median level of the habit stocks) the consumption of a bottle of beer, (cup of coffee, a cup of yogurt), leads to an increase of demand in the next period of about 0.3% (0.14%, 0.8%). Note that the "ranking" of the three commodities is different from ranking of the elasticities. This happens because elasticities are unit free measures, while the above numbers reflect the unit of measurement of the respective commodity (i.e., centiliter for beer and gram for coffee and yogurt).

22 All these statements are actually just true for the so called steady state. This state is reached when the system is in the equilibrium again after the disturbance of one or more parameter. This means that the actor will exactly consume the amount of a commodity that has been depreciated. Hence his habit stock will not change anymore. This steady state can - by definition - just be reached asymptotically.

3.5 A note on autocorrelation

One problem with estimating time-dependent equations is the appearance of autocorrelation. This leads to distorted estimators which are no longer efficient. Especially standard errors would be too small and hence, e. g., the adjusted determination coefficient too large. One may wonder if autocorrelation characterises the above estimations, especially when keeping in mind the very high t-values. To answer this question we first have to determine the structure of the model. Though we take time into account, it is not a time series model. Remember that information about time is used just for the calculation of the habit stock. Hence we use a true cross-section model where each consumption c at any point in time t is explained by its corresponding habit stock S_c. Note the difference between our estimation model and the often used so-called autoregressive model which regresses consumption c_t on the preceding consumption c_{t-1} (say: $c_t = \alpha + \beta c_{t-1}$) without further theoretical modelling of the relation between time and chosen action. Such models suffer usually from a high degree of autocorrelation (and hence of the above described distortion in standard errors).[23]

A test (Durbin-Watson d statistic) shows a rather high degree of autocorrelation in our model. This means that we can not be sure about the efficiency of the equation estimators. However, what could cause autocorrelation in the model? To answer this question we have to reanalyse the structure of the predicting variables: Recall that all cases with a habit stock value of zero were excluded. The latter because this values are certainly bad predictors for any habit. The same argument holds for the respective consecutive habit stocks. Habit stocks with a short past are worse estimators than those with a long past. Assuming that habit stocks with a short past will be on average smaller than those with a long past, this will generate a bias between the size of the habit stock and the respective residuals will become smaller on average, the bigger the habit stock is.[24] However, an even higher degree of autocorrelation is discovered in the price residuals. This may stem from the rather low variance in prices. If we assume in addition also some habit of choosing the same prices, this may explain also the halo effect in prices (and generate autocorrelation in the respective residuals).

Fortunately, we don't have to stress these points too much. The tremendous number of cases allows us to test the validity of the estimations with a simple procedure. For that

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23 Note that this autocorrelation (or serial correlation, how it is often called then) is NOT indicated by the common measure for autocorrelation Durbin-Watson d statistic (see e. g. Gujarati 1995). Instead the Durbin-Watson h test should be used. This is difficult because this test is not done by most statistical programs.

24 I owe this idea to Martin Abraham.

purpose we select just the last case of every actor - respectively household - in the sample. There the habit stock will be the best predictor available for the respective consumption because it has the longest past. This procedure reduces the number of cases to the number of households in the sample. But note that we do not loose information about consumption history of the households because that is taken into account by the habit stocks.

This procedure yields the following results (see table 4).

Table 4: OLS-regression of logarithmic quantity of consumed good and price (for beer, coffee and yogurt) on habit stock, for depreciation factors corresponding to the half-life periods of habit stock of one month, just using the last case of every household.

		std. b	std. error	t-value
Beer	habit stock S	0.293	$6.912\ 10^{-7}$	18.7
	price p	-0.097	0.062	-6.0
	income y	0.18	0.034	11,3
	adj. R^2 = 0.145	Durbin-Watson d = 2.004	n = 3429	
Coffee	habit stock S	0.173	$6.319\ 10^{-6}$	11.6
	price p	-0.238	0.043	-16.0
	income y	0.080	0.018	5.3
	adj. R^2 = 0.105	Durbin-Watson d = 1.997	n = 4124	
Yogurt	habit stock S	0.342	$3.272\ 10^{-6}$	22.7
	price p	-0.13	0.030	-8.6
	adj. R^2 = 0.136	Durbin-Watson d = 2.075	n = 3808	

The Durbin-Watson d statistic shows practically no autocorrelation for these estimations. The signs of the parameters are unchanged and have still the correct directions. The b-parameters are about the same. In fact, the habit stock becomes even a little bit more important in these models. This is not astonishing if we remind us of the fact that these predictors are the best ones available. We can conclude that estimating with the full sample of observed consumption cases does not generate overestimation of model parameters or an artefact. Autocorrelation is not a problem of the model estimation - the results are valid and reliable.

4 Conclusion

The empirical test of myopic models of rational habit formation with consumer panel data shows that this theory seems to be an appropriate model for habit formation and persistence. Its main idea that frequency and duration of a habit determine its strength confirmed. Thereby this theory provides us with a theoretically founded and empirically tested relation between time and habit formation. In addition controlling for prices and income, the robustness of the model shows up. This means that the theory suggests appropriate answers to the question for the formation, persistence and breaking of habits. Additionally it allows us to calculate elasticities of the habit stock on demand. This provides us with a practical instrument for concrete estimation of the strength of habits.

It would be interesting to improve the empirical analysis in several ways. The observation period could be prolonged providing us with more cases that could be supposed to be near the theoretical steady state. For commercial applications it would be necessary to define more subtle habits. For example we did not distinguish between different flavours of yogurt, or different brands of beer. Undoubtedly this would lead to more sophisticated results which could be the base for rational and empirically grounded marketing decisions.

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