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Does the behaviour of myopic addicts support the rational addiction model? A simulation

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Abstract:

Becker and Murphy (1988) constructed, in a well-known paper, a model of rational addiction in which people solve a dynamic optimization problem, choose an optimal timepath of drug consumption and thereby maximize lifetime utility. The model leads to the hypothesis that future consumption is a significant explanatory variable for present consumption.

This paper briefly surveys the empirical studies which provide support for this hypothesis. Most of the authors claim to have found support for the Becker-Murphy model. However, this paper will show that it is possible to obtain qualitatively the same results for the consumption patterns of myopic addicts. To this end, an economy is simulated in which everyone behaves according to Pollak's (1970) paradigmatic alternative to the model of rational addiction

Keywords: rational addiction, instrumental variables

JEL classification: C15, D12, D91

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I. Introduction

Do people maximize lifetime utility, even when (at least) one good is addictive? This is not an easy question to answer, because the consumption of an addictive good, by its very nature, changes either the next period's utility function, or it changes a variable which enters the utility function[1]. More formally, the task is to maximize[2]

$$V = \sum_{t=0}^{T} (1+\sigma)^{-t} \cdot U_t(c_t, y_t, S_t) \qquad (1)$$

where c_t is the consumption of an addictive good in period t, y_t the consumption of a vector of non-addictive goods and S_t the stock of "addictive capital" built up by consuming c in earlier periods. The paper follows the example of Becker and Murphy (1988) in calling those people rational, who are aware of the addictive good's effect, and who succeed in maximizing V. Addictive behaviour, as Becker and Murphy have shown, could be the solution to this dynamic programming problem. More commonly, however, addicts are thought to be myopic. They maximize utility in each period t as if it were their last, or as if drug consumption would not change the next period's utility function.

Quite a few attempts have been made to test the hypothesis that addicts are rational against the hypothesis that they are myopic. Almost all authors make use of a hypothesis which Becker and Murphy derive from their model, namely: c_t depends on the future consumption of the addictive good. This is a unique feature of rational addiction, in the sense that only past events and actions can enter the utility function for myopic addicts. Whereas this is clear in theory, it is empirically difficult to show that changes in c_{t+1} *cause* changes in c_t, as

[1] The latter is not different from a biological point of view; it is just a different formal representation in accordance with Becker and Stigler (1977).

[2] The following is a discrete time variant of the original approach by Becker and Murphy (1988) as used, e.g.,

correlations between these two variables can also be due to the fact that drug consumption in one period might cause drug consumption to increase in the next period, which is a central element of any reasonable model of addiction. And indeed, as will be shown below, any researcher who regresses c_t on c_{t+1} will find a significant impact of the latter in an economy made up entirely of myopic (or backward-looking) drug consumers. Most authors are aware of this problem and try to solve it with an instrumental variable approach: c_t is regressed not on c_{t+1}, but on predicted values of c_{t+1}, with p_{t+1} and sometimes lagged prices and other explanatory variables used as instruments as well. Since p_{t+1} does not depend on c_t[3], the problem of endogeneity should be resolved. This paper aims to examine the simulated economy of myopic individuals in greater detail in order to check whether the instrumental variable approach really solves all problems under all conditions.

II. Myopic individuals

The people who inhabit our simulated economy constitute a special case of myopic maximizers as modelled in Pollak's (1970) well-known paper. Pollak models habit formation in the following way: b_{ct} is the absolutely necessary quantity of the addictive good in period t, determined at least partly by past consumption[4]:

$$b_{ct} = b_c^* + \beta_c \cdot c_{t-1}$$

Pollak discusses various additive utility functions, wherein each good's utility depends on the amount consumed minus the respective b; in the following, we confine ourselves to one

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by Chaloupka (1992).

[3] Keeler et al. (1993, p.15) doubt that this is true, because it is not realistic that the price should not be determined by the process of supply and demand; they argue that, especially in the short run, supply curves can be upward sloping. However, their solution to take use the actual value of c_{t+1} as a regressor is hardly more convincing as a solution to the problem of endogeneity.

[4] The results are not markedly different if x_{it-1} is replaced by a geometrically weighted average of all past consumptions (Pollak 1970, p.750).

special case - essentially a Stone-Geary utility function with two goods and habit formation for one of these:

$$U_t(c_t, y_t) = a_y \cdot (y_t - b^*_{y\,t})^z + a_c \cdot (c_t - \beta_c \cdot c_{t-1})^z$$

with a_y, $a_c \geq 0$, $0 < z < 1$, and the stability condition $ß_c < 1$ being fulfilled. Let w_t denote income in t, p_y the vector of the normal good's price and p_c the addictive good's price. Hence individuals maximize U_t under the budget restriction

$$w_t = y_t \cdot\ p_y + c_t \cdot\ p_c$$

Lifetime utility (1) is, however, not maximized by individuals, as they disregard the effect of c_t on b_{t+1}.

It is assumed that 40 time periods (1, 2..., 40) are observed in our simulated economy, and in each of these, 40 individuals consume the addictive good[5]. However, as individuals are born and die, the composition of the economy gradually changes, and a total of 79 individuals (denoted individual i, with i = 1, 2, ..., 79) are involved. Individual i dies at the end of period i and starts to consume at the beginning of the period (i-39) - for example, individual 79 begins to consume at the beginning of period 40, whereas individual 1 begins to consume at the beginning of period -38 and dies at the end of period 1. In period 1, the addictive good is consumed by individuals 1 to 40, in period 2 by individuals 2 to 41, etc. We do not let the consumption of all individuals start simultaneously in period 1, as all of them would become addicted at the same time, producing an inherent time trend, which would not driven by the independent variables.

If it is assumed that z = 0.5; then each individual's short-run demand function becomes:

[5] Under the assumptions made above, individuals start consuming the addictive good as soon as $w_t > b_y^* \cdot p_y$.

$$c_t = \beta_c \cdot c_{t-1} + \gamma \cdot (w_t - \beta_c \cdot c_{t-1} \cdot p_c - b_y^* \cdot p_y)$$

with

$$\gamma = \frac{a_c^2 \cdot p_y^2}{p_c \cdot a_c^2 \cdot p_y^2 + p_c^2 \cdot a_y^2 \cdot p_y}$$

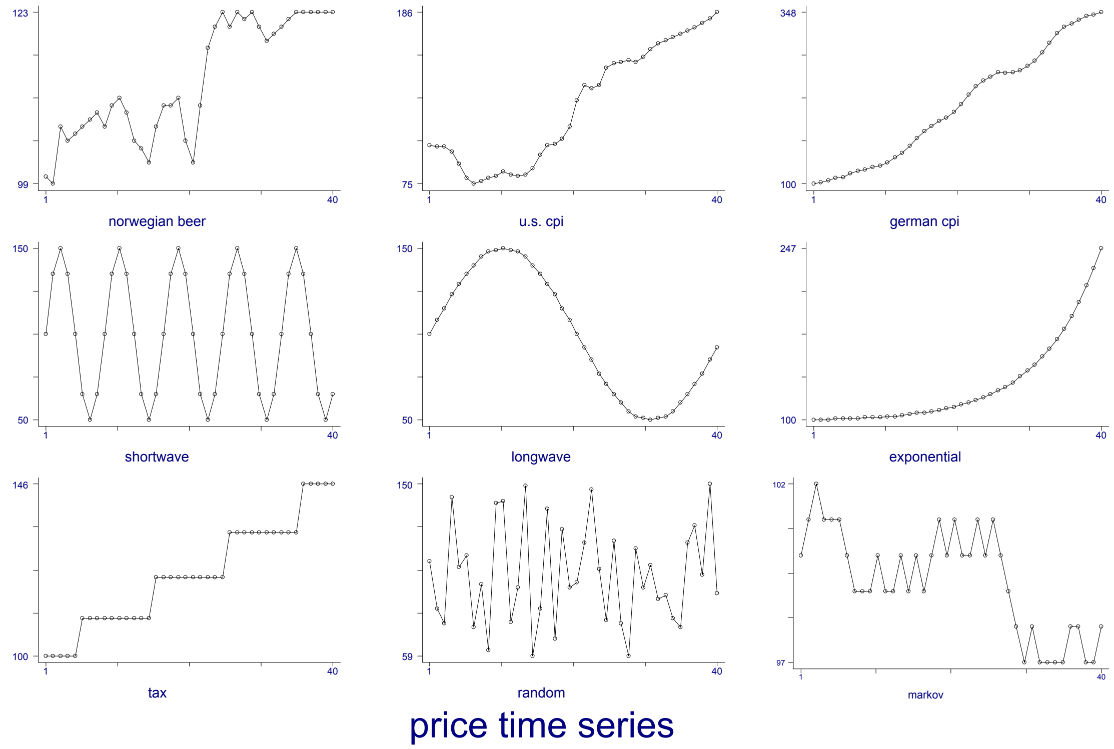
(cf. Pollak, 1970).

The following parameter values are set for the simulation: ß = 0.5; $p_y = 1$; $a_y = 1$; $b_y = 10$; $w = 1000$ in all periods and for all individuals. In order to create some noise, a_c differs between individuals; this parameter is randomly determined, with $0 < a_c \leq 1$. Nine different price time series are tried out (see Figure 1).

The time series are partly artificially generated, and are partly based on real price time series; see the bottom of Table 1 for details.

For each of the time series, the behaviour - and the finally aggregated consumption of the addictive good – of the myopic individuals is generated over 40 periods. The next section reports what happens when previous research methods are applied to these sets of data.

Figure 1: Price time series used for simulation



Norwegian beer: real price index of beer in Norway, 1960-1994, for periods 1 to 35 and remaining at the same level as that in period 35 in periods 36 to 40 (source: Bentzen, Eriksson and Smith, 1999)

U.S. cpi: U.S. consumer price index 1927-1966

German cpi: German consumer price index, 1960-1999

shortwave: price = 100 + 50·sin[45·(t-1)], with t denoting the period

longwave: price = 100 + 50·sin[9·(t-1)]

exponential: price = 99 + exp(t/8)

tax: price remaining constant at 100 until period 5, then a 10% price increase every 10 periods assumed to be induced by tax changes

random: a discrete random variable, with price ~ Un(50,150)

markov: a random walk, starting at 100 at period 1, then adding either 1, 0 or -1, each with probability 1/3, in each period.

III. Previous research methods applied to simulated data

The simplest attempt to test the key prediction of the rational addiction theory is to simply regress c_t on c_{t+1}:

$$c_t = \alpha_0 + \alpha_1 \cdot p_t + \alpha_2 \cdot c_{t-1} + \alpha_3 \cdot c_{t+1} + \; ....etc. \tag{2}$$

The "*etc.*" stands for various specific control variables such as the introduction of health warnings or restrictions on advertising, which are of no interest here. In the above equation, the problem of endogeneity is fairly obvious, as by the very nature of addiction – whether consumers are rational or not – c_{t+1} depends on c_t. Hence most authors who estimate (2) do so only for the purpose of comparison with the more sophisticated approaches described below [Cameron 1999, Fem/Antonelli/Schroeter 2001, Grossman/Chaloupka 1998, Grossman/Chaloupka/Sirtalan 1998, Liu/Liu/Hammitt/Chou 1999]. However, Cameron (1997), Keeler/Hu/Barnett/Manning (1993) and Labeaga (1999), content themselves with the above approach in their studies on cigarette demand, and all of them – not surprisingly – find results which they interpret as support for the rational addiction model. The same results are obtained by estimating (2) for our economy of myopic addicts with any of the eight price time series, see Table 1. For example, taking the price time series "Norwegian beer", equation (2) is estimated as follows[6]:

$$\underset{(1.33)}{C_t = 0.1793} \; - \underset{(-2.84)}{0.0033\, P_t} + \underset{(10.71)}{0.5655\, C_{t-1}} + \underset{(10.06)}{0.5018\, C_{t+1}} \qquad R^2 = 0.9697$$

Hence the results from estimating (2) support both the hypothesis that consumers are myopic and the rational addiction theory.

[6] t-statistics in parentheses. Detailed results for the other eight price time series are available upon request. Different runs of the simulation lead to slightly different results, as one parameter in the utility functions (a_c) is randomly determined. However, the results given here are representative in the sense that further runs lead to

Table 1: Support for the rational addiction model when consumers are myopic

	eq. (2), OLS[a]	eq. (3), instrumental variable approach[b]	eq. (4), instrumental variable approach[b]
Norwegian beer	+	+	+
U.S. cpi	+	-	-
Random	+		
Shortwave	+		-
Markov	+		-
German cpi	+	+	+
Exponential	+		
Longwave	+	-	
tax	+	-	+

a: + means that the coefficient for c_{t+1} is significantly larger than 0

b: + means that the coefficient for $\hat{C}_{t+1}$ is significantly larger than 0; - means that it is significantly smaller than 0

An obvious way of overcoming the problem of endogeneity is to find exogenous instruments for predicting future consumption. The future price p_{t+1}, often together with lagged prices, is used to obtain the predicted future consumption of the addictive good, $\hat{c}_{t+1}$, which is then used as a regressor:

$$c_t = \alpha_0 + \alpha_1 \cdot p_t + \alpha_2 \cdot c_{t-1} + \alpha_3 \cdot \hat{c}_{t+1} + \text{....} etc. \qquad (3)$$

For this regression equation, a positive and significant coefficient for $\hat{c}_{t+1}$, interpreted as support for the rational addiction model, is found for a number of goods: cigarettes

coefficients with the same signs and the same dimension of significance for this equation as well as for the following ones; again, details are available upon request.

(Becker/Grossman/Murphy 1994, Escario/Molina 2001, Fem/Antonelli/Schroeter 2001, Sung/Hu/Keeler 1994), alcohol (Grossman/Chaloupka/Sirtalan 1998, Bask/Melkersson 2001, Bentzen/Eriksson/Smith 1999, the latter in separate equations for beer, wine and spirits) and cocaine (Grossman/Chaloupka 1998).

Five studies in which (3) is estimated, however, do not find any support for the rational addiction theory: Cameron (1999) for cinema attendance, Coniffe (1995) for tobacco, Bask/Melkersson (2001) for cigarettes, Bretteville-Jensen/Biørn (2001) for heroin and Liu/Liu/Hammitt/Chou (1999) for opium.

The results for estimating (3) for the simulated economy of myopic addicts depend on the price time series used, see Table 1. For example, with the price time series "Norwegian beer", the economy of myopic addicts behaves like one of rational addicts:

$$C_t = -2.8653 - 0.0296\,P_t + 1.0904\,C_{t-1} + 1.9600\,\hat{C}_{t+1} \qquad R^2 = 0.9685$$

$$(-7.64) \qquad (-10.48) \qquad (30.85) \qquad (9.82)$$

The same holds for one more price time series (German cpi), but not for the other seven. Whether econometricians investigating the rational addiction model would draw wrong conclusions for the economy of myopics depends on the price time series used. However, there is nothing which seems to distinguish the price time series "Norwegian beer" and "German cpi" from "U.S. cpi" etc. (see Figure 1), and as far as the author is aware, nothing in econometrics allows us to predict which price time series are susceptible to this phenomenon.

Another perplexing phenomenon occurs when p_{t+1} is used as a regressor. As a starting point, one might consider replacing $\hat{c}_{t+1}$ by p_{t+1} in the regression equation as an alternative way to overcome the problem of endogeneity; however, to the author's knowledge, only one attempt to do so has been made, namely in the working paper Becker/Grossman/Murphy (1990), which was finally published in 1994 without this equation. The joint inclusion of p_{t+1} and $\hat{c}_{t+1}$ in the regression equation is more popular:

$$c_t = \alpha_0 + \alpha_1 \cdot p_t + \alpha_2 \cdot c_{t-1} + \alpha_3 \cdot \hat{c}_{t+1} + \alpha_4 \cdot p_{t+1} + ...etc. \qquad (4)$$

The following authors made claims to have found support for the rational addiction theory based on estimates of this equation: Chaloupka (1990, 1991, 1992) for cigarettes, Labeaga (1993) for tobacco, Olekalns/Bardsley (1996) for coffee and Waters/Sloan (1995) for alcohol. In our simulated economy of myopic addicts, the results for estimating (4) are similar to those for estimating (3) with the "Norwegian beer" price time series:

$$C_t = -3.0251 - 0.03517\, P_t + 1.0666\, C_{t-1} + 2.0318\, \hat{C}_{t+1} + 0.0056\, P_{t+1} \qquad R^2 = 0.9712$$

$$(-3.03) \quad (-8.33) \quad (28.83) \quad (10.24) \quad (1.73)$$

However, for one price time series ("tax"), the coefficient of $\hat{C}_{t+1}$ was significantly positive when (3) was estimated, and it is significantly negative when (4) is estimated, i.e., after inclusion of P_{t+1} in the regression equation!

IV. Discussion

A practical conclusion can be immediately drawn from the last observation in the previous section: it would be desirable to have both estimates of (3) *and* (4) at the same time (from the same data set); this is not provided by any of the papers referred to above.

More importantly, even if this were to yield the desired coefficients in both cases[7], this would not form conclusive evidence for the rational addiction model. This problem was overlooked up until recently, when Gruber and Köszegi (2001) showed that the evidence provided so far

[7] Like in the case of the price time series "Norwegian beer" in our simulation.

is compatible with non-rational - yet forward-looking - behaviour[8]. This paper goes further by demonstrating that under certain conditions, even an economy of definitely myopic consumers might behave in accordance with empirical predictions of the rational addiction model. Admittedly, this is not always the case (not for seven out of nine different price time series), and so one might argue that even if one single econometric study might not prove much, the bulk of evidence going back to 1990 would be more convincing, as it applies to many different addictive substances, time spans and countries. However, as the survey above has shown, not all of this empirical evidence points in the same direction, as some studies fail to find a significant impact of future consumption on current consumption. This is even more remarkable as it is reasonable to presume that following the publication of Becker and Murphy (1988) there was a publication bias[9] in favour of evidence supporting the new approach.

More convincing evidence disputing the hypothesis of the entirely myopic behaviour of addicts could possibly be obtained from new empirical strategies, like the regression of (legal) drug consumption on future price changes, disregarding future consumption, as in Gruber and Köszegi (2001), or advanced panel econometric methods, as in Baltagi and Griffin (1999). The evaluation of these approaches must be left to future research.

[8] For another criticism of prevailing approaches see Ferguson (2000), who shows that the estimates of Olekalns and Bardsley (1996) implicitly predict a fifty thousand percent increase in U.S. coffee consumption within 20 years. Fehr and Zych (1998) demonstrate experimentally that even in the sober atmosphere of a laboratory and even with learning, people are not able to solve dynamic optimization problems like the one posed by equation (1).

[9] On the problem of the publication bias see Sterling (1959) and Tullock (1959).

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Appendix 1: Regression results for the simulated economy of myopic addicts, eq. (3) (dependent variable: aggregated drug consumption)

	price time series								
	Norwegian beer	U.S. cpi	German cpi	shortwave	longwave	exponential	tax	random	markov
P_t	-0.0296 (-10.48)	-0.0444 (-3.07)	0.0022 (4.13)	-0.0478 (-1.04)	-0.1707 (-3.68)	-0.0061 (-0.42)	-0.0133 (-4.82)	-0.0468 (-11.13)	-0.0529 (-4.15)
C_{t-1}	1.0904 (30.85)	0.7447 (15.13)	1.0244 (33.75)	0.5865 (4.52)	0.8851 (17.88)	0.9415 (16.78)	0.4489 (4.91)	0.6094 (8.67)	0.9748 (71.96)
$\hat{C}_{t+1}$	1.9600 (9.82)	-0.9550 (-2.36)	0.1627 (2.97)	0.2086 (0.47)	-0.9884 (-2.97)	-0.1605 (-0.23)	-0.6512 (-2.83)	0.0145 (0.15)	-0.0342 (-1.40)
constant	-2.8653 (-7.64)	9.4369 (3.03)	-0.7862 (-4.28)	6.2606 (0.75)	24.8145 (3.67)	1.3380 (0.36)	4.5103 (4.57)	6.6349 (10.34)	5.6098 (4.12)
R^2	0.9685	0.9829	0.9978	0.8750	0.9865	0.9952	0.8956	0.8336	0.9976

Appendix 2: Regression results for the simulated economy of myopic addicts, eq. (4) (dependent variable: aggregated drug consumption)

	price time series								
	Norwegian beer	U.S. cpi	German cpi	shortwave	longwave	exponential	tax	random	markov
P_t	-0.0352 (-8.33)	-0.0449 (-4.14)	-0.0102 (-2.14)	-1.2504 (-2.05)	-0.1402 (-0.58)	-0.0307 (-1.29)	-0.0198 (-7.62)	-0.0466 (-11.28)	-0.0534 (-4.40)
C_{t-1}	1.0666 (28.83)	0.9242 (18.40)	1.0337 (36.56)	0.6297 (5.98)	0.8859 (17.50)	0.9486 (16.99)	0.8456 (7.52)	0.7003 (7.67)	0.9771 (75.45)
$\hat{C}_{t+1}$	2.0318 (10.24)	-2.3363 (-5.83)	0.6145 (3.41)	-18.0889 (-1.95)	-0.8593 (-0.82)	1.8577 (1.08)	19.5000 (4.46)	-0.9120 (-1.48)	-0.0991 (-2.57)
P_{t+1}	0.0056 (1.73)	-0.0421 (-5.26)	0.0168 (2.61)	-0.7262 (-1.98)	-0.0111 (-0.13)	0.0593 (1.28)	0.2235 (4.61)	-0.0391 (-1.52)	-0.0367 (-2.11)
constant	-3.0251 (-8.05)	18.7104 (6.40)	-2.4648 (-3.70)	322.1241 (2.01)	21.9752 (0.96)	-8.8942 (-1.01)	-71.6435 (-4.33)	14.7467 (2.74)	9.5698 (4.19)
R^2	0.9712	0.9907	0.9982	0.8883	0.9865	0.9954	0.9365	0.8445	0.9979

(t-statistics in parentheses)