A Note

ON ENDOGENOUS PREFERENCES AND ADAPTIVE ECONOMIZING*

Richard H. DAY

Our concern is with economizing behavior when preferences depend on experience. It is shown that such a dependence, reflecting 'deep psychological structure', even when it is stable or habit forming in a fixed environment, can be destabilizing in a market context when prices are adjusting, even when the latter process is stable when preferences are fixed. 'Preference reversal' is then shown to be a cause of cyclic or non-periodic sequences of rational choices, thus providing an explanation both of normal variety and addictive binges in consumption. The relationship between cyclicity and intertemporal consistency is discussed. It is suggested that intertemporally optimal behavior is *in principle* not possible. Instead, behavior must be governed by *adaptive economizing* procedures which have only an approximate, local and imperfectly far-sighted rationality.

So once again, you chose yourself — and opened the door to chaos.

Dag Hammarsköld

1. Introduction

There is no doubt that human behavior depends both on innate, heritable characteristics and on experience. Nonetheless, according to an important scientific and philosophical tradition (Descartes, Kant), the manner in which experience influences behavior depends itself on 'deep structure', that is, on innate, heritable properties, so that in principle behavior can be understood in terms of a theory of deep structure.[1]

*This paper began as a discussion of Christian von Weizsäcker's 'adaptive preferences' presented at this conference but which was not available for inclusion in the proceedings. I expanded it into the present form at the urging of my co-editor. I am grateful to the Netherlands Institute for Advanced Study for providing a peaceful and congenial environment in which to reflect on these issues. In no way do I wish to implicate Von Weizsäcker in any of my remarks. Hopefully, his own ideas, which push in quite a different direction altogether will appear somewhere in due course. The quotation is from Hammarsköld (1964).

[1]Noam Chomsky (e.g., 1966) has been responsible for emphasizing this 'Cartesian' term, for it has been his goal to base the explanation of linguistic competence on a 'universal grammar' that would reflect deep structure. Quite apart from the validity of Chomsky's linguistic contributions, it seems to me that his methodological position is unassailable. For him to have gone further in recognizing that the generative or creative property of language rests on innate (but perhaps unknowable) properties of mind is, it seems to me, a proper starting point for understanding 'creative intelligence' in general and for explaining its role in entrepreneurship and economic activity in particular. I am indebted to Mark Sharefkin for his suggestions (printed above, following chapter 3) relating Chomsky's ideas to my own. The necessity of illucidating deep structure for the purpose of understanding behavior is argued not only for the case of creative or generative aspects of behavior but of cognitive behavior generally in contrast to the pure behaviorist methodology. For a cogent discussion in the context of primate behavior, see Mason (1979).

This general methodological stance can be illustrated by the economic theory of adaptive preferences, which I want to reconsider in these remarks. In particular I want to explore the dynamic consequences of experience-dependent rational choice, first, when individuals do not anticipate the dependence and second, when they do.

After first reviewing some background in section 2 it is shown in sections 3 and 4 that adaptation need not be habit forming (convergent) in a stable, economic environment. Even if it is, market dynamics may destabilize it. Indeed an example illustrates how a Clower–Friedman market adjustment process that is stable in the absence of adaptive preference can become unstable, even when it is linked to an adaptive process that is habit forming, that is, stable in the absence of tâtonnement; and vice-versa. This instability can be chaotic.

Section 5 takes up preference reversing, deep psychological structure and explains how experience dependence can bring about a sequence of rationally chosen, but varied consumption activities that can be habit forming, cyclic, or erratic, depending on income and prices. Such sequences can mimic the chaotic binges of the addictive personality, thus providing an explanation for addiction that rests not on habit formation but on deep psychological structure that causes strong preference reversals.

Section 6 argues that cyclic and chaotic choice sequences are quite compatible with intertemporally optimal behavior when preferences depend on experience so that in principle persistent and destabilizing variety that would disrupt steady states is not incompatible with individual rationality. However, in section 7 it is observed that preference dependence leads to incredibly complicated intertemporal relationships among preferences and anticipated experience at various points in the future. As a rule, therefore, the exercise of rational choice will be limited to exceptional aspects of life that involves dramatic, more or less easily learned or guessed consequences of overriding importance and to problems involving current trade-offs of a more-or-less local, non-temporal nature.

When imbedded in a framework that allows for environmental feedback as well as autofeedback (experience dependence) economic behavior is best described by a general class of adaptive economizing models in which plans at any given time may be based on strategies that are temporarily and locally optimal with respect to the external and internal state of the decision unit but in which that state evolves so that desired behavior can be suboptimal or even antioptimal. Such an approach briefly summarized in the concluding section 8 provides a theoretical basis for explaining why people behave the way they do, in contrast to how they would behave if they possessed unblemished perception and boundless cognition and if their transactions were conducted in perfect harmony.

2. Experience dependent choice: A review of the literature

According to the theory we are talking about people modify their behavior not only in response to changing external (market) conditions, but also in response to what they have done and to what has happened to them in the past. This would seem to be an integral part of the human condition. It would hardly require discussion if it were not for the fact that such a dependence is usually ignored by economists. Indeed, experience dependence could be safely left to psychologists if the adaptive economizing to which it gives rise were rapidly enough convergent and if 'long-run' demand behavior were 'representable', so that static theory would apply.

Benhabib (1979) tells us that Pareto recognized the issues, while Von Weizsäcker (1970) reminds us of Marshall's formulation of the problem. It was not until Duesenberry (1949) and Modigliani (1949), however, that experience dependence received concentrated attention. Their research was motivated by a desire to bring about a satisfactory explanation of certain macro-economic phenomena, a line of work continued by Brown (1952) who provided compelling evidence of experience influenced aggregate consumption behavior for the Canadian economy. Similar supporting econometric evidence, but for commodity groups, was put forward by Houthakker and Taylor (1966), while more recently, Kapteyn, Wansbeek and Buyze (1980) obtained very strong empirical evidence using individual household data.

In the meantime a fair amount of attention has been given to the theoretical questions at issue (representability and convergence). Gorman (1967) first showed that long-run (stationary) demand functions could be derived from utility maximization only under stringent conditions, a result sharpened by Pollak (1976) and El-Safty (1976). Pollak (1970) had already addressed the question of convergence for linear demand systems. Von Weizsäcker (1971), McCarthy (1971) and El-Safty (1976) extended the results. Hammond (1976ab) provided a more or less definitive, very general treatment. The upshot of this line of investigation is that stability is closely related to acyclicity of choice, by which is meant that in a fixed environment of price and income a consumer who rejected a choice at one point in time would not be observed to choose it at a later date. But acyclicity of choice obviously rules out a wide range of human behaviors including those that exhibit periodic variety. This is no doubt why much of the literature of this genre refers to 'experience dependence' as 'habit formation', the word for a phenomenon which is essentially equivalent to stable, long-run demand when experience matters as shown by the authors cited. For the remainder of this paper I will refer to the convergent, stable case as 'habit formation'.

Unfortunately, the econometric work conducted so far is not well suited for testing any of these issues. But the pursuit of novelty, or at least of variety is so pervasive a part of human action as to lead us to reject out of hand the hypotheses that (1) long-run (static) utility functions exist, (2) long-run demand functions are stable and (3) that preferences are acyclic.

In the meantime a different approach to the theory of adaptive preferences was inaugurated by Georgescu–Roegen (1950) who discerned an implication of far-reaching consequences: namely, that endogenous tastes, while not vitiating the constancy of economic laws, could deprive the discipline of any possibility for quantitative predicatability. Peston (1967) in pursuing the matter emphasized the possible existence of locally unstable and cyclic preferences while recently, Benhabib and Day (1981) showed that *choice cycles of all orders and completely erratic behavior could exist when preferences depend on experience*, thus confirming Georgescu–Roegen's cogently argued intuition. Obviously, none of these results could be possible in the case of habit formation.

To summarize: it is quite possible to have a theory of economizing behavior based on endogenous preference formation. It is doubtful that this theory supports the relevance of convergent behavior or the proposition that in the 'long-run' people behave as if they maximize a long-run utility function. Rather that theory might best be thought of as a conventional economic way of explaining different types of consumer behavior including habit formation, cyclic and non-periodic choice sequences.

3. Implications of environmental perturbations

To permit non-convergent behavior is to introduce a source of disequilibrating perturbation into the market economy. I am going to take it up in sections 5 and 6. In between, in hopes of keeping theory simple, let us consider the case of habit formation using a simple example.

Consider a utility function

$$\phi(x, y; a_t) := A x^{a_t} y^{1-a_t}, \tag{1}$$

in which a_t is a parameter determining the strength of preferences at the close of a given period t. Given prices p_t and q_t of x and y respectively and the consumer's 'income' m_t, utility maximization yields the demand functions.

$$x_{t+1} = a_{t+1} m_{t+1} / p_{t+1}, \tag{2a}$$

$$y_{t+1} = (1 - a_{t+1}) m_{t+1} / q_{t+1}. \tag{2b}$$

The utility function (1) is (for purposes of illustration) the conscious 'surface structure' of the individual. Given a current situation at time $t+1$ represented by prices and income $p_{t+1}, q_{t+1}, m_{t+1}$ the consumer chooses x_{t+1} and

y_{t+1} according to (2). In the pure theory of habit formation the market situation (p, q, m) is assumed constant. For the time being, then, drop the time subscript from p, q and m.

Suppose that preferences depend on experience according to the 'deep structure'

$$a_{t+1} = \min\{\alpha x_t, 1\}, \tag{3}$$

where x_t is the consumption of x experienced in period t. Assume also that this 'deep structure' is *not* perceived so that behavior is governed by (1) and (2). Then

$$x_{t+1} = \min\{\alpha x_t, 1\} m/p, \tag{4a}$$

$$y_{t+1} = (1 - \min\{\alpha x_t, 1\}) m/q. \tag{4b}$$

Suppose for the moment that $\alpha m/p > 1$ and that $x_0 < m/p$. Then, for a while, until income is used up at $t = s$,

$$x_t = (\alpha m/p)^t x_0, \qquad 1 \leqq t < s, \tag{5}$$

where $s = \min\{t; p(\alpha m/p)^t > m\}$. After that time

$$x_t = m/p, \qquad y_t = 0, \quad t \geqq s, \tag{6}$$

so that 'long-run' demand exists and has a very simple form: the consumer forms a habit. Consumption of x increases exponentially until the individual consumes only x. Consumption of y decreases exponentially until nothing at all is consumed. At each point the individual thinks himself to be making an improvement given the current preferences that he perceives as the result of his most recent experience.

Suppose, in contrast to the preceding assumption, that $\alpha m/p < 1$ and $p x_0 < m$. Then eq. (5) governs the behavior of x_t as before. Now, however, it is an exponentially decreasing function and the consumption of y increases exponentially according to

$$y_t = q[m - (\alpha m/p)^t x_0], \qquad t < s, \tag{7}$$

until income is all used up at time $s = \min\{t; g[m - (\alpha m/p)^t x_0 > m\}$ when

$$y_t = m/q, \qquad x_t = 0, \quad t \geqq s. \tag{8}$$

If by chance $\alpha m/p = 1$, then no adaptation to experience takes place and $x_t = 0$, all t.

Thus, $m = p/\alpha$ *is a bifurcation point separating regimes of qualitatively differing behavior with opposite short-run directions of change and opposite long-run consequences.* When people are 'rich' habit formation leads them to (6); while if they are 'poor' it leads them to (8). See fig. 1.

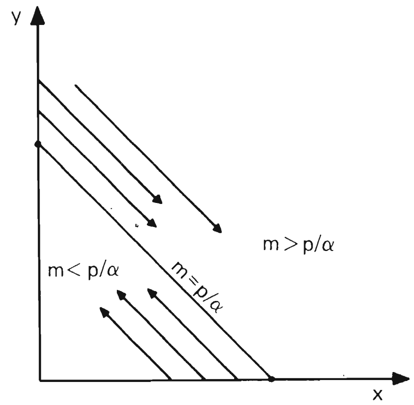


Fig. 1. Dependence of consumer behavior on income, price and 'deep structure'.

If income or prices were to fluctuate due to dynamic forces in the rest of the economy above and below this bifurcation point, consumption behavior would also switch regimes. In this case long-run demand need not exist and fluctuations in demand might be perpetuated. This is ever so more likely to be the case in that the adaptive adjustment of preference is exponential and, hence, likely to be strongly destabilizing for perturbations to an equilibrium.

4. Destabilizing interaction of habit formation and stable tâtonnement

Indeed, preference adaptation and price adjustment mechanisms which are individually stable can be mutually destabilizing, a fact that can be illustrated by imbedding the model of adaptive preferences (1)–(3) in a very simple Clower–Friedman (C–F) model of pure exchange (cf. this volume, chapter 5).

Assume two groups of individual consumers in a C–F economy with a price-adjusting 'specialist' who maintains a 'very large' inventory. Members in each consumer group have utility functions of the form (1) with preference parameters a_t^i for groups $i = 1, 2$. The groups can be aggregated without bias if the distribution of income is equal within groups. So, let x_t^i, y_t^i, m_t^i be the aggregate commodity demands and income of group i. With this notation the demand functions are

$$x_t^i = a_t^i m_t^i / p_t, \tag{9a}$$

$$y_t^i = (1-a_t^i)m_t^i/q_t, \tag{9b}$$

where $i=1,2$.

Let endowments $\bar{x}_t^i$, $\bar{y}_t^i$, $i=1,2$, be received each period and let y be the numeraire so $q_t=1$. Assume group 1 receives all the available good x, group 2, all the available good y. Given these assumptions

$$m_t^1 = p_t\bar{x}, \qquad m_t^2 = \bar{y}, \tag{10a, b}$$

so that (9a) and (9b) become

$$x_{t+1}^1 = a_{t+1}^1\bar{x}, \qquad x_{t+1}^2 = a_{t+1}^2\bar{y}/p_{t+1}, \tag{11a}$$

$$y_{t+1}^1 = (1-a_{t+1}^1)p_{t+1}\bar{x}, \qquad y_{t+1}^2 = (1-a_{t+1}^2)\bar{y}. \tag{11b}$$

Excess demands for time t, which are satisfied out of inventory by the specialist, are

$$E_{xt} = (a_t^1 - 1)\bar{x} + a_t^2\bar{y}_t, \tag{12a}$$

$$E_{yt} = (1-a_t^1)p_t\bar{x} + a_t^2\bar{y}, \tag{12b}$$

Suppose that the specialist behaves like a conventional, linear, Walrasian 'auctioneer', who sets

$$p_{t+1} = p_t + \lambda[(a_t^1 - 1)\bar{x} + a_t^2\bar{y}/p_t]. \tag{13}$$

Suppose also, for the moment, that preferences do *not* depend on experience ($a_t = a_0$, all t). The equilibrium price is

$$p_e = \frac{a_0^2\bar{y}}{(1-a_0^1)\bar{x}}, \tag{14}$$

and the long-run demands are

$$x_e^1 = a_0^1\bar{x}, \qquad x_e^2 = (1-a_0^1)\bar{x}, \tag{15a}$$

$$y_e^1 = a_0^2\bar{y}, \qquad y_e^2 = (1-a_0^2)\bar{y}, \tag{15b}$$

These are globally, asymptotically stable if

$$0 < \lambda(1-a_0^1)^2(\bar{x})^2/(a_0^2\bar{y}) < 2, \tag{16}$$

and *unstable* if

$$\lambda(1-a_0^1)^2(\bar{x})^2/a_0^2\bar{y}>2. \tag{17}$$

Suppose the combination of parameters (a_0^1, a_0^2) and endowments $(\bar{x}, \bar{y})$ are such that (16) is satisfied.

Now introduce the habit formation of eq. (3) but where it operates differently for the two groups according to

$$a_{t+1}^1=\min\{\beta^i x_t^i/\bar{x}, 1\}, \tag{18a}$$

$$1-a_{t+1}^2=\min\{\beta^2 y_t/\bar{y}, 1\}. \tag{18b}$$

Suppose also that $0<\beta^i<1$ so that, ceteris paribus, consumers in group 1 experience diminished (enhanced) preference for $x(y)$ and consumers in group 2 experience diminished (enhanced) preference for $y(x)$. I shall call this 'dichotomous deep structure'.

Given these assumptions

$$a_t^1=(\beta^1)^t x_0^1/\bar{x}\to 0, \tag{19a}$$

$$(1-a_t^2)=(\beta^2)^t y_0^2/\bar{y}\to 0, \tag{19b}$$

where $t\to\infty$.

Consequently, with the passage of time the price adjustment process (13) converges to the process with constant coefficients

$$p_{t+1}=p_t+\lambda(\bar{y}/p_t-\bar{x}), \tag{20}$$

the unique stationary state of which is

$$p_e=\bar{y}/\bar{x}. \tag{21}$$

The latter is globally, asymptotically stable if

$$0<\lambda(\bar{x})^2/\bar{y}<2, \tag{22}$$

and unstable if

$$\lambda(\bar{x})^2/\bar{y}>2. \tag{23}$$

Now, by assumption tâtonnement (13) is stable when preferences are fixed and, in the absence of price adjustment, when preferences are habit forming.

The question is, if *both* price adjustment (13) and preference adaption (18a) and (18b) are allowed, are tâtonnement and demand convergent? We have just seen that in this case the long-run behavior of price is governed by (20). Can (13) be stable when (20) is not? That is the question. For its answer to be yes, both (16) and (23) must hold, that is,

$$2<\lambda(\bar{x})^2/\bar{y}<2\gamma, \tag{24}$$

where $\gamma=a_0^2/(1-a_0^1)^2$, which is possible, if and only if

$$\gamma=a_0^2/(1-a_0^1)^2>1. \tag{25}$$

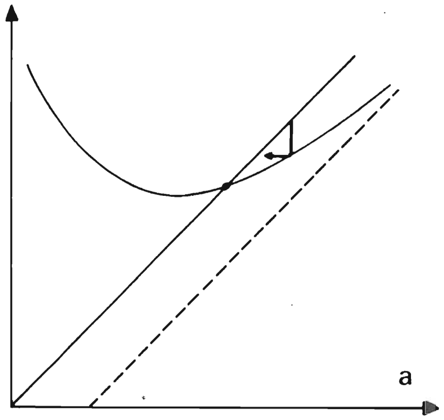
Consequently, if the initial preferences of consumer group 2 for x are very strong relative to those of consumer group 1 for good y, *then given the speed of adjustment λ there exist endowments $(\bar{x},\bar{y})$ depending on λ, consistent with stable tâtonnement without adaptive preference, which destabilize the economy with adaptive preference, even when behavior is habit forming in a stationary environment.*

In the limit, price adjustment — as we have seen — is governed by (20), the phase portrait of which is shown in fig. 2. The minimum possible price, call it $p^{\min}$ occurs at the minimizer of (20), $p^*=\sqrt{\lambda\bar{y}}$, so that $p^{\min}=2\sqrt{\lambda\bar{y}}-\lambda\bar{x}$. By making $p^{\min}$ small, $p^{\max}=p^{\min}+(\bar{y}/p^{\min}-\bar{x})$ becomes large. Let p^{c} be the larger of the two values of p such that $p^*=p+\lambda(\bar{y}/p-\bar{x})$. Then, if tâtonnement were to begin with p^{c} we would get the sequence p^{c}, p^*, $p^{\min}$, $p^{\max}$. But given any λ, $p^{\min}$ can be made as small as we like, while at the same time making $p^{\max}$ as big as we please simply by making $\bar{y}$ small enough or $\bar{x}$ big enough. See fig. 2.

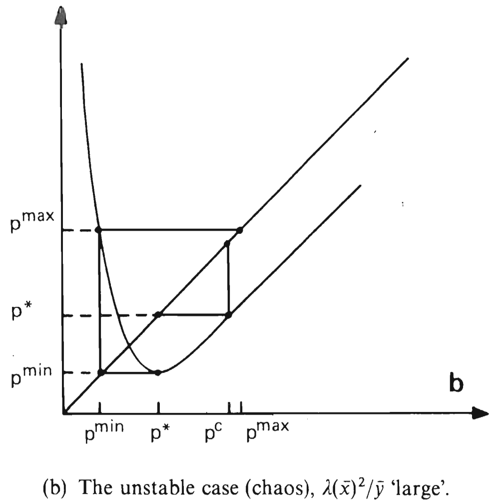
Therefore, given any speed of tâtonnement, λ, however slow, and any initial set of preference parameters $\beta^i<1$, $i=1,2$, there exist endowments $(\bar{x},\bar{y})$ (a continuum of them) such that

$$p^{\max}\geqq p^{c}>p^*>p^{\min}, \tag{26}$$

from which follows the fact that *there exist cyclic sequences of consumption patterns of every order and an uncountable 'scrambled set' of initial conditions leading to erratic sequences of demand (chaos).* See Day (1982, 1983) for details of the argument. Of course the degree of instability, which can be measured roughly by $\lambda\bar{x}^2/\bar{y}$, necessary to bring the result about may be great enough to violate the right side of (24) so that the independent tâtonnement process, governed by a_0^1, a_0^2 is unstable. Nonetheless, let $K=\lambda(\bar{x})^2/\bar{y}$ be such that (24) holds. *Then there exists a K such that the independent tâtonnement is stable and preferences habit forming in the absence of price adjustment, but*



(a) The stable case, $\lambda(\bar{x})^2/\bar{y}$ 'small'.



(b) The unstable case (chaos), $\lambda(\bar{x})^2/\bar{y}$ 'large'.

Fig. 2. Dependence of tâtonnement on endowments.

which are unstable in the chaotic sense just defined when prices adjust and preferences adapt.

To summarize we have the following startling conclusion: Any preference adapting, stable (unstable) C–F market economy with dichotomous deep structure can be destabilized (stabilized) by changing endowments appropriately.

5. Preference reversal

We have been looking at how an economy can be unstable with adaptive preferences even when behavior is habit forming in the absence of market feedback. Now, let us consider the more general situations when adaptive behavior is *not* habit forming. This involves a kind of experience dependence that I shall call *preference reversal.*

Instead of (3), assume the following form of experience dependence:

$$a_{t+1} = \alpha x_t y_t. \tag{27}$$

For simplicity hold $p = q = 1$. Then

$$a_{t+1} = \alpha x_t(m - x_t), \tag{28}$$

which exhibits preference reversal because

$$\frac{\mathrm{d}a_{t+1}}{\mathrm{d}x_t} = \alpha(m - 2x_t), \qquad \begin{cases} > 1, & x < m/2, \\ < 1, & x > m/2. \end{cases} \tag{29}$$

The dynamic demand equations are

$$x_{t+1} = \alpha m x_t(m - x_t), \tag{30a}$$

$$y_{t+1} = m[1 - \alpha y_t(m - y_t)]. \tag{30b}$$

The long-run behavior of demand depends on αm^2. It is easily shown that when

$$1 < \alpha m^2 < 2, \tag{31}$$

behavior is habit-forming; long-run preferences exist, are acyclic and representable. (Demand satisfies Weizsäcker's (1970) stability theorem in this case.) When

$$c < \alpha m^2 < 4 \tag{32}$$

where $c \sim 3.57$ it can be shown [Benhabib and Day (1981, p. 463)] that adaptive preferences lead to behavior that, depending on the initial condition, can exhibit cycles of any order (revealed cyclic preferences) or non-periodic, unstable fluctuations for an uncountable set of initial states that do not converge to a stationary cyclic pattern of any order. The same results hold for a wide variety of functional forms that could replace (27). *The key property is preference reversal of sufficient strength.*

Now fix α and decrease income, m. A value is reached at which, instead of erratic behavior, stable consumption cycles of an even order emerge. When m is decreased enough monotonic convergence to a stationary long-run demand equation occurs. Thus, the qualitative behavior of the consumer depends (as in our earlier examples) on how rich the consumer is. Roughly speaking, *the poor behave repetitively; the middle class exhibit varied consumption, but of a wholly predictable kind; the sufficiently rich possess cyclic preferences but may never reveal them, instead evolving through a never repeating sequence of choices in a wholly unpredictable way.*

Is preference reversal empirically relevant? I think so. Clearly it is consistent with an infinite variety of possible human behaviors. This gives it a powerful explanatory potential. For example it provides a possible explanation of addictive behavior. Return to the basic model (1)–(2), but instead of (3) or (18) assume that

$$a_{t+1} = e^{\alpha(1-x_t)} x_t. \tag{33}$$

Now we get the dynamic demand equation

$$x_{t+1} = x_t \, e^{(1-x_t)}(m/p), \tag{34}$$

which exhibits preference reversal. When m is large enough the complicated dynamics of the kind described above emerge. Moreover, if α is quite small the consumption of x can still be quite irregular but remains relatively small except for bursts at irregular intervals. See May and Oster (1976).

Suppose x represents alcohol and y other consumption. Then the model predicts (for appropriate α and m) irregularly timed binges interspersed with periods of fluctuating alcohol consumption but relative sobriety. The consumer does not drink much during these latter periods because binges reverse his preference so he drinks less except from time to time when gradually growing consumption leads explosively to a powerful desire for drink. Nonetheless, a violent enough binge reduces the preference for alcohol so much, that he may behave as if he is a teetotaler much of the time.

This model seems more or less in accord with current clinical views of alcoholism. Abstinence ($x_0 = 0$), is unstable and, given an income-psychology pair (m, α) of the right kind the tiniest initial experiment or the tiniest slip off 'the wagon' leads to the erratic binges typical of addictive behavior.

Presumably a potential addict avoids the disease only by looking ahead to the potential explosive development of need based on use. He must prefer abstinence above any future preference, even though a subjectively improving sequence exists that would lead him to the addictive behavior he wishes to avoid. Possibly, then, addiction may have more to do with preference reversing effects of experience, caused by deep psychological structure, than with the development of habits that continue even when their involvement in the problem of choice has receded from consciousness.

But preference reversal need not be so extreme. In much milder forms it is a type of 'deep structure' that explains sequences of rational choices that exhibit variety. Thus we see how a rational mind can enjoy the spice of life even in an absolutely stable environment.

It would be instructive to imbed our little model of preference reversal within the dynamic market model considered above but that might carry us further in the direction of highly stylized examples than we ought to go for our present purposes. We may conjecture, however, that in such a setting the prospects for highly complicated, unstable behavior of demand and price are much enhanced.

6. Consistent planning, cyclic behavior and long-run demand[2]

When the individual anticipates the feedback effect of possible actions on future conditions he invests his decision making with a far-sighted, strategic quality that is embodied in the various forms of intertemporal optimizing, optimal control or dynamic programming models used in economic theories of savings and investment. Consider a consumer who has a choice of two alternative vacations 'a' and 'b' costing p_a and p_b respectively. Choice 'a' might be a skiing trip to the mountains; choice 'b' might be a holiday by the sea. If he can afford neither he loafs which we denote as choice l. These choices are ordered so that $a > b > l$ where $>$ means 'is strictly preferred to', so they can be represented by an index u_x where $u_a > u_b > u_l$. The consumer's choice 'space' is $X = \{a, b, l\}$ and his budget set is

$$B(p,m) := \{x \in X \mid p_x \leqq m\}, \tag{35}$$

where m is the predetermined vacation budget. Given the indicated preferences and assuming that $p_a > p_b > p_l = 0$, the choice (demand) function is

$$x = C(p,m) = \begin{cases} a & \text{if} \quad p_a \leqq m, \\ b & \text{if} \quad p_b \leqq m < p_a, \\ l & \text{if} \quad m < p_b. \end{cases} \tag{36}$$

A poor consumer loafs; a middle class consumer goes to the beach; a rich consumer skis.

Now allow the consumer to contemplate a sequence of future choices.

[2]There is a substantial, very important literature dealing with issues only sketched here. See, for example, Strotz (1956), Peleg and Yaari (1968) and Hammond (1976ab).

Possible sequences are

$$A:=(a,a,a,\ldots),\quad B:=(b,b,b,\ldots),\quad L:=(l,l,l,\ldots).$$

Given any discount factor a rich consumer would always choose A. He would ski in each time period. He would also be consistent for he would never revise his plan. The same can be said for the middle class, who would always choose B, and the poor, who would always choose L.

But what about someone who wanted to choose a sequence like $U=(a,b,a,b,\ldots)$, or like $V=(b,a,b,a,\ldots)$.

An additive discounted utility function would lead our rich consumer to choose U in each period (he would have to in order to avoid being cyclic), but then he would always ski! Consistent, non-cyclic choice thus leads to a revealed consistent behavior A although true preferences are for U, which shows that the additive, discounted utility function that we are using cannot truly represent the preferences being discussed.

If a consumer were to behave according to a sequence U or V he would have to choose U or V *once and for all* (precommitment), or, he would have to choose the sequence, $U, V, U, V, \ldots$. In the first case we do not allow him to contemplate revising his plan; in the second case, we allow him to do so with the result that he becomes inconsistent!

The problem is readily solved, however, if we recognize that the consumer like U has preferences that seem to depend on experience. Let $U(x;y)$ be the utility of x given that y is experienced and define

$$\begin{aligned}
&U(a;b):=U(b;a)=U(a;l)=U^3,\\
&U(a;a):=U(b;b)=U(b;l)=U^2,\\
&U(l;a):=U(l;b)=U(l;v)=U^1.
\end{aligned}\tag{37}$$

Define the budget set $B(p,m)$ as before. Then the choice problem with adaptive preferences can be written

$$\max U(x;x_t),\qquad x\in B(p,m).\tag{38}$$

Our rich agent chooses a if he just experienced b or b if he just experienced a. The middle class always chooses the beach while the poor always loaf at home. The short-run demand function is

$$x_{t+1}=C(x_t;p,m)=\begin{cases} a & \text{if}\quad m\geqq p_a \quad\text{and}\quad x_t=b,\\ b & \text{if}\quad m\geqq p_a \quad\text{and}\quad x_t=a \quad\text{or if}\quad p_b\leqq m<p_a,\\ l & \text{if}\quad m<p_b.\end{cases}\tag{39}$$

Choice is cyclic for the rich so no long-run demand function exists for them (Weizsäcker, Hammond).

Now consider a consumer with foresight who anticipates the dependence of his preferences on experience and who has a perfect knowledge of his deep structure (37). At the beginning of period $t+1$ the agent has experienced $x_t \in B(p,m)$. He looks forward to an endless future (say) of choices $(x^0, x^1, \ldots)$, where x^i is the choice planned for period $t+1+i$. To represent his preferences he uses

$$\phi(x^0, x^1, \ldots; x_t) := U(x^0, x_t) + \sum_1^{\infty} \lambda^i U(x^i; x^{i-1}), \tag{40}$$

maximizing this intertemporal adaptive utility function subject to the budget constraint $x^i \in B(p,m)$ to obtain a planned sequence $x^0_{t+1}, x^1_{t+1}, \ldots)$. Ignoring the general problem of interagent compatibility we let $x_{t+1} = x^0_{t+1}$.

A dynamic programming argument shows that (39) is the optimal strategy for this problem. Consequently one cannot only behave with variety, one can plan optimally and consistently to do so without confining oneself to acyclic behavior and therefore to the existence of long-run demand.

As trivial as this example is (and one should really work through the argument when savings is allowed) it does illustrate the very important fact that the lack of fixed habits and the non-convergence to long-run demand functions does not imply a lack of rationality. The association of habit formation with intertemporal optimization can, therefore, be quite misleading just as its association with long-run demand can be.

7. Strategic and boundedly rational behavior

Perpetuated variety in consumption need not be incompatible with efficient aggregate equilibrium. We could imagine either an 'equilibrium' macroeconomic cycle in which capacity and its utilization are matched cyclically with aggregate demand, or in which rich people gradually adjust their choices so that their aggregate demand is stationary while individual behavior is cyclic. The latter case would arise when the cost of shifting capacity is high instead of very low or nil. It is inviting to argue in this way (as some prominent economists have done) that general equilibrium theory can describe non-steady-state behavior.

Choice need not be so simple, however, as it was described in the example of section 6. Consider instead the model of section 5 with temporary utility function (1) and deep structure (27). A strategic plan would have to be based on the intertemporal utility function

$$U[(x,y)^0, (x,y)^1, \ldots, (x,y)_t] := A(x^0)^{\alpha x_t y_t}(y^0)^{1-\alpha x_t y_t} + \sum_1^{\infty} \lambda^i A(X^{i+1})^{\alpha x^{i-1} y^{i-1}}(y^i)^{1-\alpha x^{i-1} y^{i-1}}. \tag{41}$$

This would appear to be complicated enough to tax the minds of most ordinary people.

Moreover, we know from our analysis of the myopic case that for some parameters the impact of a given period's anticipated behavior on potential behavior even a few periods into the future is extremely difficult to compute. Indeed, with bounded memory and imperfect computational accuracy, the possibility of computing a sequence of anticipated behaviors $(x,y)^0,\ldots,(x,y)^t,\ldots$ that is consistent with deep structure is *in principle* not possible. The open-loop solution to the consumer's dynamic planning problem is, therefore, not a viable means of decision-making. (Woe betide the potential addict!)

Instead, one might argue that the forces of evolution have produced a 'wired-in' capability for humans to behave according to optimal strategies, i.e., to act as if they could derive a strategy

$$(x,y)_{t+1} = C(y_t, y_t; p_x, p_y, m), \tag{42}$$

where $(x,y)_t^0 = (x,y)_t$, that satisfies the Bellman principle for eq. (41) given the budget constraints. But imbed such a class of agents into a C–F exchange economy. How can our agents adapt optimally if it turns out that their behavior and market adjustments are mutually destabilizing?

It seems that strategic behavior must likely be confined to a rather narrow range of very important choices in which the relation between behavior and preference is strong and capable of being learned to some useful degree of approximation. Tactical (or myopic) rationality which focuses cognition on choice *within the current temporary context* is likely to cover a wider range of decisions. And even this level of rationality will be impossible for much of what we do.

8. Adaptive economizing

Economic behavior must be adapted to experience (auto-feedback) and to the environment, which is dependent on the past behavior of all the agents (environmental feedback). The joint affect of these two sources of dynamic structure will be to propagate change, and, it seems plausible, on the basis of the discussion above, to propagate irregularly changing states. This will make learning difficult. It will render forecasting problematic. Strategically optimal behavior will be impossible.

Reflections such as these lead one to the behavioral, boundedly rational, adaptive man [Day (1975, p. 27)].

> '"If I am to learn a great deal in the future about what is, what might be and what I want,... should I rather incorporate strategic considerations only when I have evidence that far-sighted behavior pays off, and

limits the scope of possible plans to some perceptively safe-enough set as dictated by my sense of caution?" If the answer to the question is affirmative then adaptive man is described by cautious, local, approximate optimization, that is, by adaptive optimizing tactics which account for only a part of the total situation.'

In short, adaptive man, when he economizes at all, economizes adaptively. His economizing behavior is described by sequences of optimizations with feedback (recursive programs) the 'solution' of which at best can represent optimal strategies only in terms of perceived structure, hence are temporarily optimal and in general have only an approximate, imperfectly far-sighted and local rationality [cf. Day (1971, 1978)]. This of course, is equivalent to bounded rationality a la Schumpeter and Simon (cf. this volume, chapter 2).

In a succession of studies beginning with my dissertation, published in 1963, and continuing through the paper which I prepared for this conference I have investigated models based on this view. In them, economizing at any given point in time, however, short- or far-sighted it might be and however low or high it might fall on the scale describing the sophistication of rationality, depends in its preferences and in its constraints on the past behavior of the agent or the system of agents being represented. I originally labelled such models 'recursive programming models' (1961), later using the term 'recursive decision systems' [Day and Kennedy (1970)]. In particular I indicated how these models captured at least some of the realities of behavior including the dependence of preference on experience (1971) in a study inspired in part by Georgescu–Roegen's reflection on the subject which I cited above.

The class of all models of this kind I now prefer to call 'adaptive economizing models' because they incorporate economizing explicitly while recognizing its dependence on past behavior in a way that incorporates bounded rationality to whatever degree seems appropriate. It is a term that need not imply actual improvement but one that acknowledges that behavior involves a response to what has been done and what has happened within the person or organization and in the surrounding environment. Such models need not rule out strategies, far-sighted behavior of the most sophisticated kind involving an Adaptive Bayesean, Dynamic Programming Structure. But for purposes of understanding how real economies work the economic scientist will represent explicit decisions as imperfectly and at best, conditionally optimal. It is in this broad sense that I believe March and Simon (1958) utilized the word 'adaptive'. The special cases that Von Weizsäcker presented in his verbal remarks and the little examples that I set forth above indicate that numerous new theoretical results and practical insights may be forthcoming from further study along these lines.

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