Chapter 2
Demand Theory Under Review

The conventional (i.e., neoclassical) theory of consumer choice is one of the great prides of economics, for, among other things, it provides a rigorous and elegant mathematical underpinning to the common-sense notion of the law of demand, that there is an inverse relationship between the price of a good and the amount of the good that a consumer is willing to buy. Macroeconomic theories over the years come and go, and to a lesser extent, the same is true of theories of production, but not the theory of consumer choice. For, although there periodically have been questions concerning the assumptions that underlie it, the theory has essentially retained its present form since the 1930s. It is, in short, one of the great invariants (along with the theory of least-squares estimation) in the core education of an economist. In the circumstances, accordingly, it might pretty much seem a waste of readers’ time to begin a demand study with a review of conventional theory, for one could easily begin, as is so often the case in demand studies: “Economic theory teaches us that quantity demanded is a function of price and income, that (in normal circumstances) demand functions slope downward with price and shift outward with income, and so on and so forth.” However, while the neoclassical theory (whether directly or in its equivalent alternative form in terms of revealed preference) will be a guiding framework within which the analyses of this book proceed, there will be a number of points at which results (and other considerations) emerge that tempt explanation or interpretation that go beyond that offered by this theory. For this reason, a brief review of conventional theory is in order.

2.1 Conventional Theory of Consumer Choice

An economic agent, identified as an individual consumer, is assumed to allocate an income of $y$ over $n$ market goods $q_i$, which can be purchased at unit prices of $p_i$, in such a way that a “utility” function defined over the $n$ goods, $\varphi(q_1, \ldots, q_n)$, is at a maximum. More formally, purchase decisions are assumed to follow as the solution to the following constrained maximization problem:
Find the values of $q_i, i = 1, \ldots, n$, that maximize the function

$$
\varphi(q) = \varphi(q_1, \ldots, q_n),
$$

subject to the condition that

$$
\sum p_i q_i = y.
$$

To solve this problem, one first formulates the expression

$$
\Phi(q, \lambda) = \varphi(q) - \lambda \left( y - \sum p_i q_i \right),
$$

where $\lambda$ is a Lagrangean multiplier representing the marginal utility of income, differentiates this expression with respect to $q_i$ and $\lambda$:

$$
\frac{\partial \Phi}{\partial q_i} = \frac{\partial \varphi}{\partial q_i} - \lambda p_i, \quad i = 1, \ldots, n,
$$

$$
\frac{\partial \Phi}{\partial \lambda} = y - \sum p_i q_i,
$$

equates the $n + 1$ derivatives to zero, and then solves the resulting first-order conditions for the $n$ demand functions $q_i$ as functions of the $n$ prices $p_i$ and income $y^1$:

$$
q_i = q_i(p_1, \ldots, p_n, y), \quad i = 1, \ldots, n.
$$

The explicit expressions for the demand functions in equation (2.6) obviously depends upon the analytic form of the utility function. For some utility functions, such as the Stone–Geary utility function (which yields the equations associated with the linear expenditure system), the demand functions are easily derived and often fairly easily estimated, while for other utility functions (such as the direct addilog utility function of Houthakker), the demand functions are both complicated and highly nonlinear. The demand functions corresponding to both of these utility functions, as well as those from several other utility functions, are estimated in Chapter 8.\(^2\)

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1 Solution of the first-order conditions requires that the utility function $\varphi(q)$ satisfy a variety of regularity conditions. For present purposes, we will take these to include $\varphi$ to be continuous in the $n q_i$, with continuous first and second partial derivatives that are positive and negative, respectively.

2 Much of the elegance of this theory is that one can equally well take the demand functions in expression (2.6) as the starting point (the demand functions, after all, are what are in principle observable), and, under certain conditions, associate them with a utility function. These conditions (the so-called Slutsky conditions, which are both necessary and sufficient) are that the matrix, whose typical element is

$$
\frac{\partial q_i}{\partial p_j} + q_i \frac{\partial q_i}{\partial y}, \quad j = 1, \ldots, n,
$$
2.2 Neoclassical Demand Theory as a 19th-Century Conservative Energy System

The theory of consumer choice as just presented is widely viewed (and rightly so) as one of the real triumphs of economic theory, for it yields a conclusion (that income-compensated demand functions are downward-sloping in price) that is not only elegantly derived, but intuitively satisfying, and felt to be in accordance with real-world behavior. What is perhaps not appreciated is that this theory, in form, represents a 19th-century conservative physics energy system. The utility function is the counterpart to the potential energy function, while the income (or budget) constraint is the counterpart to kinetic energy. Marginal utilities form an invariant vector field of “forces,” and the “work” function has its counterpart in an expenditure line integral. The invariants in the choice problem are independent of the “path of motion,” while the conservative principle that is counterpart to the conservation of potential and kinetic energy is that the sum of utility and income is conserved. The structure that the vector field of marginal utilities has to satisfy (in vector-field terminology) is that the curl of the vector field must be equal to zero, which is to say that the vector field must be irrotational. In economics terminology, these restrictions represent the integrability conditions stated in Footnote 2.

What we wish to do now is to discuss several possible applications of the neoclassical theory as illustrations of both appropriate and inappropriate uses of the theory. In our view, neoclassical theory is most appropriately used when the questions involved are of the “what if” variety. Such would be the case, for example, if the questions asked (with reference to a given choice set of market baskets of goods and services) were of the form:

1. Assuming the vector of prices to be held constant, which market basket would be chosen if income were A as opposed to the market basket chosen if income were B?
2. Assuming income to be held constant, which market basket would be chosen if the price vector were w as opposed to the market basket chosen if the price vector were z?

The first question relates to the derivation of what are ordinarily referred to as Engel schedules, while the second question relates to the derivation of demand functions that satisfy these conditions are said to be integrable (or, alternatively, theoretically plausible).

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3 Much of the material in this section is taken from Appendix 1 of Taylor (2000).
4 Although economists are generally well-versed in linear algebra, this is usually not the case with respect to the concepts of vector fields. Mirowsky (1989) provides some discussion of the concepts in question, but not in sufficient detail for a full understanding of the relationship between neoclassical theory and 18th-century conservative physical systems. The needed concepts, which include gradient, vector cross (or outer) product, curl, and divergence, can be found in any standard advanced calculus book, such as Apostol (1957).
schedules. In neither case is there any assumption that the behavior at issue is actually to be observed. Indeed, the presumption (although usually tacit) is that it is not. Contrast, now, the above questions with the following two questions:

1*. If an individual (with a given level of income A) were repeatedly (i.e., during a sequence of consumption periods) to be faced with the same price vector w, what would be the market basket of goods consumed?

2*. If in a subsequent sequence of periods, the individual continued to face the price vector w, but with income B rather than A, what would be the market basket consumed?

In these two questions, the assumption is that consumption actually occurs within each of the consumption periods. For neoclassical theory, this should not matter, for the market baskets consumed in the sequence of consumption periods in (1*) should be the same basket as would been chosen in (1), while the market baskets chosen in the sequence of consumption periods in (2*) should be the same as would have been chosen in (2).

Almost certainly, however, this is not what would be observed. With consumption actually taking place in (1*) and (2*), there would in all likelihood be an interaction between the consumption in one period and the marginal utilities operative during the next period. Because of the intrusion of real-time dynamics, the assumptions for a conservative vector field would accordingly be violated. For the questions in (1) and (2), in contrast, this would not be a problem, for one could reasonably expect that marginal utilities would remain invariant in the face of “what if” questions, since no consumption actually takes place.

We should emphasize that the issue involved here is not, as a practical matter, the ignoring of some factors that impinge upon consumption and that behave randomly from one consumption period to the next. The issue, rather, is one involving real-time irreversible alterations of marginal utilities in a systematic, yet not necessarily predictable, manner. The question of whether the standard paradigm can be modified to accommodate such “endogenous taste changes” will be discussed later in this chapter. However, for now, we want to consider another example that illustrates the problem at issue.

Suppose, as has frequently been the case in the telecommunications industry, there is a question before a regulatory commission regarding the amount of “repression” on telephone usage that might be expected to occur as a result of a proposed increase in tariffs. In assessing this question, the usual procedure is to use a price elasticity that has been estimated from an econometric model to calculate the expected amount of repression. The expected repression can be calculated either by using the price elasticity directly or (what is usually done) by simulating the model first under the status quo, then with the new tariff, and then by attributing

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5 “Repression” in this situation refers to the revenue that would be lost because of the existence of a non-zero price elasticity.
repression to the difference. The models in question are usually theoretically based, often with considerable dotting of i’s and crossing of t’s. Question: Is this procedure an appropriate application of the underlying neoclassical demand theory?6

The answer is clearly yes, in our opinion, provided the question is framed in terms of comparative statics (i.e., of the “what if” variety) as opposed to real-time dynamics. However, if the question is framed in terms of estimating what the actual impact of the tariff change would be on telecommunications usage, then the question would involve real-time dynamics and the answer would in general be no, for the invariances required of a conservative system would once again be unlikely to be fulfilled.

The upshot, thus, would seem to be that the neoclassical theory of consumer choice can be meaningfully used in assessing alternative courses of action at a planning stage, but cannot be used in predicting the result from a course of action actually selected. As a general conclusion this seems to be a correct statement, for neoclassical theory imposes invariance assumptions that real-time consumption behavior almost certainly invalidates. Yet, this is not to say that conventional theory cannot be modified to accommodate the invalidations that arise. This can be done, but the modifications required have to be embedded in a theoretical structure that allows for an “arrow of time.” It is to this that we now turn.

2.3 Dynamics: Some Preliminaries

That consumption behavior needs to be analyzed taking dynamics explicitly into account has been recognized for years and has been the subject of much empirical research, including much of our 1970 book. For the most part, however, the dynamics that have been postulated have been of a classical form. The notion of “earlier and later” is center stage, but the laws of motion ply in mechanical time, motion is reversible, and real time is important only for purposes of measurement and empirical application. Heraclitus’s dictive that “one cannot step in the same river twice” is not observed by most existing dynamical models. However, as we shall now discuss, it might seem that applied econometricians go to great lengths in attempts to assure that this is the case.

Something that is often not recognized, at least in the terms being discussed in this section, is that the conditions that must be satisfied for the validity of the statistical inference in applied econometrics are in a sense isomorphic to the invariance conditions for a conservative vector field.7 For illustration, consider the estimation of a system of theoretically plausible demand functions that have been derived (say)

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6 We leave till later the question of whether the parameters estimated in the econometric model can be identified with the parameters of the theoretical model.

7 That this is indeed the case was already implicit in Haavelmo’s classic monograph on the probability approach in econometrics (1944). It is also just below the surface in the reinterpretation of extension of the Haavelmo paradigm by Spanos (1989). LDT’s reinterpretation of the Haavelmo paradigm is given in Chapter 10 of Taylor (1994).
from the Stone–Geary–Samuelson utility function. Suppose that the demand functions are estimated, subject to all of the integrability conditions, from an appropriate body of data. In this situation, a conservative vector field of preferences is not only assumed, but is, in fact, imposed as part of estimation. Assuming the econometrician is well-schooled in the Haavelmo paradigm, however, this imposition is not as mechanical as it might appear. For a number of problems have to be dealt with before estimation actually occurs, most of them related to the fact that the data set being analyzed arises not out of controlled laboratory conditions, but from a natural experiment generated by history. Be that as it may, the sine qua non of the Haavelmo paradigm nevertheless is a presumption that the observations in the data set can be viewed as a sample drawn at random from a common underlying population.

For this presumption to be justified, it becomes a major task of analysis to model not only the phenomenon of interest (namely, the relationship between consumption, prices, and income), but also the structure of the natural experiment that generated the data to begin with. **Structural changes** during the period of the sample have to be taken into account, as well as the fact that most behavior represented in the data set will reflect disequilibria. We put structural changes in italics because, in the natural experiment that generated the data, there are two different forms of structural change to contend with. The first refers to autonomous structural change arising from the “outside” that affects preferences, and therefore consumption, but which is not, itself, consumption caused. The other form of structural change is the endogenous change in the field of marginal utilities caused by real-time consumption.

Of the two types of structural change, the second type is clearly the most problematic to take into account, for it requires an explicit representation of the feedback on preferences as consumption occurs. The usual way of accomplishing this empirically is to specify a model in which current consumption depends not only upon current income and prices, but upon past consumption as well. Endogenous preference changes are assumed to be reflected in the coefficient on past consumption. An alternative procedure, which relates to the state-adjustment model of the two editions of *Consumer Demand in the United States*, is to postulate a state-dependent vector field of marginal utilities in which the composition of the field at any point in time depends upon a set of state variables, which themselves evolve in response to real-time consumption together with the passage of mechanical time.

If the econometrician is successful in specifying a model that appropriately takes into account the two types of structural change (and also appropriately reflects the probability structure of the random component of the implicit natural experiment), then the requirements of the Haavelmo paradigm will be satisfied. Moreover, it can also be argued that the invariance conditions for a conservative vector field will be

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8 Care must be taken at this point to distinguish between mechanical dynamics that occur in mechanical time (and reflect disequilibrium behavior) and real-time dynamics that reflect the feedback of consumption on preferences. With the way that many models are specified, it is unlikely that these two forms of dynamics can be separately identified. The distinction between these two concepts of dynamics is discussed in much more detail in Section 2.6 below.

satisfied as well. Estimation of the model can then proceed under the assumption that the parameters estimated in the econometric model are to be identified with the parameters of the underlying theory.

The argument that the invariance conditions for a conservative vector field are satisfied when the Haavelmo assumptions are met can be stated as follows: If the real-time feedback of consumption on preferences is appropriately modeled, then the sample can be viewed as a sequence of state-dependent conservative vector fields in which the states are determined exogenously. Historical time is no longer reflected in the data, because its effects are held constant through the explicit modeling of how the states, themselves, evolve. Dynamics may still be present, but these would be of the mechanical variety and therefore invariant to historical time. Thus, each observation in the data set can be viewed as having arisen in answer to a “what if” type of question, namely: What quantities would be demanded if income were this and prices were thus and so?

Though the conditions for a conservative vector field may be satisfied for purposes of estimation, it does not follow (as already discussed) that they would be satisfied for purposes of using the estimated model to predict the evolution of real-time consumption in response (say) to a change in prices. As just noted, the estimated model could be used to analyze “what if” types of questions in which there is no presumption of actual consumption ever occurring. But to predict real-time consumption would require also being able to predict real-time evolution of the state-dependent vector fields of preferences.\(^\text{10}\) The problem, clearly, is that predicting human consumption behavior is materially different from predicting the motion of an inanimate particle, for the motion of an inanimate particle does not interact with the forces defined in the field. With human behavior, on the other hand, motion does interact with these forces, for what one consumes today alters the marginal utilities that inform what one will consume tomorrow, perhaps in unpredictable ways.

### 2.4 State- and Flow-Adjustment Models of Consumption

In the two editions of *CSUS*, two dynamical models were employed: a state-adjustment model, in which flows react to discrepancies between actual and desired states; and a flow-adjustment model, in which flows react to discrepancies between actual and desired flows. In applying these models to more than 80 categories of personal consumption expenditure from the National Income and Product Accounts for the years 1929–1964 (as well as higher levels of aggregation for a number of other countries), dynamical effects were found across a wide variety of durables,

\(^{10}\) This is obviously a tall order, but, as will be discussed later in this chapter, there is hope that, as we come to better understand how the brain is organized and functions, appropriate evolutionary laws (perhaps even of a mechanical variety) can be formulated.
nondurables, and services. We begin in this section with brief descriptions of these models in their original form.\footnote{A generalization of these models suggested by Bergstrom and Chambers (1990) will be developed in Chapter 13.}

The point of departure for the state-adjustment model is a demand function that relates the flow of expenditures for a good or service at time \( t \), \( q(t) \), to the level of a state variable, \( s(t) \), the flow of income, \( x(t) \), and the level of price, \( p(t) \):

\[
q(t) = \alpha + \beta s(t) + \gamma x(t) + \lambda p(t).
\] (2.7)

Time is measured continuously. Later in this chapter, we will discuss the inclusion of a state variable in genetic terms. However, for now, it is useful to return to our original motivation for its presence as presented in the 1970 edition of \textit{CDUS}:

A simple example will illustrate the principles involved. Let \( q(t) \) be an individual’s demand for clothing during a very short time interval around \( t \), let \( x(t) \) be his income during that interval, and let \( s(t) \) be his inventory of clothes at time \( t \). More exactly, let \( q(t) \) be the rate of demand at time \( t \) and \( x(t) \) be the rate [of flow] of income at that time. All other variables are ignored for the time being. Then the basic assumption is that

\[
q(t) = \alpha + \beta s(t) + \gamma x(t),
\] (2.8)

so that the individual’s current demand for clothing depends not only on his current income, but also on his stock of clothing. We may expect that, for a person with given tastes and given income, the more clothes he has to begin with, the fewer he will be buy currently. In the case of a durable good such as clothing the stock coefficient \( \beta \) will be negative, but it will now be shown that equation (2.8) may also hold for other types of commodities if we allow a more general interpretation of \( s(t) \). In fact the equation can represent not only the stock-adjustment behavior just described, but also habit formation or inertia, which is apparently a more widespread phenomenon.

Consider a commodity of which consumers do not normally hold physical inventories of any significance, say tobacco. By all accounts tobacco consumption is habit-forming, which means that it does not adjust immediately to changes in income (or in prices, for that matter) and that current consumption is positively influenced by consumption in the more or less recent past. In this case, we can say metaphorically that the consumer has built up psychological stock of smoking habits. His current consumption will be affected by that stock (or, if one prefers, “state variable”) just as it is for clothing, but the sign of \( \beta \) will now be positive: the more he has smoked in the past, the more he will smoke currently (tastes and income again being given).

The question arises at once: How can we measure such a psychological stock? It will be shown in a moment that under certain reasonable assumptions there is no need to measure it, because \( s(t) \) can be eliminated from the regression equation. Yet it should be stressed first that this difficulty is not peculiar to habit-forming commodities, but arises almost as strongly for durable commodities such as clothing.\footnote{In fact, there is often no a priori basis for deciding whether, in the demand for a commodity, habit formation or stock adjustment will predominate.} In the latter case we cannot measure \( s(t) \) simply by the number of suits, shirts, and such, for some of these may worn out and due for replacement; moreover, their heterogeneity also makes direct measurement hard. Clearly some depreciated measure of inventories is needed, but the appropriate depreciation rates are usually not known a priori and would either have to be estimated from the data or
guessed. Hence even for durables, where the state variable has a concrete interpretation, it is desirable to eliminate it.

This can be done in the following manner. First consider the accounting identity
\[ \dot{s}(t) = q(t) - w(t), \] (2.9)
where \( \dot{s}(t) \) stands for the rate of change in the (physical or psychological) stock around time \( t \) and \( w(t) \) stands for the average “using up” of “depreciation” of that stock at the same time. From now on, moreover, we shall assume that
\[ w(t) = \delta s(t) \] (2.10)
where \( \delta \) is a constant depreciation rate. Hence the rate of depreciation at any time \( t \) is proportional to the stock at that time. The assumption of proportionality corresponds to the “declining balance” method of depreciation, which has been found to be realistic in many practical situations. Combining equations (2.9) and (2.10) we find that
\[ \dot{s}(t) = q(t) - \delta s(t). \] (2.11)
Integration of equation (2.11) shows, incidentally, that
\[ s(t) = \int_{-\infty}^{t} q(u)e^{\delta(u-t)}du \] (2.12)
or, in words, the state variable at any time is equal to the sum of the discounted flows bought up to that time. This formula applies equally well to durable as well as to habit-forming commodities. Next eliminate \( s(t) \) from equation (2.11) by using equation (2.8):
\[ s(t) = q(t) - \frac{\delta}{\beta} [q(t) - \alpha - \gamma x(t)]. \] (2.13)
Now differentiate equation (2.8) with respect to time and substitute equation (2.13) for \( s(t) \):
\[ \dot{q}(t) = \alpha \delta + (\beta - \delta) q(t) + \gamma \dot{x}(t) + \gamma \delta x(t), \] (2.14)
which is a first-order differential equation involving only observable quantities \( q \) and \( x \).

The long-run (or steady-state) solution for the dynamic system described by equations (2.7) and (2.11) is obtained by setting \( \dot{s}(t) = 0 \), and then solving for \( q \) in terms of the exogenous quantities \( x \) and \( p \):
\[ \hat{q} = \frac{\alpha \delta}{\delta - \beta} + \frac{\gamma \delta}{\delta - \beta} x + \frac{\lambda \delta}{\delta - \beta} p. \] (2.15)
The dynamics of the system can then be easily characterized in terms of the derivatives for \( q \) with respect to \( x \) and \( p \). Changes in income or price will have two types of effects on \( q \): a short-run (or instantaneous) effect that arises before there is any feedback on the state variable and a long-run (or steady-state) effect that reflects full adjustment in the state variable. From equations (2.7) and (2.15), we see that
the short- and long-run derivatives with respect to $x$ and $p$ are given by $\gamma$ and $\lambda$, and $\gamma \delta / (\delta - \beta)$ and $\gamma \delta / (\gamma - \beta)$, respectively.

As noted, the model can be applied to a full complement of consumption expenditures, whether they be durables, nondurables, or services. The only difference is in the interpretation of the state variable. For durables, the state variable can be seen as representing physical stocks (such as automobiles), while for nondurables and services, the state variable can be seen as representing psychological quantities (such as the stocks of smoking habits). The coefficient $\beta$ is expected to be negative in the case of durables, but can be positive with nondurables and services. A positive $\beta$ corresponds to habit formation, while a negative $\beta$ corresponds to inventory (or stock) adjustment.

The dynamics of the two cases are obviously different. Consider a change in income in conjunction with the short- and long-run derivatives for $q$, $\gamma$, and $\gamma \delta / (\delta - \beta)$. The former is seen to differ from the latter by the factor $\delta / (\delta - \beta)$. Since $\delta < 0$, we will have $\delta (\delta - \beta)$ less than 1 for $\beta$ less than 0, and greater than 1 for $\beta$ greater than 0. This implies that short-run derivatives will be greater than long-run derivatives for goods characterized by inventory adjustment, and the opposite for goods characterized by habit formation. Expenditure flow rates for goods subject to inventory adjustment respond quickly to changes in income or price, while flow rates for goods subject to habit formation respond sluggishly.

Returning to equation (2.7) for a moment, we see that, in long-run equilibrium,

$$\hat{q} = \alpha + \beta \hat{s} + \gamma x + \lambda p. \quad (2.16)$$

Subtraction of (2.16) from (2.7) then yields,

$$q(t) - \hat{q} = \beta [s(t) - \hat{s}], \quad (2.17)$$

which is the relationship that gives the state-adjustment model its name, for expenditures can be interpreted as adjusting so as to bring the state variable into line with its steady-state value.

We now turn to the flow-adjustment model, whose structural equations (again in continuous time) are given by

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13 An alternative (and physiologically appealing) interpretation of the state variable in the case of habit formation is as a measure of memory. Initial exposure to a consumption activity gives rise to new (or alters existing) synaptic connections, which can become strengthened with subsequent exposures. The coefficient $\beta$ then measures the “pleasure” associated with the activity, while $\delta$ measures the rate at which memory of it fades. For an extraordinarily readable account of the biological processes involved, see Chapter 15 of Kandel (2006). Also, care must be taken not to equate habit formation described here with habituation in the psychological literature, which refers to “a simple non-associative form of learning in which a subject learns about the properties of a single, innocuous stimulus.” Again, see Kandel (2006).

14 Stability of the dynamical system described by equations (2.7) and (2.11) requires $\delta < \beta$, which is to say that habit formation should never be so great as to overcome the tendency of the habit to wear off. The latter, should it occur, would characterize addiction.
\[ \dot{q}(t) = \theta (\hat{q}(t) - q(t)), \quad (2.18) \]
\[ \hat{q}(t) = \kappa + \mu x(t) + \xi p(t). \quad (2.19) \]

Substituting for \( \hat{q}(t) \) in (2.18) from (2.19), we have
\[ \dot{q}(t) = \theta \kappa + \theta \mu x(t) + \theta \xi p(t) - q(t). \quad (2.20) \]

The dynamics in this formulation can be interpreted in terms of an adjustment in the flow rate of expenditures so as to partially eliminate discrepancies between the actual flow rate of \( q \) and a desired rate \( \hat{q} \) as determined in equation (2.19). Consumers in this model are assumed to target the flow variable, whereas in the state-adjustment model, they are assumed to target a state variable. It is to be noted, however, that the decision variable in this model is \( \hat{q} \), whereas the action variable is \( \dot{q} \). Consequently, from equations (2.20) and (2.19) we see that the short-run derivatives of \( q \) with respect to income and price are \( \theta \mu \) and \( \theta \xi \), respectively, while the long-run derivatives are \( \theta \) and \( \xi \).

As no state variable is present in the flow-adjustment model, dynamics arise because of delays and constraints in adjusting actual to targeted expenditure flows. In discrete time (about which more later), adjustment is of the standard geometric distributed-lag variety, in that a change in income or price this period will have some impact next period, a further (but smaller) impact next period, and so on. The dynamics are accordingly reminiscent of habit formation in the state-adjustment model. Inventory adjustment behavior cannot arise in this model.\(^{15}\) The dynamics in this case can be seen as representing “outside” varieties of dynamics, as discussed in the preceding section. This is in contrast to the state-adjustment model, where the feedback of consumption onto the state variable gives rise to dynamics of the “inside” variety, that is, of the type that allows current consumption to affect marginal utilities.

A discrete time model for the state-adjustment model for empirical application is obtained by integrating equations (2.7) and (2.11) over finite intervals of time, and then by solving the resulting relationships for the reduced form for \( q \). Specifically, we begin by integrating equations (2.7) and (2.11) over the interval from \( t \) to \( t + h \):\(^{16}\)
\[ q_t = \alpha h + \beta s_t + \gamma x_t + \lambda p_t, \quad (2.21) \]
\[ \Delta^s s(t) = q_t - \delta s_t, \quad (2.22) \]

\(^{15}\) However, as will be noted in Section 10.3, inventory-adjustment behavior can be inferred in the flow-adjustment model for large values of \( \theta \).

\(^{16}\) In empirical application, \( h \) will be set to one, so that \( t \) will as usual refer to the current period and \( t-1 \) to the immediate past period. However, the use of an arbitrary period of \( h \) is useful in relating (at a theoretical level) the relative magnitudes of structural coefficients estimated from quarterly data (say) to those estimated from annual data.
where

\[ \int_t^{t+h} q(t) dt, \quad \int_t^{t+h} s(t) dt, \text{ etc.} \]  \hspace{1cm} (2.23)

Similarly, we will have for \( q_{t-h} \):

\[ q_{t-h} = \alpha h + \beta s_{t-h} + \gamma x_{t-h} + \lambda p_{t-h}. \] \hspace{1cm} (2.24)

We now subtract equation (2.16) from equation (2.13):

\[ q_t - q_{t-h} = \beta(s_t - s_{t-h}) + \gamma(x_t - x_{t-h}) + \lambda(p_t - p_{t-h}). \] \hspace{1cm} (2.25)

We now approximate \( s_t - s_{t-h} \) by \( \frac{h}{2} \left[ \Delta^* s(t + 1) + \Delta^* s(t) \right] \).\(^{17}\) Hence, from equation (2.22)

\[ s_t - s_{t-h} \approx \frac{h}{2} \left[ q_t + q_{t-h} - 2\delta(s_t + s_{t-h}) \right], \] \hspace{1cm} (2.26)

so that substitution into equation (2.25) (and assuming that the approximation is good enough for practical purposes) gives

\[ q_t - q_{t-h} = \frac{h\beta}{2} [q_t + q_{t-h} - 2\delta(s_t + s_{t-h})] + \gamma(x_t - x_{t-h}) + \lambda(p_t - p_{t-h}). \] \hspace{1cm} (2.27)

Returning now to equations (2.21) and (2.24), we have for \( s_t \) and \( s_{t-h} \)

\[ s_t = \frac{1}{\beta}(q_t - \alpha h - \gamma x_t - \lambda p_t), \] \hspace{1cm} (2.28)

\[ s_{t-h} = \frac{1}{\beta}(q_{t-h} - \alpha h - \gamma x_{t-h} - \lambda p_{t-h}), \] \hspace{1cm} (2.29)

which, when substituted for \( s_t + s_{t-h} \) in equation (2.27), yields for \( q_t - q_{t-h} \) (after rearrangement and notational simplification):

\[ q_t = A_0 + A_1 q_{t-h} + A_2 x_t + A_3 x_{t-h} + A_4 p_t + A_5 p_{t-h}, \] \hspace{1cm} (2.30)

where

\[ A_0 = \frac{\alpha \delta h^2}{A}, \] \hspace{1cm} (2.31)

\[ A_1 = \frac{1 + \frac{h(\beta - \delta)}{2}}{A}, \] \hspace{1cm} (2.32)

\(^{17}\) This involves application of the mean-value theorem applied to interval of length 2 \( h \) between \( t-h \) and \( t+h \). If \( s(t) \) were to behave linearly within this interval, then the approximation would of course be exact.
2.4 State- and Flow-Adjustment Models of Consumption

\[ A_2 = \frac{\gamma(1 + \frac{\delta h}{2})}{A} , \]  
\[ A_3 = -\frac{\gamma(1 - \frac{\delta h}{2})}{A} , \]  
\[ A_4 = \frac{\lambda(1 + \frac{\delta h}{2})}{A} , \]  
\[ A_5 = -\frac{\lambda(1 - \frac{\delta h}{2})}{A} , \]  
\[ A = 1 - \frac{h(\beta - \delta)}{2} . \]  

For computational reasons, it is convenient to express \( x_t \) as \( (x_t - x_{t-h}) + x_{t-h} \equiv \Delta x_t + x_{t-h} \) (and similarly for \( p_t \)), which transforms equation (2.30) into

\[ q_t = A_0 + A_1 q_{t-h} + A_2 \Delta x_t + A_3 x_{t-h} + A_4 \Delta p_t + A_5 p_{t-h} , \]  

where now \( A_3 \) and \( A_5 \) are equal to

\[ A_3 = \frac{\gamma \delta h}{A} , \]  
\[ A_5 = \frac{\lambda \delta h}{A} . \]  

Equation (2.38) represents the finite approximation, as a difference equation, to the first-order differential equation in expression (2.14).\(^{18}\)

The structural coefficients \( \alpha, \beta, \gamma, \lambda, \) and \( \delta \) are obtained from \( A_0, \ldots, A_5 \) in equation (2.38) as follows:\(^{19}\)

\[ \alpha = \frac{A_0(2A_2 - A_3)}{h^2 A_3(A_1 + 1)} , \]  
\[ \beta = \frac{2(A_1 - 1)}{h(A_1 - 1)} + \frac{2A_3}{h(2A_2 - A_3)} , \]  
\[ \gamma = \frac{2A_2 - A_3}{h(A_1 + 1)} , \]  
\[ \lambda = \frac{2A_4 - A_5}{h(A_1 + 1)} . \]  

\(^{18}\) The derivation of equation (2.38) is the original one from CDUS. An alternative not involving the calculus is given by Winder (1971).

\(^{19}\) The depreciation rate \( \delta \), it will be noted, is obtained from the coefficients \( A_4 \) and \( A_5 \), as well as from \( A_2 \) and \( A_3 \), which means that \( \delta \) is overidentified. The implications of this will be discussed in the next chapter.
\[ \delta = \frac{2A_3}{h(2A_2 - A_3)}, \]
\[ = \frac{2A_5}{h(2A_4 - A_5)}. \]  

Turning now to a finite approximation for the flow-adjustment model, defined over the interval \( t \) to \( t + h \), we have [from expressions (2.18) and (2.19)]

\[ \Delta^* q_t = \theta (\hat{q}_t - q_t), \]  

\[ \hat{q}_t = \kappa h + \mu x_t + \xi p_t, \]

where \( q_t \) and the other quantities are as defined in expression (2.23). Using the mean-value theorem as before, we approximate \( q_t - q_{t-h} \) by \((h/2)(\Delta^* q_t + \Delta^* q_{t-h}),\)\(^{20}\) which after rearrangement and notational simplification yields

\[ q_t = A_0^* + A_1^* q_{t-h} + A_2^* (x_t + x_{t-h}) + A_3^* (p_t + p_{t-h}), \]  

where

\[ A_0^* = \frac{2\theta \kappa h}{2 + \theta h}, \]  

\[ A_1^* = \frac{2 - \theta h}{2 + \theta h}, \]  

\[ A_2^* = \frac{2\theta \mu h}{2 + \theta h}, \]  

\[ A_3^* = \frac{2\theta \xi h}{2 + \theta h}, \]  

\[ \theta = \frac{2(1 - A_1^*)}{h(1 + A_1^*)}, \]  

\[ \kappa = \frac{A_0^*}{h(1 + A_1^*)}, \]  

\[ \mu = \frac{2A_2^*}{h(1 + A_1^*)}, \]  

\[ \xi = \frac{2A_3^*}{h(1 + A_1^*)}. \]

\(^{20}\) The logic of this procedure is that we wish to obtain a difference equation in an approximation for \( \dot{q}(t) \), hence the focus on \( q_t - q_{t-h} \).
2.5 A Neuroscience Approach to Consumer Behavior

In the mid-1980s, a young colleague of one of the authors mentioned that real progress was not going to be made in understanding consumption behavior until we better understand how the brain is organized and functions. In the last 20 years, the neurosciences (together with evolutionary biology and psychology) have made great strides in this direction, and it seems to us that sufficient is now known about the brain for one to begin putting the theory of consumer behavior in a neurobiological framework. Such is the motivation for the rest of this chapter.\(^{21}\)

We begin with the following list of postulates and principles:

1. All laws of physics, chemistry, and evolutionary biology are respected.
2. Ditto for currently established structures and functioning of the brain.
3. Human beings are social animals.
4. There exists a hierarchy of five Maslovian needs that are genetic in nature, namely, physiological needs, security, love, self-esteem, and self-actualization.\(^{22}\)

As a point of departure, we take the evolutionary phenomenon that the only goal of genes is to reproduce. Reproduction requires energy, or a need to make a living, which at the most basic level is simply being able to find enough food to survive. For most animals, time is proscribed in the search for food and other activities of physical survival. However, for human beings, at least for those fortunate enough to live in countries where income is in excess of the subsistence level, things are different, for there is time beyond that needed for basic survival. The question then becomes how to occupy this surplus time. In contrast to traditional demand theory, our view is that an individual’s main preoccupation is how to spend time rather than income. Unlike income, for which most people have to work, time appears each day as a gift. The amount is fixed, and its receipt cannot be escaped.

Now, here is the key to how time will be utilized: The physiology and psychology of the human organism is such that unless a certain number of neurons are firing at any time, the individual is uncomfortable. In psychological terms, arousal is a too low a level. In general, stimulation in some form is required in order to maintain arousal, and much of this occurs through the consumption of market goods and services. Since goods and services are scarce, some of the individual’s time must be spent in acquiring the income needed for their purchase. When not asleep or at work, however, the basic question facing the individual is how to allocate time amongst consumption activities in order to maintain an acceptable level of arousal. Since the time that is available is fixed, people typically run out of it, so that time itself

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21 Reference must obviously be made at this point to the flourishing subfield of behavioral economics that is increasingly combining psychology and economics with the neurosciences. Camerer et al. (2005) provide an excellent recent survey.

becomes scarce. When this happens, time must be used more efficiently. Generally, this involves trading off time for market goods in consumption activities. For most people, the primary force in reducing the scarcity of time is increased efficiency at work (i.e., an increase in the real wage rate), but consumption activities generally become more time efficient as well.\footnote{How the latter is often accomplished is described in detail, with great insight and a highly entertaining manner, by Linder (1970).}

In general, an acceptable level of arousal will involve combining novelty with redundancy, where redundancy in this context refers to the amount of familiarity in a consumption activity and can be identified with what Stigler and Becker (1977) define as consumption capital.\footnote{See also Tversky and Sattath (1979).} Too much redundancy leads to boredom because everything has an aura of \textit{deja vu} (or “familiarity breeds contempt”), while too much novelty leads to confusion and immobility because one does not know what to expect. Some surprise is highly desirable, but too much causes discomfort because of limited capacity to process new information. Redundancy is created through exposure and arises through the internal dynamics of consumption. The quest for novelty, in contrast, is seen as in hering in the psyche. It functions independently of exposure (although exposure to a new activity can remind one how pleasant novelty can be) and provides the motivation for seeking new activities. The quest for novelty can thus be seen as leading to wants being endless, which in turn continually incites the appearance of new goods.\footnote{In Chapter 18, it will be argued that, in giving rise to a continuing demand for new goods, the quest for novelty is a primary driver of economic growth in nonsubsistence economies.}

We now turn to a detailed development of the ideas of these paragraphs, taking as a point of departure the assumption that tastes and preferences derive, at the most fundamental level, from motivations that are products of evolution, and are therefore genetically based. In one of the classic 20th-century treatises in psychology, \textit{Motivation and Personality}, Abraham Maslow (1954) identified five fundamental genetically influenced motives driving human behavior, namely, physiological needs (air, food, water, and sex); security (both physical and psychological); love (desire for affection and a sense of belonging); self-esteem (desire for a stable, firmly based, high self-evaluation, self-respect, and respect for others); and self-actualization (desire for self-fulfillment).\footnote{These needs will be described and discussed in detail in Section 2.7 below.}

Although economists are traditionally hesitant to speak in terms of needs (as opposed to wants), physical minimums of food and shelter are obviously \textit{needed} for survival, and to a lesser extent, the same can also be said to be true of security. Love, self-esteem, and self-actualization needs will be put to the side for the moment. The genes dictating survival behavior in terms of physiological and security needs should, because of evolutionary pressure, be fairly invariant across humans (just as they are within animal species), in which case one ought, accordingly, to be able to identify blocks of consumption that are reasonably invariant across individuals.
and time. At the subsistence level, there is thus little scope for choice. However, once subsistence is crossed, new factors come into play, which generate possibilities for choice. Included in these are cultural and social factors, but perhaps most importantly, the accumulation of consumption experience.

At base, what we mean by consumption experience is the idea that every activity involves the firing of a network of neurons in the brain. The first time that a consumption activity is undertaken, a network of firing neurons has to be created, which is then in place (at least partially) the next time that the activity is contemplated. Once an individual has experienced an activity, the previous exposure forever alters the lens (i.e., the tastes and preferences) through which it is viewed. The feedback of consumption on tastes and preferences, which in turn affects the desire (or a lack thereof) for future consumption, clearly represents a form of consumption dynamics. A simple representation of this situation is with a single (generally unobservable) state variable as in the original state-adjustment model described in the preceding section.

As has been noted, the state variable in the state-adjustment model allows for two types of dynamical behavior, depending upon the sign of the coefficient $\beta$, which attaches to it: $\beta < 0$ has been described as representing adjustment of current consumption (or more particularly expenditure) to the inventory of the good that is held, while $\beta > 0$ has been described in terms of habit formation or inertia. However, while we ordinarily think of a negative $\beta$ being associated with durable goods such as automobiles or appliances, this need not be the case, for stock-adjusting behavior can also be associated with rapid short-run satiation (such as occurs with repeated hearing of the same song or musical composition). Continual firing of the same neuronal network can, in this situation, be seen as leading to discomfort, in which case a negative $\beta$ can be interpreted as counseling against short-run repetition of the activity. On the other hand, a positive $\beta$ for a consumption activity, in addition to indicating the presence of habit formation, can also be interpreted as signifying that repetition of the activity leads to a strengthening of the associated neuronal network, in short, a form of learning.

The problem with these interpretations of the state-adjustment model is a surfeit of riches, for the state variable can allow for many phenomena, none of which in ordinary circumstances can be separately identified. This being the case, it will be useful to discuss a brain-based framework that allows for a much richer dynamics than is possible with the simple state-adjustment model.

### 2.6 Brain Structure and Consumption Dynamics

It is now generally accepted in the neurosciences that the human brain functions modularly, in that it consists of distinct, but interconnected, centers whose functionalities overlap (at least to some extent), but which in general practice a

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27 Cf., Chapter 5.
28 Cf., Cross (1983); see also Kandel (2006).
29 Much of the material in this section first appeared in Taylor (1992).
division of labor. A related view is that the Homo sapiens brain really consists of three brains: a “lizard” brain that is located at the top of the spinal column that controls autonomic processes such as breathing and heartbeat; a “monkey” brain that lies at the base of the skull and that (among other things) is capable of learning from experience; and a third-level brain that occupies most of the brain cavity and what we ordinarily think of as the human brain.

As noted earlier, a primary motivation in this chapter is a strong belief on our part that demand analysis can benefit materially from an approach that takes its cue from the organizational structure and functioning of the brain. The purpose of this section is to show a few of these benefits by examining some implications for consumption behavior of the three-level modular brain structure just described. We are especially interested in the consumption dynamics that such a structure can imply. One might think that simple brain structures might give rise to simple dynamics, but this is not the case, for we shall see that the dynamics generated by the lizard and monkey brains can be surprisingly complex. Indeed, most of the standard dynamical consumption models, including the original state- and flow-adjustment models, can be adduced from the functionalities of the lizard and monkey brains.

### 2.6.1 Assumptions and Terminologies

Our point of departure will be a stylized human brain that is assumed to consist of three connected levels. These three levels will be referred to as the alpha, beta, and gamma brains, with the alpha brain at the lowest level and the gamma at the highest. The assumptions concerning the functionalities of the three levels are as follows:

**Alpha Brain:** The alpha brain is assumed to control the autonomic process of the body, such as breathing, heartbeat, and the standard reflexes. This brain can be viewed as monitoring the basic physical life needs of the organism in terms of minimum consumption levels of food, clothing, and shelter.

**Beta Brain:** The beta brain, unlike the alpha brain, is capable of learning from experience of figuring out the most efficient way of achieving a particular goal. It is capable of forming likes and dislikes and acting upon these in relationships with others, and in responding to changes in environment. Many emotions are seated in this brain, including fear, love, anger, anxiety, excitement, boredom, and regret. Habits can be formed and budget constraints recognized.
Gamma Brain: Unlike the alpha and beta brains, the gamma brain is capable of abstract reasoning and of thinking through the implications of a particular action. It can form expectations and act upon the basis of these expectations, and can embellish or dampen actions arising out of the alpha and beta brains. The gamma brain recognizes the passage of real time and can recognize that tastes and preferences can be real-time dependent, and is capable of initiating actions to counteract the destructive consequences of certain consumption activities. It is the overall monitor of consumption activity and searches for activities that contain sufficient novelty to relieve boredom, but with enough redundancy to forestall panic.  

The gamma brain is assumed to have a modular structure, consisting of a group of interconnected centers that have some functional overlap, but which in general practice a division of labor. Information is assumed to flow in both directions among these centers. Information flow in the vertical structure, however, is assumed to be one-way. The beta brain receives information from the alpha brain, the gamma brain receives information from both the alpha and the beta brains, but the alpha brain receives no information from the beta and gamma brains, and the beta brain receives no information from the gamma brain.

The brain structure being assumed necessitates several breaks from conventional demand theory, beginning with the standard assumption that the individual optimizes with respect to a single utility indicator. While this assumption could probably be retained, it would require the presence of a “headquarters” center in the gamma brain of a type that we do not presently wish to postulate, the reason for which will shortly become clear. It is assumed instead that the three brains pursue individual goals, which in most circumstances are mutually compatible (or even reinforcing). The goal at each level will be taken to be “comfort.”

Comfort at the alpha level is defined in terms of motivation to maintain the autonomic processes at proper levels. For processes, such as metabolism, that require goods as inputs, discomfort is dealt with by the sending of signals to the upper brains, which in turn decide upon the inputs needed and how they are to be provided. Comfort at the beta level will be defined in the next subsection. Comfort at the gamma level is defined in terms of an “acceptable” filling of time as discussed in Section 2.6 above. As described in Section 2.6, when not asleep or working the basic question facing an individual is how to occupy one’s time, which appears each day as a gift, so as to maintain neuronal activity at an acceptable level, which amounts to allocating time among consumption activities. Such decisions are assumed to lie in the province of the gamma brain.

A second break with standard demand theory, at least at the level of principle, is the separation of consumption from expenditure. The view in the present context is that the individual has two roles in the theory of demand, as a consumer and as

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33 For a discussion of novelty and redundancy in this context, see Scitovsky (1976), also Tversky and Sattath (1979).
a purchasing agent. Time is the constraint on consumption behavior, while income is the constraint on expenditure. An individual, acting as a consumer, decides what consumption activities to pursue, and the goods required as input are assumed to be in inventory in amounts necessary for the activities to proceed. Income becomes a constraint when the individual, acting as a purchasing agent, receives orders for the goods to be stocked.

A third break with standard demand theory relates to orderings of wants and preferences. Economists since Pareto have been reluctant to think in terms of hierarchical preferences, but that some needs are of higher order than others is a clear consequence not only of common sense but of the brain structure that is being assumed. The physiological needs of the autonomic processes controlled by the alpha brain are cases in point. Later, in Sections 2.8 and 2.9, we will find it useful to assume that needs associated with certain psychological processes have a hierarchical structure as well.

Still another break with standard demand theory relates to rationality. Two concepts of rationality are involved: the psychologist’s concept, which focuses on the processes of decision-making; and the economist’s concept, which focuses on outcomes and is usually identified with transitivity of preferences. The individual here is assumed to be rational in the psychologist’s sense, but not necessarily in the economist’s sense. More will be said about this later in this section.

We now turn to a discussion of factors that motivate consumption behavior of the beta and gamma brains. From evidence generated in experiments involving rats and pigeons “workers,” it is clear that the beta brain is capable of organizing much of the static demand and labor-supply behavior predicted by the Slutsky–Hicks–Allen theory of demand. Animal workers recognize budget constraints and respond in predictable ways to changes in prices, income, and wage rates.\(^34\) The beta brain is also clearly capable of learning from experience. The suggestion, accordingly, is that much of observed demand behavior can be viewed as arising in the beta brain—downward-sloping demand functions, negative income-compensated substitution effects, positively sloping supply curves of effort, and a potentially rich dynamics arising from experience and state- and flow-adjustment processes.

The assumption in this section is that the consumption behavior controlled by the beta brain is in response to signaled needs. These needs are psychological in origin as well as physiological. The physiological needs arise from the autonomic process controlled by the alpha brain, while the psychological needs are assumed to arise from psychological processes that reside in the beta brain itself. In both cases, it is postulated that the needs in question are defined in terms of desired values of certain flow or state variables. As actual values of these variables depart from the values desired, the beta brain initiates actions to eliminate the discrepancies. The dynamics involved, which involve a form of bang-bang control system, will be described in the chapter.

\(^34\) See Battalio et al. (1979) and Battalio and Kagel (1985).
2.6 Brain Structure and Consumption Dynamics

As noted, the primary motivation for the gamma brain is assumed to be to maintain a satisfactory overall state of physiological and psychological well-being.\(^{35}\) Doing this requires the processing of a great deal of information that flows not only from the external environment but also from the activities controlled by the alpha and beta brains, as well as those controlled by the gamma brain itself. The highest center in the gamma brain is viewed metaphorically as an executive processor whose basic function is to keep tabs on what is going on. Following Gazzaniga (1988), this executive processor is constantly engaged in “making sense” of information that arises from both within and without. It can acquire information both through interrogation (i.e., by directing questions such as why such and such is happening) and through the receiving of distress signals.

Tastes and preferences are assumed to be described in terms of a set of state variables. As has been described, included in the state variables will be concrete quantities such as stocks of durable goods and stocks of financial assets, as well as (a possibly long list of) variables of purely psychological dimensions, together with neuronal networks that have been formed from past consumption activities. State variables will also include the core beliefs and myths that in an important sense can be said to guide an individual’s behavior, not just consumption behavior, but behavior in general. The set of beliefs will embody the individual’s moral code, or sense of right and wrong, and will reflect attitudes toward self-interest, altruism, and cooperation.\(^{36}\)

### 2.6.2 Consumption Dynamics Associated with the Alpha and Beta Brains

The consumption dynamics that arise from actions of the alpha and beta brains are essentially of the state- and flow-adjustment variety discussed in Section 2.4. For notation, let \(q\), as before, denote the flow (measured instantaneously) of an input into an activity, and let \(s\) denote a state variable that is associated with the activity. Finally, let \(S^*\) denote a desired value of the state variable.\(^{37}\) Comfort, then, can be defined in terms of maintaining \(s\) equal to \(S^*\), in which case consumption can be defined in terms of manipulating \(q\) so as to achieve this relationship.

\(^{35}\) Comfort for the gamma brain could equally well be defined in terms of security in a broad sense—security in emotional and economic senses, as well as security in a physical sense.

\(^{36}\) Experimental evidence suggests that the executive processor (or what Gazzaniga refers to as the interpreter) is physically located in the left hemisphere of the gamma brain and is associated with the so-called language facility of this hemisphere. Gazzaniga sees core beliefs as arising out of the actions of this interpreter. See Gazzaniga (1985, Chapter 11).

\(^{37}\) There is no presumption of \(S^*\) being determined by an optimization process. For activities involving autonomic processes, the \(S^*\)s are physiologically determined; for activities involving psychological processes, they can be interpreted as representing minimum acceptable levels of comfort. On the other hand, this is not to say that elimination of a divergence of \(s\) from \(S^*\) may not be subject to an optimization process.
Assume \( s \neq S^* \) and consider

\[
\dot{q} = \gamma [q(t) - \alpha - \beta s(t)], \quad (2.57)
\]

\[
\dot{s} = q(t) - \delta s(t), \quad (2.58)
\]

where \( \dot{q} = dq/dt \), etc., and \( \alpha, \beta, \gamma, \) and \( \delta \) are parameters. Expression (2.57) can be interpreted as the consumption activity initiated by one of the lower-level brains in response to a divergence between \( s \) and \( S^* \). The parameters in this relationship represent both the behavioral response of the controlling brain and the production technology of the activity or process. Expression (2.58), on the other hand, represents the involuntary dynamic that describes the law of motion of \( s \).

The process described by expressions (2.57) and (2.58) will be in equilibrium, i.e., comfort will be achieved—when both \( \dot{s} \) and \( \dot{q} \) are zero, in which case we can write

\[
q^* = \alpha + \beta S^*, \quad (2.59)
\]

\[
q^* = \delta S^*. \quad (2.60)
\]

Subtracting and adding \( q^* \) to the term in brackets in expression (2.57) and then using expression (2.59) allows expression (2.57) to be written as

\[
\dot{q} = \gamma [q(t) - q^* - \beta \{s(t) - S^*\}], \quad (2.61)
\]

which describes how \( q \) adjusts in response to a discrepancy between \( s \) and \( S^* \).

For autonomic processes controlled by alpha brain, \( S^* \) can be interpreted as a physiological determined constant. In the case of nutrition, for example, \( S^* \) can represent a desired reserve of “nutritional well-being,” while \( \delta \) represents the body’s physiological demands on this reserve, and \( q \) represents the rate at which the reserve is replenished. On the behavioral side, \( \beta \) can be interpreted as representing the beta brain’s desired response in \( q \) to a change in the actual value of \( s \). This response, however, is tempered by the coefficient \( \gamma \).

The dynamical system described by expressions (2.57) and (2.58) embodies a number of well-known dynamic demand models, including both the flow- and state-adjustment models discussed in Section 2.5. The state-adjustment model is obtained as a limiting case by dividing expression (2.57) by \( \gamma \) and then letting \( \gamma \) become large. This corresponds to instantaneous adjustment in \( q \). The flow-adjustment model, in contrast, corresponds to the state variable \( s \) being absent for the behavioral equation, which could arise either because the state variable is irrelevant (\( \beta = 0 \)) or because the state variable depreciates instantaneously (\( s = 0 \)). Other interpretations of this model are also possible. As it stands, the model is identical with the generalization of the original H-T state-adjustment model that has been suggested by
Bergstrom and Chambers (1990) (which will be the focus of Chapter 13) and it can also support an error-correction interpretation.\footnote{See Sargan (1964), Hendry et al. (1984), Salmon (1982), and Pagan and Wichens (1989). The error-correction interpretation is as follows: In equilibrium, $q$ will be equal to $\alpha + \beta S$, so that $q(t) - \alpha - \beta S(t)$ represents the disequilibrium error; $q$ is then corrected in response to this error according to the adjustment parameter $\gamma$.}

\subsection*{2.6.3 Opponent Processes and Consumption Dynamics} \footnote{39 Much of the material from this section is taken from Taylor (1987, 1989a).}

While it is reasonable to define comfort in autonomic processes in terms of physiological constants, this is not the case for psychological processes, for allowances need to be made for desired values of the state variables to evolve in response to exposure to the activities involved. To this end, we now turn to a discussion of a framework based upon psychological opponent processes. The point of departure for an opponent-process model is the observation that many feelings of pleasure or pain seem to be followed by a contrary after-effect—pain by a feeling of relief and pleasure by a feeling of let down or emptiness.\footnote{Opponent processes in psychology were introduced by Hurvich and Jameson (1957), but have been most extensively studied and developed by Richard Solomon and his associates. See, in particular, Solomon and Corbit (1974) and Solomon (1980). Opponent processes were brought to the attention of economists by Tibor Scitovsky in The Joyless Economy (1976). An edited version of the Solomon–Corbit paper was reprinted in the 1978 Handbook of the American Economic Association.} The model consists of three components, a primary process that is initiated by a stimulus, a secondary process that is triggered by the primary process, and an integrator that sums the hedonic effects of the primary and secondary processes. Solomon and Corbit (1974) refer to the primary process as an $a$-process and the secondary process as a $b$-process. The magnitude of the $a$-process is postulated to be closely correlated with the intensity, quality, and duration of the stimulus. The function of the $b$-process is to oppose or suppress the state generated by the $a$-process, and is postulated to be (i) of sluggish latency, (ii) inertial, or slow to build to its peak intensity, and (iii) slow to decay after the stimulus has terminated and the $a$-process has stopped. Finally, the $b$-process is hedonically opposite to that of the $a$-process.

To illustrate the role that opponent processes can play in describing consumption dynamics, let us consider a consumption activity that has associated with it a pair of such processes, an $a$-process that is initiated by the stimulus that defines the activity and a $b$-process that is triggered by the onset of the $a$-process. For convenience, it will be assumed that the $a$-process is hedonically positive, so that the $b$-process is hedonically negative. The activity will have goods and time as inputs, and the stimulus will be identified with the physical consumption of the goods. The individual is assumed to influence the $a$-process by controlling the timing, intensity, and duration of the stimulus. The $b$-process, however, is governed by its own dynamics and can be controlled only through reapplying the stimulus (or by “redosing”). When
redosing occurs in order to kill the effects of a painful \( b \)-process, the individual can be said to have reached a state of addiction.\(^\text{41}\)

Following Solomon and Corbit (1974), let the hedonic function at time \( t \) that is associated with the consumption activity be given by

\[
\varphi(t) = \varphi_a(t) + \varphi_b(t),
\]

(2.62)

where \( \varphi_a( > 0) + \varphi_b( < 0) \) denote the hedonic values of the \( a \)- and \( b \)-processes, respectively. For \( \varphi_a \), it will be assumed that

\[
\varphi_a(t) = \beta d(t) q(t),
\]

(2.63)

where \( \beta \) is a parameter, \( d(t) \) is a stimulus indicator variable, and \( q(t) \) represents the intensity of the stimulus. A stylized illustrative shape for \( \varphi \) is given in Fig. 2.1. The solid portions of these curves correspond to \( d(t) = 1, q(t) > 0 \), while the dashed portions correspond to \( d(t) = 0, q(t) = 0 \). Since \( \varphi_a = 0 \) for \( d = 0 \), the dashed portions accordingly represent \( \varphi_b \) when \( d= 0 \).

![Fig. 2.1 Opponent processes](image)

Redosing can be taken to occur when the discomfort associated with the \( b \)-process reaches a point where it can no longer be tolerated. The timing of the redose for an addicting activity will therefore be determined by the shape of

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\(^{41}\) An obvious example is redosing to escape the withdrawal pains from heroin. A less-destructive example is the so-called “salted-peanut syndrome,” in which short-run mini-addictions are set up following an initial succumbing to a first handful of peanuts, popcorn, potato chips, etc. In passing, we might note that much of the snack-food industry would appear to be premised on this syndrome.
the $b$-process. The curve in Fig. 2.1 describes an activity that nonaddicting, as the dashed curve does not reach a threshold level of discomfort. For an addicting activity such as smoking, on the other hand, the curve $\varphi_b$ does reach such a threshold, which leads to a redosing in order to eliminate the discomfort. The extreme, of course, is chain smoking, which corresponds to continuous redosing. Finally, we can also consider a physiologically addicting activity such as (normal) eating. In this case, $\varphi_b$ begins slowly, eventually reaches a threshold, and then keeps on falling, reflecting the fact that endless fasting ultimately results in death.

For many consumption activities, the scope and duration of the activity are more or less predetermined. Movies and football games are of a certain length, apples of a certain size, etc., and, once begun, the activity is usually pursued to its natural conclusion. With eating an apple, the apples may be small, and one may not be enough. What determines how many will be eaten? The conventional answer to this question is that apples will be consumed to the point where the marginal utility from another apple (another bite?) divided by the price of apples is equal to the marginal utility of income. But this seems to be a poor description of behavior, for most people, if given the opportunity, will eat until the taste for apples is sated.\footnote{Or until, as has been suggested to one of the authors by Barbara Sands and Gordon Winston, the marginal utility of the activity falls below that of another activity. See Winston (1980, 1985, 1987).} This suggests a natural way of defining the duration of an activity: consumption ends at the point where the marginal utility from continuing the activity falls to zero. Taking consumption activities as the object of choice thus enables satiation to be brought into the analysis in a straightforward way.

It seems reasonable to assume that each opponent process has associated with it a minimum of two state variables, one for the $a$-process and one for the $b$-process.\footnote{One should in fact think in terms of a minimum of three state variables, rather than two, two of which represent quales (or feelings) and the third the neural networks that are brought into existence through exposure and experience.} The state variable for the $a$-process can be viewed as a generalized stock of consumption capital in the sense of Stigler and Becker (1977). Intangibles will be contained in this stock, and in many cases physical capital as well. Included in the intangibles will be knowledge of the activity that has been acquired through previous exposure, or what has been referred earlier as redundancy. This stock of consumption capital, which will be denoted by $A$, can be assumed to be subject to depreciation. The law of motion for the state variable for the $a$-process can accordingly be given the same form as for the state variable in the state-adjustment model of Section 2.5 [cf. expression (2.9)]:

$$
\dot{A} = q(t) - \delta A(t), \quad (2.64)
$$
in which case, the hedonic function $\varphi_a$ in expression (2.63) can more generally be written as

$$\varphi_a(t) = \beta d(t) A(t). \quad (2.65)$$

The law of motion for the state variable for the $b$-process will be more complicated than expression (2.59), for, among other things, there is evidence from laboratory studies of opponent processes that when a stimulus of medium intensity is repeated many times within a short period of time, the reaction to the stimulus tends to diminish.\(^{44}\) This is a habituation (or “getting used to”) effect that can be interpreted as resulting from the strengthening of the $b$-process. Thus, the state variable for the $b$-process needs to allow for its hedonic effect to strengthen with repetition. Accordingly, let us define (as one possibility) a state variable $B(t)$ for this process as

$$B(t) = B_0 + \sum_{i=1}^{n^*} e^{-\sigma q[i]}, \quad \sigma > 0, \quad (2.66)$$

where $B_0$ denotes the strength of the $b$-process at the time of the first exposure to the activity, $q[i]$ denotes the intensity of the stimulus during the $i$th exposure, and $n^*$ denotes the number of distinct exposures. Finally, $\sigma$ is a parameter that allows for $B(t)$ to reach an eventual asymptote. The hedonic function $\varphi_b$ can then be defined as

$$\psi_b(t) = -S(t, \tau), \quad (2.67)$$

$$= -e^{-k(t-\tau)} B(t).$$

It is important to note that two forms of time are represented in this expression: historical (or chronological) time, which refers to consumption decision points, and process (or activity) time, which refers to the time interval over which a consumption activity occurs. The former in indexed by $t$ and the latter by $\tau$. Note, too, that it is assumed that $B(t)$ is independent of $\tau$, i.e., the state variable for the $b$-process is affected only by the frequency and intensity of the stimulus associated with the activity. Finally, let $B^*$ denote a threshold level of discomfort such that $B \geq B^*$ will trigger re-application of the stimulus.

From the foregoing, it is clear that actions of the beta brain in regard to opponent processes and the nature of the consumption dynamics involved will depend upon whether or not the consumption activity is addictive, i.e., whether $B(t)$ reaches the threshold level of discomfort $B^*$. Activities for which this is the case can reasonably be assumed to be re-triggered automatically by the beta brain whenever $B \geq B^*$, hence the consumption dynamics for these activities should be similar to those already discussed in connection with the autonomic processes. $B^*$ serves the

\(^{44}\) See Solomon and Corbit (1974) and Solomon (1980).
same function as the desired value ($S^*$) of the state variables. However, the situation is different for nonaddicting activities, for without the automatic trigger afforded by $B \geq B^*$, the beta brain lacks the capability of initiating an activity. “Redosing” in this case is an act of choice exercised by the gamma brain.

In thinking about the dynamics associated with opponent processes, it is important not to confuse consumption dynamics with the internal dynamics of the processes themselves. Consumption dynamics are external to the processes and describe how the individual responds to signals to initiate the activities involved. Consumption dynamics operate in historical time and are indexed in terms of $t$. Process dynamics, in contrast, are internal to the processes, operate in process time, and are indexed in terms of $\tau$.

From the foregoing, it is clear that much of the consumption associated with activities that have negative $b$-processes can be viewed as being motivated by a desire to eliminate discomfort. The extreme, obviously, is an addicting activity for which $\varphi$ is never positive. This would describe an activity in which $\varphi_b(t)$ is “beaten down” by exposure and repetition. The individual may receive no stimulation from this activity $\varphi_b(t)$, but its absence causes discomfort.\(^{45}\)

### 2.6.4 Dynamics Associated with the Gamma Brain

We now turn to the activities of the gamma brain, which in contrast with the alpha and beta brains are not constrained to be reactive. The primary motivation of this brain, as has been noted, is assumed to be the maintenance of an acceptable level of physiological and psychological well-being. As with the alpha and beta brains, this is assumed to be accomplished through the monitoring of a set of state variables that, among other things, embodies the moral (or ethical) code of the individual. Well-being is assumed to be acceptable when actual values of these state variables are in proximity of certain desired values. The gamma brain has capacity to choose among activities (when real time permits this to be done), can initiate activities in response to distress signals from the alpha and beta brains, and in some cases can alter decisions of those two brains.\(^{46}\) In addition, the gamma brain can form expectations that become inputs into consumption plans that cover both near-term and long-term horizons. The gamma brain directs the acquisition of market goods and provides for their purchase through choosing the amount of time to be spent in the pursuit of income.

\(^{45}\) Cf. Scitovsky (1976, Chapter 6). This type of consumption is also related to what Hawtrey (1925, pp. 189–192) once referred to as defensive consumption, as opposed to creative consumption. Also, it should be noted that the focus in the discussion has been on opponent processes in which the $a$-process has been positive and the $b$-process negative. There are also activities in which this is reversed (i.e., where the $a$-process is negative and the $b$-process positive). Skydiving and bungee jumping provide instances. Solomon and Corbit (1974) discuss other examples.

\(^{46}\) For a discussion of the tempering of actions triggered by the emotions by reason, see, inter alia, Chapter 2 of Damasio (1999).
One of the capabilities of the gamma brain is to monitor the addictive processes of the beta brain and to assess whether an addiction is “good” or “bad.” If an addictive is deemed hostile, the gamma brain has the capability of taking corrective action (though not always successfully), that is, of initiating activities that can overcome or break the addictions. A “bad” addiction in this context can be defined in terms of the effect that the addicting activity has on the state variables that describe the individual’s *overall feeling of well-being*. Denote the desired values of these state variables by $M^*$ and the actual values by $M$.

Assume, next, that the elements of $M$ are functions of the threshold levels of pain that trigger redosing of the addicting activities, that is, let

$$M(t) = G[B^*(t), Z(t)],$$

(2.68)

where $B^*$ is as previously defined and $Z$ represents all of the other factors affecting $M$.

An addicting activity (with a negative $b$-process), $j$, can be defined as bad if, for some $M_i, \partial M_i/\partial B^*_j < 0$. Such an activity will cause $M_i$ to depart negatively from $M^*_i$. Eventually, the shortfall can reach a value that causes the central monitor of the gamma brain to begin searching for ways to combat the addiction. As this occurs, conflict will almost certainly emerge, for the individual is not behaving in accord with his/her moral code. The result could be ambivalence or even mental pathology.

Latter possibilities aside, the central monitor of the gamma brain can be viewed as taking action to combat addiction whenever $M^*_i - M_i$ reaches a particular threshold. Such actions can vary from establishment of “anti-markets” of the type discussed by Schelling (1978), participation in support groups (Alcoholics Anonymous, Weight-Watchers, etc.), “lashing to the mast” (*a la* Ulysses), to sheer acts of will (i.e., quitting the addicting activity “cold turkey”). Such “stop and go” consumption behavior can give rise to dynamics—specifically, to nonlinear dynamics—that are more complicated than any that have been discussed in connection with the alpha and beta brains.

We now turn to the gamma brain’s capacity to anticipate and to form expectations. As has been noted, the gamma brain can monitor both its own activities and those of the alpha and beta brains. When combined with a capacity to anticipate,

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47 The elements of $M^*$ can be seen as representing the core beliefs of an individual [in the sense of Gazzaniga (1985)] and are assumed as invariant to consumption activities, so that in a sense they can be viewed as the preferences of conventional demand theory. However, they are more inclusive than the preferences of conventional demand theory, in that they will embody attitudes toward love and marriage, religion, interpersonal relations, self-interest, and altruism.

48 This would be reflective of situations in which “part of me wants to do this and part of me wants to do that,” but where one action forecloses the other. In neurobiological terms, there is conflict between the cognitive and affective spheres of the brain. See Camerer et al. (2005).

49 For an analysis of such dynamics in the context of opponent processes, see Lancry and Saldanha (1978).
this means that the gamma brain has the potential for thinking through the consequences of not only its own actions, but also the actions of the two lower brains. If the consequences of a particular act are judged to be harmful, the decision to act to be revised or a consumption plan could be formulated that contains or undoes the harm.\textsuperscript{50}

In formulating consumption plans, the gamma brain is assumed to have the capacity to form expectations regarding the future course of prices and income, and also to anticipate the wants and needs that relate to different stages of the life cycle. Expectations in these cases are with reference to calendar time rather than to process time and are more relevant to purchase decisions than to consumption decisions. A variety of expectations mechanisms could be considered at this point, including naive, extrapolative, adaptive, Bayesian, or rational. Of these, it would seem that rational expectation is the only one that requires the capability that has been ascribed to the gamma brain. Expectations for all of the other mechanisms can be formulated on the basis of current and past information, for which the potential for doing can be ascribed to the beta brain. Rational expectations, however, would seem to require abstract reasoning that only the gamma brain is capable of.

2.6.5 From Consumption to Expenditure

The dynamics that have been considered to this point in this section relate to the consumption side of the consumption/expenditure dichotomy that was postulated earlier. This dichotomy has been characterized in terms of the individual wearing two “hats,” one as a consumer whose motivation is primarily to maintain an acceptable level of physiological and psychological well-being through time via consumption activities that use time and market goods as inputs, and the other as a purchasing agent whose motivation is primarily to obtain the market goods required in the most efficient way possible given the resources that are available. The next task is to examine the expenditure side of this dichotomy.

The bridge between consumption and expenditure obviously has to occur in the gamma brain, where one can imagine that consumption needs are transmitted to the “purchasing agent” who then goes out into the markets to shop. Dynamics on the expenditure side arise from two different sources. The first source is the consumption dynamics that we have been discussing, that is, the dynamics that inhere in the consumption activities that are undertaken in efforts to maintain physiological and psychological well-being at acceptable levels. State variables change over time in response to exposure, experience, and depreciation, and this leads to time-dependent changes in the amounts and types of market goods that are required by consumption activities as inputs. This is the type of dynamics associated with inertia, habit formation, and stock adjustment.

\textsuperscript{50} For a model endogenous taste change that allows for considerations such as this, see Manove (1973).
The second source of dynamics on the consumption side is described by how the individual, functioning as a purchasing agent, responds to changes in the external environment. The behavior reflected in these dynamics will include delays in adjusting changes in prices and wage rates, the appearance of new goods, and changes in the type and intensity of marketing efforts. Response delays can arise for a variety of reasons, including recognition lags and other imperfections in information flows, uncertainty, and certain intrinsic characteristics of the individual. Also, expectations can contribute to this category of dynamics if they are formulated on the basis of past values of income, prices, and interest rates.

Complicated expectations aside, the dynamics represented in expressions (2.57) and (2.58) are appropriate for goods that involve the holding of physical inventories. In this case, equation (2.57) should be augmented by price and income, so that we would have

\[
\dot{q}(t) = \Phi[q(t) - \alpha - \beta x(t) - \gamma x^e(t) - \lambda p(t)]
\]

\[
\dot{s}(t) = q(t) - \delta s(t),
\]

where \(x\) and \(p\) denote the flow rate of income and level of price and \(s\) denotes the level of inventory. The coefficient \(\delta\) can now be seen as representing the using up of the good in question as input into consumption activities. The coefficients \(\alpha\), \(\beta\), \(\gamma\), and \(\lambda\) reflect intrinsic behavioral characteristics of the individual (as purchasing agent), while \(\Phi\) can be viewed as incorporating delays and adjustments resulting from imperfections in information flows.

The bridge between the consumption and expenditure sides in the gamma brain is represented in the using-up parameter \(\delta\). Strictly speaking, \(\delta\) should be written as a function of time, for in substantial part it should be seen as psychologically based, and thus reflective of the “endogenous” taste changes occasioned by the internal dynamics of consumption activities, together with the gamma brain’s efforts to maintain an acceptable level of psychological well-being. Closing the system would accordingly require the specification of a law of motion for \(\delta\).

Expressions (2.69) and (2.70) can also be used to describe the expenditure behavior of activities, such as concerts, theater, and sporting events, which are consumed at the time of purchase. Inventories will continue to be relevant for such activities, except that reference must now be to psychological quantities, rather than to physical stocks. For concerts, for example, one can imagine a stock of “music enjoyment” that periodically needs replenishing, and similarly for theater and sporting events. Moreover, many services, such as travel and telecommunications, are inputs into consumption activities that have conceptually well-defined state variables associated with them, which in some instances can be directly identified with the psychological quantities in question.

Expectations clearly complicate. One way that they can be brought into the picture is rewrite equation (2.69) as:

\[
\dot{q} = \Phi[q(t) - \alpha - \beta s(t) - \gamma x^e(t) - \lambda p^e(t)],
\]
where \( x^e \) and \( p^e \) denote the purchasing agent’s expectations for income and price. To illustrate the complications that can be introduced, assume that the formation mechanisms for \( x^e \) and \( p^e \) are as follows:

\[
\dot{x}^e(t) = \psi [x(t) - x^e(t)] \tag{2.72}
\]

\[
x^e(t) = \int_{t-\Delta}^{t} w(\tau)x(\tau)d\tau \tag{2.73}
\]

\[
\dot{p}^e(t) = \theta [p(t) - p^e(t)] \tag{2.74}
\]

\[
p^e(t) = \int_{t-\Delta}^{t} w(\tau)p(\tau)d\tau, \tag{2.75}
\]

where \( \Delta < 0, w(\tau) \geq 0, \) and \( \int w(\tau)d\tau = 1. \)

These expressions posit that expectations are formulated as a weighted average of past values of \( x \) and \( p \), with a partial adjustment to new information. Differentiation of expression (2.71) with respect to time, and then using expressions (2.72) and (2.74) for \( \dot{x}^e \) and \( \dot{p}^e \) yields:

\[
\ddot{q}(t) = \Phi[\dot{q}(t) - \beta \dot{s}(t) - \gamma \{x(t) - x^e(t)\} - \lambda \{p(t) - p^e(t)\}], \tag{2.76}
\]

which is a second-order differential equation in \( q \).\(^{51}\)

As the purchasing agent’s expenditure behavior at any point in time is obviously constrained by the income that is available, a final task is to incorporate the budget constraint into the analysis. For notation, let \( y \) denote income, \( q \) a vector of consumption activities, and \( x \) a vector of market goods and services that [per Becker (1965) and Lancaster (1971)] are inputs into these activities. Let \( p \) denote the vector of associated prices, and finally, for those goods for which physical inventories are relevant, let \( X \) and \( X^* \) denote vectors of actual and desired levels of inventories. Specifically, \( X^* \) is assumed to represent a “safe” level of inventories (paper towels, milk, soap, etc.) over some relevant consumption horizon. In particular, let \( X^* \) be defined by:

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\(^{51}\) The point of the foregoing exercise is simply to show that the capacity to form expectations has material implications for expenditure dynamics. As simple adaptive expectations lead to a second-order process, one can imagine (without getting caught up in details) the complexity that more sophisticated expectation mechanisms would entail. As has been noted, the dynamics represented in expressions (2.69) and (2.70) can be associated with decisions of the beta brain, as can also the formation of simple adaptive expectations. Dynamics arising out of more complex expectation mechanisms, however, must be attributed to the gamma brain.
where $\Delta$ represents the consumption horizon, and $x(\tau)$ is determined by the activity “production” functions, $q(\tau) = f[x(\tau)]$. Next, let $x(t)$ be defined by:

$$X^*(t) - X(t), \quad X^*(t) > X(t)$$

$$x(t) = 0 \text{ otherwise.} \quad (2.78)$$

Finally, let it be assumed that the purchasing agent acquires $x(t)$ at minimum cost subject to the income constraint:\textsuperscript{52}

$$p'(t)x(t) \leq y(t). \quad (2.79)$$

### 2.6.6 Consumption/Income Relationships

A clear implication of the three-brain structure of consumption behavior being discussed here is that activities controlled by the alpha and beta brains have first claim on income, followed by the needs of addicting psychological processes. It is only after the needs of these two categories have been satisfied that needs associated with boredom-relieving activities can assert claims. We can accordingly conclude that goods that are primary inputs into activities controlled by the alpha and beta brains will have smaller income elasticities than goods that are primarily inputs into activities controlled by the gamma brain. In terms of the traditional grouping of goods into luxuries and necessities, goods that inputs into activities associated with the alpha and beta brains will tend to be necessities, while those that are inputs into activities associated with the gamma brain will tend to be luxuries.\textsuperscript{53}

An obvious empirical implication of the foregoing is that we should expect to observe greater variation in consumption patterns among individuals with high incomes than with low incomes. Consumption will be more proscribed the closer it is associated with activities that involve elimination of physiological and psychological discomfort, activities that in general will be controlled by the alpha and beta brains.

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\textsuperscript{52} Since saving is not being taken into account, the income constraint will normally be satisfied as an inequality. Because of possibilities to dissave or borrow, there is actually no necessity for any particular point in time that the income constraint be satisfied. Persistent deficits could not occur, however, not only because of the obvious threat of bankruptcy, but also because solvency for most individuals is an important part of their moral code (as defined by $M^*$ in the present section). Once the gamma brain recognizes that solvency is threatened, actions would be initiated to avert it.

\textsuperscript{53} Consumption decisions initiated by the alpha, beta, and gamma brains will be related to the Maslovian hierarchy of wants in Section 2.7 below.
brains. One would expect these activities to have greater uniformity across individuals than activities controlled by the gamma brain, which allows for much greater expression of individual tastes. High income, in short, provides much greater scope for individual tastes to manifest themselves.\(^{54}\)

Another implication of this analysis is that, in general, consumption behavior should be asymmetrical with respect to income increases and income decreases. Since goods that have first claim on income are those that are associated with eliminating physiological and psychological discomfort, expenditures for these goods will almost certainly not fall proportionately with any fall in income. For increases in income, on the other hand, novelty and new wants can be pursued, and expenditures will increase. While increases in expenditures may again be less than proportionate to the increase in income, the increases will almost certainly be larger (in absolute value) than any decreases would be for a likely fall in income. The likely result, accordingly, is a “ratchet” in expenditures for changes from the current level of income.\(^{55}\)

### 2.6.7 Rationality

Earlier, it was noted that, in considering the framework of this section, it is important to distinguish between the economist’s concept of rationality and that of the psychologists. To repeat what was said earlier, the focus for psychologists is with the process (or processes) of decision-making, while for economists the focus is on the outcomes of decisions.\(^{56}\) In conventional demand theory, rationality is usually identified with the transitivity of preferences: If A is preferred to B, and B is preferred to C, then A is preferred to C. In general, the three-brain model that has been discussed in this section would appear to be consistent with the first concept of rationality, but not with the second. In its role as the ultimate arbiter of consumption decisions, the gamma brain takes into account both current information and consequences of past activities and forms expectations concerning the effects of current actions. Cognitive processes are many, and there is no reason to think that these

\(^{54}\) Moreover, such is consistent with the heteroscedasticity that is often observed in the residuals of Engel curves.

\(^{55}\) This paragraph assumes that the income level from which changes are measured is one to which the individual has more or less adjusted. The effects described accordingly refer to short-run responses. Long-run responses may be more symmetrical to income increases and decreases, although it is doubtful because of experience and state-variable creation that consumption behavior is ever fully reversible, as is the case in conventional demand theory. Thus, at the level of the individual, the short-run dynamics of this section are consistent with the Relative- and Permanent-Income Hypotheses [Duesenberry (1949), Friedman (1957)] and also the Life-Cycle Model [Modigliani and Brumberg (1954, 1980)]. This is not necessarily the case for the long run, however, because of irreversibility.

\(^{56}\) See Simon (1986). For a discussion of how the concept of rationality has evolved in economics, see Arrow (1986).
(in normal circumstances) are not coordinated in a compatible fashion by its central monitor to provide an acceptable level of comfort and well-being.

Rationality in the second (or economists’) sense, however, is another matter. As a way of analyzing this question, let us imagine a conceptual experiment (as per Section 2.2) in which from a given set of initial conditions a short segment of real time is repeated. Rationality in the second sense would require that an individual make identical consumption decisions. However, unless all consumption activity is controlled by the alpha and beta brains, there is no reason for this to be the case. This is because, for consumption activities that do not involve the elimination of discomfort, the particular consumption activities that are engaged over any interval would seem to be inherently random as a consequence of the random firing of neurons. Put another way, there is no reason to think the moods (or dispositions) that drive the selection activities to stave off boredom would be repeated. Rationality in the second sense would therefore seem to be an event with probability zero.

The foregoing is with reference to the individual as a consumer. A different conclusion can emerge with regard to expenditure behavior. The conceptual experiment to be imagined here is the usual one in which income is held constant and the individual is confronted with a sequence of vectors of relative prices that at some point begins to repeat itself. The question is then whether the expenditure pattern would also begin to repeat. If this were the case, the demand functions would be integrable, or equivalently the expenditure pattern would be consistent with the strong axiom of revealed preference.57 In either interpretation, rationality in the second sense would be present.

Whether or not this would be the case turns on what besides income is assumed to be held constant. If everything on the consumption side were held constant, there would seem no reason why rationality in the second sense should not hold. The question, however, is whether everything on the consumption side can meaningfully be held constant. The problem is that the conceptual experiment envisioned implies a passage of time, and this could, among other things, affect expectations that are formed by the gamma brain, which in turn could lead to nonrepeating expenditure patterns, and hence to intransitivities.

### 2.7 The Maslovian Needs Hierarchy

Over the course of a long and distinguished career, the psychologist Abraham Maslow put forth a compelling and influential argument that human behavior, at the most fundamental level, is motivated by five basic needs (listed in Section 2.5 above): physiological, security, love, self-esteem, and self-actualization. With the three-brain framework of the preceding as background, these will now be described.

57 See Houthakker (1950) and Chapter 22 below.
2.7 The Maslovian Needs Hierarchy

2.7.1 Physiological Needs

Physiological needs are the needs that must be fulfilled in order for the body to survive, which, for our purposes will be taken to include, food, drink, basic shelter, and sex. Obviously, the most basic of these are the inputs into the autonomic processes controlled by the brain stem (i.e., the alpha brain) that are required to maintain the bodily functions in homeostasis, such as breathing, digestion, and appropriate chemical balances of the blood stream. As Maslow notes, the physiological needs are the most prepotent of all needs, in that for the human being who is missing everything in life in an extreme fashion, it is most likely that the major motivation would be the physiological needs rather than any others. A person lacking food, safety, love, and esteem will almost certainly hunger for food more strongly than for anything else. However, in non-third-world countries, chronic extreme hunger of the emergency type is rare. In most circumstances, people are experiencing appetite rather than hunger when they say, “I am hungry.” They are apt to experience sheer life-and-death hunger only by accident, and then only a few times in their lives. And even when they say they are hungry, people may in fact be seeking more for comfort or dependence than for carbohydrates and protein.

2.7.2 Security Needs

Once the physiological needs are satisfied, a new set of needs emerges—security; stability; dependency; protection; freedom from fear, anxiety, and chaos; need for structure, order, law, and limits; strength in the protector; and so on—which Maslow characterizes as safety needs. Once these needs come into play, all that has been said of the physiological needs is equally true of them, although in a lesser degree. When unsatisfied, these desires may serve as the almost exclusive organizer of behavior, and, as in the hungry human, the dominating goal is a strong determinant not only of a person’s current world outlook and philosophy, but also of the future and of values. Practically everything looks less important than safety and protection, and even the physiological needs, which being satisfied, may be underestimated. Indeed, as Maslow states:

The safety needs can become very urgent on the social scene whenever there are real threats to law, to order, to the authority of society. The threat of chaos or of nihilism can be expected in most human beings to produce a regression from any higher needs to the more prepotent safety needs. A common, almost an expectable reaction, is the easier acceptance of dictatorship or of military rule. This tends to be true for all human beings, including healthy ones, since they too will tend to respond to danger with realistic regression to the safety need level and will prepare to defend themselves. But it seems to be most true of people who are living near the safety line. They are particularly disturbed by threats to authority, to legality, and to the representatives of the law. [Maslow (1970, p. 20; italics added.))}
2.7.3 Community and Affection (Love) Needs

Once the physiological and safety needs are satisfied, the needs of human beings as social animals make an appearance, beginning with the needs for affection and community. In Maslow’s words:\footnote{58}

If both physiological and the safety needs are fairly well gratified, there will emerge the love and affection and belongingness needs, and the whole cycle already described will repeat itself with this new center. The love needs involve giving and receiving affection. When they are unsatisfied, a person will feel keenly the absence of friends, mate, or children. Such a person will hunger for relations with people in general—for a place in the group or family—and will strive with great intensity to achieve this goal. Attaining such a place will matter more than anything else in the world and he or she may even forget that once, when hunger was foremost, love seemed unreal, unnecessary, and unimportant. Now the pangs of loneliness, ostracism, rejection, friendlessness, and rootlessness are preeminent.

We have very little scientific information about the belongingness need, although this is a common theme in novels, autobiographies, poems, and plays and also in the newer sociological literature.\footnote{59} From these we know in a general way the destructive effects on children of moving too often; of disorientation; of the general over-mobility that is forced by industrialization; of being without roots, home and family, friends, and neighbors; of being a transient or a newcomer rather than a native. We still underplay the deep importance of the neighborhood, of one’s territory, of one’s clan, of one’s “kind,” one’s class, one’s gang, one’s familiar working colleagues. And we have largely forgotten our deep animal tendencies to herd, to flock, to join, to belong. [Maslow (1970, p. 20)]

2.7.4 Esteem Needs

Upon gratification of the needs for affection and belonging, there arise a need or desire in people for a stable, firmly based, usually high evaluation of themselves, for self-respect and the esteem of others. For Maslow, these needs take two forms.\footnote{58} A cogent statement of the genetic basis of these needs is also supplied by Polanyi (1974, pp. 209–210): The sentiments of trust and the persuasive passions by which the transmission of our articulate heritage is kept flowing, bring us back once more to the primitive sentiments of fellowship that exist previous to articulation among all groups of men and even among animals. Evidence of the primordial character of such conviviality and of the lively emotions engendered and gratified by its interplay is supplied by the experience both of animals and men. […] Companionship among men is often sustained and enjoyed in silence. Mr. Utterson, in Stevenson’s Dr. Jekyll and Mr. Hyde, puts aside any business, however unimportant, to take his regular walk with his friend Mr. Richard Enfield, during which neither of them pronounces a single word. But conviviality is usually made effective by a more deliberate sharing experience, and most commonly by conversation. The exchange of greetings and conventional remarks is an articulation of companionship, and every articulate address of one person to another makes some contribution to their conviviality, in the sense of their reaching out to one another and sharing each other’s lives. Pure conviviality, that is, the cultivation of good fellowship, predominates in many acts of communication; indeed, the main reason for which people talk to one another is desire for company. The torment of solitary confinement is that it deprives one not of information but of conversation, however uninformative. \footnote{59} It should be kept in mind that Maslow first wrote these words in 1954.
The first is the desire for strength, achievement, adequacy, mastery and competence, positive self-image, confidence in the face of the world, and independence and freedom, while the second is the desire for reputation or prestige (defined as respect or esteem from other people), status, fame, and glory, dominance, recognition, attention, importance, dignity, or appreciation. As will be discussed below, much of consumption expenditure in high-income economies would seem to be motivated by this set of needs. Expenditures for “position goods” and on Veblenesque “conspicuous consumption” seem prime examples.

2.7.5 Self-Actualization Need

Once physiological, security, belonging, and self-esteem needs are gratified, the fifth and final basic motivation in the Maslow hierarchy emerges, namely, self-actualization. For Maslow:

Even if all these [i.e., the first four] needs are satisfied, we may still often (if not always) expect that a new discontent and restlessness will soon develop, unless the individual is doing what he or she, individually, is fitted for. Musicians must make music; artists must paint; poets must write if they are to be ultimately at peace with themselves. What can be, they must be. The must be true to their own nature. This need we may call self-actualization. [Maslow (1970, p. 22; italics in original)]

Self-actualization refers to people’s desire for self-fulfillment, that is, a tendency for them to become in fact what they are potentially, “to become everything that one is capable of becoming.” The specific form that these needs take can vary greatly from person to person. In one person, they may take the form of the desire to be an excellent parent, in another they may be expressed athletically, and in still another they may be expressed in painting pictures or invention. However, the common feature of the needs for self-actualization is that their emergence usually rests upon prior satisfaction of the physiological, safety, love, and esteem needs.60

2.8 Some Implications of a Hierarchy of Needs

As just presented, the five Maslovian needs form a rigid hierarchy, in which higher needs do not come into play until lower ones are satisfied. As a framework for organizing real-world consumption behavior, such an interpretation of Maslow’s hierarchy is obviously too strict. Short of extreme physiological or security deprivation, an individual’s consumption behavior at any point in time is probably best seen

60 In the first edition of Motivation and Personality, Maslow (1954) discussed the fifth motivation, self-actualization, as being independent of age. However, subsequent empirical research has pretty much established its emergence only in individuals once they have reached their fifties, which (given the nature of self-actualization) of course makes intuitive sense.
as being determined by whatever desire, at that moment, is most in need of gratification. Sometimes, this might be expenditures related to a physiological need, or it might be installation of a security device to thwart potential burglary, or it might be the purchase of artist supplies in pursuit of a long-term desire to paint. Indeed, for the very wealthy, it might be the purchase of a plot in a prestigious locale for the purpose of building a house that is larger than any of the individual’s friends or acquaintances. In short, for normal, well-adjusted individuals, whose basic physical and physiological needs are in “copacetic” equilibrium, the desire most in need of gratification at any point in time may fall into any of the higher-order needs, which is to say that probably the best that a forecaster can do is to make a probabilistic statement as to the basic need category that an about-to-be-undertaken consumption activity will fall into. However, over longer periods of time, the need hierarchy should be quite predictive of consumption behavior, specifically in determining the proportions of total expenditure that fall into each of the hierarchical categories.

Related to the foregoing is the fact that a characteristic of the human organism when it is dominated by a certain need is that the whole philosophy of the future tends to change. For a chronically and extremely hungry person, for example, Utopia can be defined simply as a place where there is plenty of food. He or she may tend to think that, if only guaranteed food for the rest of life, they will be perfectly happy and will never want anything more (which of course dissipates once the hunger need is sated). Similar feelings can arise when there is a breakdown in security or (for the pathologically ill) when at the extremes of not belonging or loss of self-esteem. In these circumstances, tastes and preferences, as economists ordinarily think of them, can be extremely unstable, so ephemeral, in fact, that it is probably not meaningful even to speak of preference stability at the point in time. Stability in these circumstances is once again probably only meaningful over intervals of time.61

As with needs (as opposed to wants), mainstream economic theory has been reluctant to consider tastes and preferences as lexicographical.62 For with lexicographical preferences, there are no indifference classes, and accordingly no straightforward way, as in the Hicks–Allen framework, of deriving demand functions with income and substitution effects. However, a hierarchy of needs clearly implies a hierarchy of preferences. Consequently, developing a theory of consumer

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61 Cf., Chapter 13 below, where a generalization of the dynamic models of Section 13.5 is presented.

62 Henceforth, needs and wants, for our purposes, will be used interchangeably. It may be of interest to note in passing that LDT once submitted a paper (co-authored with a graduate student) based upon lexicographical preferences to one of the leading economics journals. Rejection was almost immediate, with a statement (and stern admonishment!) from the editor (who had once been one of the author’s professors) that only a drunken sailor could conceivably display such preferences, and to never stray from the fold in this way again! Given the advances in evolutionary biology and the neurosciences, and emergence of journals in evolutionary and behavioral economics, such an attitude is hopefully no longer endemic.
behavior that allows for a Maslovian need hierarchy not only has to deal with preference instability, but hierarchical preferences as well.63

While Maslow is clear in stating that his five motivating needs are genetic in origin, he is equally clear that they are not the only determinants of behavior. Cultural and social factors are also important motivators of desires, and in normal circumstances, i.e., when individuals are in (what was referred above as) copacetic equilibrium with respect to physiological and security needs, are probably more important than their genetic counterparts. This being the case, one way that we might approach integration of Maslow's hierarchy of needs into a theory of consumer behavior is to view preferences as consisting of the five Maslovian needs, each of which in turn consists of three functional components: genetic, cultural, and social. From the discussion to this point, it should be clear that the genetic component will be fundamental in all of the needs, but that its strength as a motivator of observed behavior might be expected to be inversely related to the order of the needs, i.e., strongest for the physiological and security needs and weakest for self-esteem and self-actualization. By fundamental in this context, we simply mean that the need, quas need, is genetic in origin.64 On the other hand, how the need is gratified can be culturally/socially determined, and the more so the higher is the order of the need. Also, at levels of income in which all base needs are satisfied, needs within needs can be created that are both hierarchically structured and culturally/socially based.

By culture in this context, we have in mind two concepts, one broad and the other narrow. Culture in the broad sense refers to the institutions, broadly construed, that human beings have developed in order to survive and coexist as social animals. Genetics provide the “hardware” for this to occur, while culture provides the “software,” software that the culture itself transmits from one generation to the next. Language provides a cogent example. Genetics provide both the need and possibility for language, but the culture that an individual is born into determines the particular language that is learned. On the other hand, culture in the narrow sense is as we ordinarily think of the term, religion, education, civic, literature, theater, music, art, etc. Most of the time in this study, when we refer to needs that are culturally based, the narrow concept will be the one that is in mind, that is, needs that, as noted above, are really needs within needs. The actual form that these needs will take, however, will vary from culture (in the broad sense) to culture.

63 Early efforts to develop a theory of consumer choice based upon hierarchical preferences include Georgescu-Roegen (1954) and Ironmonger (1972). Both studies still reward reading, but especially that of Georgescu, who, among other things, presents an elegant treatment of probabilistic preferences. See also Encarnacion (1987). Another approach to probabilistic preferences, although in a discrete-choice context, is the random-utility models of McFadden and his associates [Domencich and McFadden (1975), Ben-Akiva and Lerman (1985), and Train (1986)].

64 The genetic components arise from evolution, and thus are intrinsic to the organism, while the cultural and social components arise from without, and accordingly are extrinsic to the organism.
Some conclusions and implications of the foregoing are as follows:

(1) Tastes and preferences, as economists ordinarily think of them, have structure only when consumption behavior is measured over intervals of time. At points in time, consumption behavior is, at best, probabilistic.

(2) Because of genetic variability and diversity in life experiences, no two individuals will ever have identical preference structures, even when consumption behavior is measured over intervals of time. Consequently, stable preferences can only meaningfully be spoken of only in connection with ensembles of individuals.

(3) Stability in this context is to be taken in terms of stability of distributions across ensembles of consumers both in and across time. The order of the five Maslovian needs is genetically fixed across individuals, but their relative strengths are not. However, we should expect the distributions describing relative strengths to be stable across ensembles of individuals both at same points in time as well as over time. That is, the distributions of need strengths should, in general, be no different for individuals in a village in Papua New Guinea than for a similar-sized ensemble of individuals in the U.S., and the same for ensembles of individuals over time. In contrast, the distributions of cultural and social determinants of consumption will differ both across peoples as well as over time for people in the same culture, however in ways that, in general, should be (at least partially) measurable.

(4) At any point in time, consumption decisions will be determined by the lowest-order want that is not already satisfied.

(5) An empirical regularity that is taken to be one of the few genuine laws of economics is Engel’s Law for food expenditures, which states that the income elasticity of demand for food is positive, but less than 1. The needs hierarchy provides a rationalization for this phenomenon. For food is a physiological necessity literally at the very beginning of the need hierarchy, hence once its need is satisfied, it no longer figures in consumption behavior.

As just noted, income elasticities with hierarchical preferences continue to have a straightforward interpretation. Price elasticities, however, appear to be another

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65 See Chapter 5 below.
66 After Ernst Engel (1857); see also Houthakker (1957).
67 The reference here is obviously to food at the survival level. However, much of food consumption is, as noted by Maslow, motivated by “appetites” (rather than by necessity), and is often combined with activities that serve needs other than physiological. A dinner party, for example, is an extraordinarily complicated consumption activity that is motivated by a wide variety of needs. As has been noted by Dennis Weisman in private correspondence, a slice of bread consumed at a dinner party will in general have a much different marginal utility than the same need for survival. Housing expenditures provide another complex example. As with food, expenditures for basic shelter ought to have an income elasticity that, again, is positive but less than 1. However, because housing expenditures frequently are motivated in terms of position goods [see Hirsch (1976) and Frank (1985)] and Veblenesque conspicuous consumption, which in general are associated with high-order needs, their income elasticity, depending upon how expenditures are measured, can (as we shall see) be well in excess of 1.
matter, at least in terms of price effects as usually defined in terms of income and substitution effects. For, with indifference not in the picture, it is not clear how pure substitution effects might be measured. However, while indifference clearly has no meaning between need categories, it nevertheless might still be possible for indifference to arise within a given need category. Consider, for instance, an individual with a semi-chronic deficit in belonging and self-esteem needs who is able periodically to alleviate their symptoms through hosting of dinner parties for close friends and acquaintances. Now, dinner parties have many inputs—food, wine, candles, music, etc.—of which many combinations can lead to the same consumption end. In this situation, it would be perfectly reasonable for the individual, first, to specify a total budget for the party, and, then, to select the inputs in a way that gives rise to the maximum “satisfaction” for that expenditure. In this situation, different relative prices can lead to different combinations of purchases, in which case one should be able (in principle, anyway) to calculate pure price substitution effects.

2.9 Toward Empirical Application

Unfortunately, empirical implementation of a model incorporating a consumption hierarchy is hardly clean and straightforward. It would be one thing if consumption data currently available were to correspond to gratification of specific needs, but even in an ideal world of data collection, this would not be the case. For, as has been noted, most consumption activities serves a multiplicity of needs, some basic, some higher-order within a given need, and some multiple across needs. Accordingly, what our approach is going to be at this stage is to attempt to classify categories of expenditure from the BLS consumer expenditure surveys (and later from the National Income and Product Accounts) accordingly to the basic need categories that they serve. In this section, we will illustrate doing this with a six-category classification that has been devised for integrating price data collected by ACCRA with the CES expenditure data.

The categories of consumption expenditure included in the six-category classification are: food consumed at home, shelter, utilities, transportation, health care,

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68 This example obviously conflates a number of topics in demand theory, including household production functions (Becker, 1965; Lancaster, 1971), separability (Strotz, 1957), and two-stage budgeting (Blackorby et al., 1978); Pollak and Wales, 1992). A utility function appears to have been slipped in as well. However, none of these present problems for the framework that, bit-by-bit, is being developed here. First, given the postulate of a hierarchy of needs for motivating consumption behavior, the assumption of household production functions (i.e., consumption activities) that generate the means for gratifying desires seems almost mandatory. And the same is true for separability and two-stage budgeting. As for our slipping in a “satisfaction” function, a hierarchy of needs does not rule out utility functions, just the assumption of a single-valued function. Finally, it should be noted that, as mentioned earlier, a dinner party is a complex consumption activity that typically cuts across several basic need categories, in which case it has to be assumed that a non-varying mix of need categories is being tended to.

69 We will return to this point in several chapters below, wherein price elasticities using a number of different demand models are estimated.
and miscellaneous expenditures. An initial effort to cross-classify expenditures from these categories with the five Maslovian needs is given in Fig. 2.2. Arrows in this figure run from needs to expenditure categories, indicating that expenditures are motivated in order to gratify needs. Width of the arrow shafts represents our (obviously subjective) attempt to specify the relative importance of individual needs for each category of expenditure. For physiological needs, arrows are shown as running to all categories of expenditure, but with food and shelter obviously being of most importance. Arrows from the security need run to shelter, utilities, health care, and miscellaneous expenditures. Out of ignorance on our part, the arrow shafts for this need are all made the same width. Arrows for the love/belonging need run to all expenditure categories except food, while for the self-esteem need, all categories are represented. The arrows for these needs are again depicted width the same thickness. Finally, the arrows for the self-actualization need, which again are depicted to run to all categories of expenditure, are assumed to be slightly thicker for shelter, transportation, and miscellaneous expenditures. Discussion and use of the schema depicted in this figure will be put off until Chapters 11 and 18.

### 2.10 Emotions and Consumption Behavior\(^7\)

In this section, we shall consider the role that emotions might play in consumer behavior. The traditional economist’s view of the rational consumer is that they have no role at all, that choice arises out of purely rational utility calculations. Such a

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view, though, begs a number of important questions, such as, what informs and constitutes "utility," and is also in conflict with an increasing body of neural research. Where traditional economics errors, in our opinion, is the tendency to view emotions in a humanist tradition as consisting purely of feelings, instead of a complex set of primal nervous systems whose evolutionary role has been to protect against harm in hostile environments. Take fear, for example. As put by Plutchik (1980): “Although a deer may run from danger, a bird may fly from it, and a fish may swim from it, there is a functional equivalence to all the different patterns of behavior; namely, they all have the common function of separating an organism from a threat to its survival.” What we associate with fear in human behavior is the feeling of being afraid. However, as posed by William James more than a hundred years ago: Do we run from a bear because we are afraid, or are we afraid because we run? James (1884) averred the former, but his answer, as it has turned out, was wrong. For the feeling of being afraid (at least in humans) is a conscious phenomena, and arises after a subconscious decision as to the appropriate survival response has already been made.

For present purposes, our view regarding the role of emotions (which is now pretty standard in neural research) will be:

1. All emotions derive from primitive structures whose evolutionary roles have been to keep organisms away from harm.
2. Although, emotions are functions involved in survival, different emotions are involved with different survival functions: defending against danger, finding food and mates, caring for offspring, and so on, each of which may involve different brain systems. As a result, there is, in general, not a single emotional system in the brain, but many.
3. Signals triggering emotions enter the brain at the thalamus, and then divide along two pathways, one (via the amygdala) involving immediate response at the most primitive brain level (but which nevertheless may entail appraisal as to an appropriate response), and the second involving higher brain levels, which may ultimately give rise to feelings such as fear, joy, anger, etc.

Since emotions, at the most base level, are responsible for survival, and since survival requires consumption, much of consumption behavior will accordingly be determined by the base emotions. This being the case, it seems straightforward to

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71 See, in particular, the conclusions of Damasio (1994) arising from research on patients with damaged frontal lobes. Specifically, Damasio and his colleagues show that individuals with minimal cognitive, but major affective, deficits have difficulty making decisions, and often make poor decisions when they do. As noted by Camerar, Lowenstein, and Prelec (2005, p. 29): it is not enough to know what should be done; it is also necessary to feel it. Emotions accordingly can be viewed as what imbue tastes and preferences with both definition and “sharpness.”


74 See Le Doux (1996, Chapter 4).

75 See Goleman (1994, Chapter 2).
identify the subconscious structures associated with the base emotions with a good part of “tastes and preferences” as conventionally understood, and, more specifically, to identify the consumption involved with the most basic of the Maslovian wants. Higher-order wants, on the other hand, and the consumption that these give rise to, can then be seen as being associated with the “feelings” that are more traditionally associated with emotions such as love, joy, and happiness. Consumption of the former type will be governed by the lower-order (i.e., alpha and beta) brains, while the latter consumption will be associated primarily with the gamma brain.

2.11 Consumption Behavior and the Pursuit of Happiness

Interestingly absent from Maslow’s hierarchy of wants is happiness. Clearly, everybody wants to be happy (as opposed to being unhappy), but is happiness itself a fundamental need? In our view, it is not. Genetically, the motivation of living organisms at the most basic level is simply to survive and reproduce. Happiness (or rather its possibility) is a state (or feeling) that comes later. *Copacetic equilibrium*, as we have defined it, can obviously be associated with happiness, but it is probably better identified in terms of an acceptable level of satisfaction or well-being. One might think that higher levels of satisfaction will be associated with higher levels of income and consumption, but this is not necessarily the case, for according to what are increasingly being accepted as objective measures of happiness, mean levels of such in the U.S. are no higher currently than they were 50 years ago. In many cases, consumption activity itself is thought to be the culprit.

While the focus in this book is on what consumption behavior actually is, as opposed to what it might or ought to be, it nevertheless is of interest to take a few moments to speculate on how consumption patterns that give rise to unhappiness might be rationalized in terms of the neurobiological framework of this chapter. The extremes, of course, are consumption activities with negative $b$-processes that are physiologically or psychologically addicting. Drug dependence is an obvious example. Less extreme, but almost certainly a major motivator of much of consumption behavior connected to higher-order wants (especially those arising out of the self-esteem need), is consumption associated with *position goods*, a notion


77 See Frank (1999), Frey and Stutzer (2002), Layard (2005), and Schor (1998). However, in our opinion, conclusions concerning happiness and income should be viewed with a lot of skepticism, for very little is currently known concerning the neurobiological mechanisms associated with happiness and how these might be affected by income and consumption activity [cf., Nettle (2005)]. For income levels above subsistence, happiness, as we ordinarily think of it, is likely more associated with continuing accomplishments and interpersonal relationships than with consumption activity (or its absence), with which each generation, no matter what its level of income, has to come to grips. Moreover, economists analyzing happiness pretty much overlook the fact that happiness has been a center of philosophical and religious controversy and debate since ancient times. Cf., McMahon (2006).
that was first introduced by Fred Hirsch in his book, *Social Limits to Growth*, in 1976. In his categorization of such goods, Hirsch distinguishes between consumption goods that are physically in fixed supply and consumption goods for which the scarcity is socially induced. Examples of the former would be a Rembrandt painting or exclusive access to a natural landscape that is physically unique. In these cases, consumers derive at least part of their satisfaction from just the inherent characteristics of the goods, i.e., from the painting simply as a painting or acres simply as acres, rather than as objects that are scarce. However, with a second category of position goods:

[... ] consumer demand is concentrated on particular goods and facilities that are limited in absolute supply not by physical but by social factors, including the satisfaction engendered by scarcity as such. Such social limits exist in the sense that an increase in physical availability of these goods or facilities, either in absolute terms or in relation to dimensions such as population or physical space, changes their characteristics in such a way that a given amount of use yields less satisfaction. This is equivalent to a limitation absolute supply of a product or facility of a given “quality,” and it is in this sense that it is regarded here as a social limitation.

This social limitation may be derived, most directly and most familiarly, from psychological motives of various kinds, notably envy, emulation, or pride. Satisfaction is derived from relative position alone, of being in front, or from others being behind. Command over particular goods and facilities in particular times and conditions becomes an indicator of such precedence its emergence as a status symbol. Where the sole or main source of satisfaction derives from the symbol rather than the substance, this can be regarded as pure social scarcity.

Such satisfaction may also be associated with absolute physical scarcities. Thus to at least some people, part of the attraction of a Rembrandt, or of a particular natural landscape, is derived from its being the only one of its kind; as a result, physically scarce items such as these become the repository of pure social scarcity also ... [Hirsch (1976, pp. 20–21, italics added).]

In recent years, entire volumes, notably Frank (1999) and Layard (2005), have been written about the negative consequences of position goods for happiness. For when consumption behavior is directed towards position goods, what one individual

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78 As a contemporary instance of such a good, consider the “One-of-a-Kind Low Rider” described by Robert Nesmith on p. 18 of the February, 2007, issue of *Art and Antiques*: An exclusive Daimler 1931 Double Six 50 Sport Corsica Drophead Coupe still exists today—and that’s quite a feat considering that only one was made. A project begun in 1926 by the Coventry, England-based automaker that took roughly 8 years, this low-riding 12-cylinder was a direct response to arch-rival Rolls-Royce’s 1925 New Phantom. The Double Six 50 is amazingly quiet, thanks to its double-sleeve valve design. Originally a flex-head (hardtop) coupe, the car was later modified to the drop-head, or convertible, style in 1933, with further coach modifications in ’34. It was thought that possibly two or even three versions of this automobile were made, but photographs confirm the same serial number: 30661. The car was pursued and bought by Ontario-based RM Auctions in 2004, when it was immediately sold to its present owner and meticulously restored, also by RM. The so-called Corsica Roadster won Best of Show at Pebble Beach Concours d’Elegance in August 2006. “The Pebble Beach Best of Show is the ‘Holy Grail’ of car awards,” says RM Auctions spokesperson Terrence Lobzun. “It’s as close to a time machine as you can get.” This car also serves as something else—a reminder to onlookers who “have everything” of one small detail: They don’t have this. [Italics added.] Now we know.
gains in satisfaction, another loses, so that overall happiness (assuming that it can be summed across individuals) is at best not reduced.\textsuperscript{79} Since much of position-good consumption can almost certainly be taken to have its roots in the self-esteem need, which in turn can be seen as generating an endless sequence of wants within a need, it is easy to see why mean levels of satisfaction in high-income economies may be relatively independent of the level of income, yet nevertheless give rise to income (or total expenditure) elasticities that are in excess of 1.\textsuperscript{80}

A final factor making for nonincreasing happiness in consumption behavior is simply the broad spectrum of consumption activities that are subject to (nonaddicting) habit formation. For such activities, a part of consumption expenditure (because of possible strengthening of negative opponent processes) will be focused on eliminating discomfort, rather than adding to satisfaction. Since, as will be shown in Chapter 17, about 65\% of aggregate consumption expenditure in the U.S. is characterized by habit formation, this represents a potentially large drag on happiness.\textsuperscript{81}

\subsection*{2.12 Summary and Final Comments}

Following a brief overview of conventional demand theory, the primary purpose of this chapter has been to develop a framework for the analysis of consumer behavior that is based on evolutionary and neurobiological foundations. While a theoretical

\textsuperscript{79} For a discussion of the welfare costs associated with consumption expenditures for position goods, see Frank (2007).

\textsuperscript{80} Some anecdotal insight into the power of the self-esteem/position-good motive in driving consumption expenditures of newly super-rich is provided in an article in \textit{The Wall Street Journal} (December 16–17, 2006, pp. A1 and A6). The article notes that income of managers of the top 26 hedge-funds averaged $363 million in 2005, and includes a table showing mean expenditures for 10 luxuries for a group of hedge-fund managers (having an average net-worth of nearly $200 million) for the 12-month period ending in the first quarter of 2006. Heading the list are expenditures for fine art of nearly $4 million, followed by expenditures for yacht charters and jewelry of $430,000 and $376,000, respectively. Tenth on the list are expenditures for wine and spirits for the home of nearly $50,000. As is evident in the prices paid at auctions of over the last 20 years for paintings of Klimt, Monet, Picasso, Renoir, Van Gogh, and others, the importance of art as position goods to the ultra wealthy can hardly be overstated. [This paragraph, it should be noted, was written in early 2007 just as the financial meltdown that devastated most (if not all) of these hedge funds in the summer and fall of 2008 was getting started.]

\textsuperscript{81} Another basic need that can give rise to at-best zero-sum satisfaction consumption activities is the security need, specifically those expenditures that are caused by the need to protect self, home, and property from thievery and vandalism. Still another example of consumption expenditures that are of the ‘eliminate-discomfort’ variety are ones that are socially induced so as to be able “to appear in public without shame,” a notion, incidentally, that can be traced to the Talmud (Tamari, 1987). Related notions include Veblen’s Conspicuous Consumption (1899), “bandwagon” and “snob” effects of Leibenstein (1950), and “Keeping-up-with-the-Joneses” (Duesenberry, 1949). For an extensive discussion and analysis of the negative aspects of intertwined tastes and preferences, especially as they give rise to “competitive consumption,” see Schor (1998). Also, for a detailed account of the emergence of a consumerist society in the 17th and 18th centuries in France, see Roche (1997).
structure comparable to that of neoclassical theory (whether in Hicks–Allen–Slutsky or revealed preference formulations) is obviously absent, it is hoped that sufficient elements of this way of conceptualizing consumer behavior are present to provide—if nothing else as an augmentation to conventional theory—an interpretive framework for guiding the empirical analyses of this study and assessing results. In approaching this task, our basic premise has been that the framework must have a basis in evolutionary biology and be consistent with currently accepted findings regarding functioning of the human brain. As a point of departure, the “black box” of utility maximization has been replaced with the postulate that the behavior of human beings is motivated, following the psychologist Abraham Maslow, by five basic needs (or wants): physiological, security, love/belonging, self-esteem, and self-actualization. These wants are assumed to be hierarchical in the order presented. At the most basic level, physiological needs must be fulfilled before security needs emerge, security needs must be fulfilled before love/belonging needs emerge, and so on and so forth.

However, the assumption of a hierarchy of wants conflicts with one of the basic premises of conventional demand theory, namely, that there is just a single want—utility—that can be described in terms of a single-valued function of the goods in a consumer’s choice set. With a hierarchy of wants, this premise can no longer be maintained. Although there may be equivalence classes (or indifference curves) within a need category, such cannot be the case between categories. Preferences of this form have obvious implications for defining income and price effects. While income effects can seemingly be defined in a straightforward way, this does not appear to be the case for price effects (at least as measured in terms of usual income and substitution terms) because of the absence of indifference between wants. A condition has been defined, copacetic equilibrium, intended to refer to a point in time, in which all of the basic needs of an individual are gratified. When this condition holds, as should be the case for normal individuals most of the time in high-income economies, the desires wanting to be satisfied will all be arising from higher-order wants within the higher basic needs, and, accordingly, the desires being satisfied at any point in time are almost certain (for neurological reasons) to be random. At best, therefore, consumption behavior at a point in time can only be modeled probabilistically.

Consumption behavior over intervals of time, on the other hand, is another matter. For if desires waiting gratification at points in time are stable probabilistically, then the resulting probabilities when integrated over time can be seen as fashioning preferences that, in turn, give rise to expenditures that are stable proportions of

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82 As mentioned at the start of Section 2.7, the “consumption” problem for most individuals, when not at work or asleep, is how to keep a sufficient number of neurons firing so as not to become bored. For individuals in copacetic equilibrium, the desire that, at any point in time, might be in play to motivate a consumption decision almost certainly emerges at random.
total expenditure.\textsuperscript{83} At a theoretical level, this allows for the estimation of demand functions, although, in general, not ones that can be rationalized in terms of utility maximization.

An additional implication of hierarchical preferences (together with the notion that much of consumption activity is initiated by the lower-level alpha and beta brains) is that they provide a useful vehicle for rationalizing the size of income elasticities. In ordinary economics discourse, goods are classified according to whether they are inferior, normal, or luxury depending upon whether their estimated income elasticities are negative, positive but less than one, or greater than one, respectively. Just as conventional demand theory takes preferences as given (i.e., does not attempt an explanation as to where preferences come from), it also provides no explanation for why income elasticities are as they are, not even for a phenomenon as basic as Engel’s Law for food consumption. With hierarchical preferences, in contrast, Engel’s Law is an immediate consequence of satiation of the most basic physiological need. Other income elasticities may not be so easy to rationalize, but at least there is the potential for so doing.

While the hierarchy of wants is genetic in origin, and therefore provides the foundation for an individual’s preferences, actual preference structures, i.e., the way that wants, especially the higher-order desires embedded arising within the basic needs (and controlled by the gamma brain), will be gratified, will come into being primarily through consumption experience. Thus, in an important sense, preference structures can be viewed as being self-assembled.\textsuperscript{84} In general, much of the self-assembly will be the result (per the discussion in Section 2.4 above) of dynamical formations of neural networks within the brain. Within a preference structure, some consumption activity will be triggered by the lowest-order brain (the brain stem, or alpha brain) in order simply to maintain homeostasis in the autonomic processes. Other consumption desires can emerge from unconscious slave processes (i.e., habit formation or even addictions), residing mostly in the mid-level brain centers (i.e., the beta brain), that have come into existence through previous consumption activity, while still other consumption behavior will be directed from the highest brain centers in conscious searches for new and novel gratifications.

Finally, despite the assumption that there are only five basic needs, the number of wants themselves (when considered as higher-order wants that emerge from within the basic wants) is endless.\textsuperscript{85} Once one want is satisfied, there will always be another

\textsuperscript{83} By stable budget proportions in this context, we do not mean budget proportions that are totally invariant with respect to time and place, but rather budget proportions whose variation can be explained, at least to some extent, by variations in income, prices, and cultural-socio-demographical factors. Also, reference here, as noted in Section 2.7, is to ensembles of individuals.

\textsuperscript{84} By “self-assembled,” we mean that preferences are created on-the-fly within the organism in response to external exposure and experience.

\textsuperscript{85} This is hardly a novel precept, but is fundamental in the 18th-century Enlightenment thinking. Cf. J. Locke [in the Essay Concerning Human Understanding, as quoted in McMahon (2006, p. 320): “We are seldom at ease, and free enough from the solicitation of our natural or adopted desires, but a constant succession of uneasiness out of that stock, which natural wants, of acquired
to take its place. The basis for this assertion is the neurological need for a minimum level of arousal, which for most individuals will not occur with a fixed number of consumption activities. Repetition leads to satiation, which then leads to desires for new activities, and so on and so forth.\textsuperscript{86} On the other hand, this does not rule out that a desire for a new activity may in fact be for a minor variation on an existing activity. For while arousal may demand something new, the basic security need may demand something that is not too new. The optimal new activity, accordingly, will often be something that combines a small amount of novelty with a great deal of redundancy.\textsuperscript{87} But, even so, the quest for novelty would appear to be a real neurological phenomenon, and represents the magnet for a continual appearance of new goods.\textsuperscript{88}

\begin{itemize}
\item Habits heaped up, take the will in their turns; and no sooner is one action dispatch\’d, which by such a determination of the will we are set upon, but another uneasiness is ready to set us on work.” Cf. as well, de Tocqueville (also, as quoted in McMahon, pp. 333–334): In certain remote quarters of the Old World you may sometimes stumble upon little places which seem to have been forgotten among the general tumult and which have stayed still while all around them moves. The inhabitants are mostly ignorant and very poor; they take no part in affairs of government and often governments oppress them. But yet they seem serene and often have a jovial disposition. In America I have seen the freest and best educated of men in circumstances the happiest to be found in the world; yet it seemed that a cloud habitually hung on their brow, and they seem serious and almost sad even in their pleasures. The chief reason for this that the former do not give an moment’s thought to the toils they endure, whereas the latter never stop thinking the good things they have not got.

\textsuperscript{86} For normal individuals in copacetic equilibrium, the needs in question can often arise through what Polyani (1974, p. 173) refers to as \textit{intellectual passions}, i.e., passions that reflect an individual\’s need for discovery, which leads to new knowledge, which, once gratified, then in turn leads to a need for more new discovery, and so on and so forth. Intellectual passions thus perpetuate themselves by their fulfillment.

\textsuperscript{87} Symphony music directors are aware of this problem when they usually include no more than one contemporary composition in any single program. Old ears require the soothing security of familiar notes. See Tversky and Sattath (1979) for a discussion.

\textsuperscript{88} The higher-order intellectual passions, such as science, mathematics, religion, fiction, and fine arts (including music), are validated by becoming happy dwelling places of the human mind, and thus provide the outlet for an endless stream of new desires. [Cf. Polyani (1974, p. 280).] On the other hand, it should be noted that novelty is an individual experience, for what is novel to one may be redundant or of no interest to another.
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