Why Isn't Growth Making Us Happier? Utility on the Hedonic Treadmill

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Abstract

A preference structure is constructed, grounded in psychological evidence, with well-being a function of the consumption level and the growth of the variety of goods consumed. Such preferences are analyzed in an endogenous variety growth model. The implications are consistent with the increase in income and the variety of goods consumed in developed economies in the post-war period that have not been accompanied by an increase in reported well-being. Moreoever, the results suggest a connection between the stagnancy of reported well-being and diminishing returns in technological change, despite an increase in the variety of goods available over time.

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1 Introduction

It seems fair to presume that a fundamental goal of economists is to improve the well-being of humans. Modern economists since Edgeworth and Pareto have adopted the concept of utility as a way of measuring well-being. As we tell our undergraduates, utility is meant to measure the pleasure or satisfaction humans derive from their consumption of goods and services. Economists prefer to use an ordinal concept of utility rather than a cardinal concept. The intellectual appeal of using ordinality rather than cardinality is due to the fact that economists are not in the business of directly measuring well-being; we prefer to infer well-being by observing human behavior. If a person chooses to consume one good over another, we infer that the good consumed yields a higher level of well-being than the other good, all else equal. How much higher well-being may be is something economists tend to refrain from discussing.[1]

What economists have, perhaps, not paid sufficient attention to is how human choices can help us to infer how well-being is determined, that is, how the utility function is structured. The results of any such inference are of immediate interest if, as conjectured, our purpose is to improve well-being. We frequently assume that instantaneous utility is a function only of the current level of consumption. Such an assumption may not be appropriate, and its use may significantly constrain understanding of observed economic patterns. Understanding how the utility function is structured does not require an abandonment of ordinal utility. It may, however, be assisted by the application of the results from research in hedonic psychology, or the psychological study of well-being, to understand how the well-being of a person at a point in time is determined.

This paper examines how the existence of a "hedonic treadmill," which has been described and studied by psychologists (see Kahneman (1999)), can be formalized in a utility function. Related preferences structures have been used in economic theory, though they generally have not been linked as explicitly to the psychological literature as will be done in this study. Doing so enriches the interpretation of these preference structures. In addition, empirical evidence suggests that income is growing over time in most industrial economies, but well-being is not. The paper argues that this evidence is linked to supply-side technological constraints, particularly to the observed expansion in the variety of goods produced and consumed in the North America and Western Europe. In a model allowing for endogenous variety growth, the phenomenon of hedonic adaptation can lead

[1] Economists do, however, sometimes compare utility using cardinal measurements (see van Praag and Fritjers (1999)).

to an outcome where utility per unit of expenditure is falling. As one novelty of the model, the element of utility that represents hedonic adaptation will be treated as a tradeable commodity. The model's equilibrium can generate a research sector that becomes large relative to other sectors in the economy, consistent with empirical patterns. Thus, policy to alleviate the stagnation of well-being may be fruitfully focused on research sector productivity.

2 Empirical Evidence on Income and Well-Being

In North America and Europe during the post-war period, incomes per capita have been rising; growth has been positive. However, over the same period, reported well-being has been roughly untrended, as documented by Blanchflower and Oswald (forthcoming), Easterlin[2] (1974, 1995), Kenny (1999), Oswald (1997), Smith (1979) , and Veenhoven (1994). There are at least two qualifiers to this last statement. First, within this period, reported well-being does seem to be positively correlated with income (see Blanchflower and Oswald (forthcoming), Di Tella et al. (forthcoming), and Easterlin (2001)). Second, the interpretation of the data is subject to some debate. For some groups, such as the young, well-being does seem to be increasing over time and appears to be attributable to changes in relationships rather than income (Blanchflower and Oswald (1999)). This finding raises the rather important point that well-being is probably not determined by consumption variables alone. If one looks at surveys that ask about some specific indicators of well-being, then the results are more mixed. For instance, suicides in the U.K. have fallen overall during the post-war period, although suicides of men have increased since the 1970's (see Oswald). Job satisfaction is decreasing over time in the United States (Blanchflower and Oswald (1999)).

Nonetheless, if one accepts the conclusion that the well-being derived from each unit of income has fallen over time, then one might next consider why. This paper proposes hedonic adaptation, leading to a hedonic treadmill, as a possible explanation. This explanation has support in psychological theory and experimental evidence. Its formalization within a growth model results in predictions consistent with the data, although distinct from other related theories.

[2] Questions about Easterlin's use of data in his 1974 study are also raised by Blanchflower and Oswald (1999) . They argue that Easterlin's use of surveys with different definitions of well-being leads to the absence of positive correlation between income and happiness. When one examines the longest consistent series of Easterlin's data (1946-1957), the percentage of those reporting themselves "very happy" increases (39% to 53%) and those reporting themselves "not very happy" declines (10% to 3%).

3 Formalizing the Hedonic Treadmill

Hedonic adaptation is a process by which the cognitive effects of a repeated experience (for instance, consumption) are reduced (see Frederick and Loewenstein (1999)). A hedonic treadmill results when the adaptation occurs to the point where the experience is rendered neutral in its effect on well-being. Formally, utility $D_1(t)$ dependent on adaptation alone would be a function of a current experience $n(t)$ minus the level of experience at which current experience would have no effect on well-being $\bar{n}(t)$:

$$D_1(t) = f(n(t) - \bar{n}(t)). \tag{1}$$

The neutral experience level $\bar{n}(t)$ is typically take to be some function of past experiences, $n(s)$, $s < t$. As it stands, this utility function looks like the formalization of some habit formation models[3] that, in light of the psychological evidence and relative to this paper's model, are discussed further below.

Psychologists (Frederick and Loewenstein (1999), Hsee and Abelson (1991), Hsee et al. (1991), Loewenstein and Sicherman (1991)) have also proposed that well-being, while derived from experience, comes not from the absolute change in experience but from the rate of change.[4] Empirical evidence is considered in the next section. In this case, defining $\bar{n}(t) = n(t-1)$, utility $D_2(t)$ would be

$$D_2(t) = f\left(\frac{n(t) - n(t-1)}{n(t-1)}\right). \tag{2}$$

A final modification put forward by psychologists (Frederick and Loewenstein (1999), Hsee et al. (1991)) incorporates the notion that experiences can contribute to well-being aside from their contribution via comparison. They can be pleasing in their level as well. There is some well-being derived from the level of experience, or position, $c(n(t))$. This term has been formalized as additive in utility. The resulting instantaneous utility would be

$$D(t) = c(n(t)) + f\left(\frac{n(t) - n(t-1)}{n(t-1)}\right). \tag{3}$$

The formulation is to be interpreted as follows. Instantaneous utility $D(t)$ at an instant t is determined by a function of the rate of change of experience n, $f\left(\frac{n(t)-n(t-1)}{n(t-1)}\right)$, and by some

[3] Nor is it very different from interpersonal comparison models if $\bar{n}(t)$ were interpreted as the experience of some other person or people.

[4] A related explanation is the endowment and contrast effects described and empirically supported by Tversky and Griffin (1991).

function of the level of experience, $c(n(t))$.

Empirical support for the formulation (3) is given and is then compared with related theories of utility determination.

4 Empirical Evidence on the Hedonic Treadmill

Evidence on the baseline formulation of hedonic adaptation, where well-being is determined solely by an absolute change in a level of experience (e.g. consumption), is reviewed first. This is followed by evidence on the two modifications: well-being dependent on the rate of change of experience, and well-being as a function of hedonic adaptation as well as a level input.[5]

It is possible to consider hedonic adaptation to many types of experience, both positive and negative. Empirical research on several different experiences, from bereavement to cosmetic surgery, are reviewed by Frederick and Loewenstein . For our purposes, evidence on overall income and wealth as well as food consumption are of particular interest. As described above, the existing evidence suggests little or no correlation between income and reported well-being. This in itself is suggestive of hedonic adaptation. Confirming such a suggestion is evidence that workers prefer increasing wage profiles in studies by Clark (1999), Frank and Hutchens (1993), and Loewenstein and Sicherman (1991). Workers appear to link their reported well-being to changes rather than levels of their wages. Evidence reviewed by Kahneman (1999) suggests that people use a change in their situation to evaluate the situation itself.

Hedonic adaptation may not represent a link between the absolute change in income and well being, but rather the rate of change. That is, the utility derived from a change in income is measured relative to a (previous) level of income. The level of income is a status quo against which the change is compared. An increase in income of \$20000 will probably have a different hedonic impact if the initial income is \$20000 rather than \$80000. Such a notion is related to Kahneman and Tversky's (1979) prospect theory, discussed below. Empirical evidence of a relation between the rate of change in income and utility is provided by Frank (1999), Hsee and Abelson (1991), Hsee et al. (1991), and Lowenstein and Sicherman (1991).

For instance, Hsee and Abelson surveyed undergraduates, directly asking them about their relative satisfaction between two outcomes related to their class rank. In some questions outcomes

[5] This section relies on the review of the literature by Frederick and Loewenstein.

were described in terms of the rate of change.[6] They found that students chose the higher rate of change outcome (when the change was positive), holding constant the level of change. Therefore, the survey results suggest that the rate of change is important to well-being, beyond the level of change.

Taken alone, the rate of change in income does not allow the level of income to contribute to utility. Such an implication seems flawed. This issue is noted by Frederick and Loewenstein (1999) and Hsee et al. (1991). The latter study attempts to measure the relative weighting in a utility function of the standard of living, proxied by the average level of income (over time) and of the rate of change in income.[7] They find positive weighting for both elements, although the relative weights differ across situations. Hsee et al. suggest the weights differ according to the following pattern. When behavior (e.g. consumption) is chosen because it is inherently pleasurable, then the rate of change is relatively more important. Examples of this type of consumption would be expected to have relatively high demand elasticity. When behavior (e.g. consumption) is done as a means to an end, then the absolute level is relatively important. Examples of this type of consumption would be necessary goods, like food, with inelastic demand.

Such a suggestion is consistent with Scitovsky's (1976) view that consumption is made up of comfort and stimulation elements. Comfort consumption he associates with necessities. Positing that humans' need for comfort is finite, he views stimulation as the consumption of leisure or a variety of non-essential goods that help people avoid boredom (see Scitovsky (1999)), such as the ability to read books, visit an art museum, or play a video game.[8]

Scitovsky's suggestion is also consistent with evidence regarding hedonic adaptation and food consumption. Studies of people's enjoyment of foods, reviewed by Frederick and Loewenstein , indicates that people actually experience an increase in well-being from repeated consumption of a particular food. There appears to be a temporal issue here - while one might get tired of eating the same food every day for a week, one might derive increased pleasure from eating the type of food

[6] Other questions had outcomes described in terms of absolute level, and others absolute change. The students' judgment of the two outcomes were as would be expected: higher absolute level was deemed better than lower, and higher absolute change - for positive events - was deemed better than lower.

[7] Frederick and Loewenstein motivate this term as the benefit from experience at a point in time.

[8] Scitovsky stresses in his 1999 article that stimulation can vary in quality and in depth. He argues that if humans choose to consume stimulation that requires less mental or physical exertion, boredom will occur more easily and spur a further rush for more stimulation. This distinction between types of stimulation is beyond the scope of the present study.

once a week over several weeks. These studies may help to shed some light on the mixed evidence on whether consumption patterns are consistent with habit formation models. The theoretical basis for habit formation and a comparison with this paper's formalization of the hedonic treadmill are described below. Dynan (2000) reviews the mixed evidence for habit formation. Arguing that a major reason for the ambiguous results is that previous studies use aggregate consumption data, which is prone to serial correlation.

Dynan uses the household-level PSID data on overall food consumption and finds no evidence of habit formation at an annual frequency. In her formulation, habit formation in consumer preferences for food is equivalent to $\Omega > 0$ in the following setting:

$$\begin{aligned} u &= u\left(\tilde{c}\left(t\right)\right), \\ \tilde{c}\left(t\right) &= c\left(t\right) - \Omega c\left(t-1\right). \end{aligned}$$

She finds estimates of Ω are insignificant and almost always negative, and this finding is robust to a number of specifications and instruments. However, in light of the psychological research that finds that food consumption may enter utility more in terms of its level than in terms of hedonic adaptation, this result is not surprising. Even if one still views hedonic adaptation as supported by other evidence, Dynan's study supports the case for including the consumption level in a utility specification with hedonic adaptation.

5 Variety Growth

In the endogenous variety growth model with a hedonic treadmill developed in this paper, the trade-off for consumers will be between the utility from hedonic adaptation and the utility from the level of consumption. Such a formalization of the hedonic treadmill closely follows the psychological literature that has been described. The model predicts that consumption will be increasingly directed toward hedonic adaptation's contribution to utility. The supply side will direct resources toward technological change, increasing variety, rather than increasing the level of consumption of each variety. The endogenous growth in variety will be seen to create a vicious cycle, where an increase in variety simply creates more demand for an increase in variety, with diminishing impact on well-being.

This result is, at least in part, empirically verifiable beyond the evidence that already exists and that has been described above. It is possible to examine whether technological change is directed at creating new products or at improving and increasing consumption of existing products. Existing evidence, though not extensive, suggests resources are increasingly allocated toward variety-increasing technological change.

There is no clear-cut way to define what constitutes a new variety of good. For the purposes of this paper, though not necessarily for all of the empirical evidence cited below, the motivating definition of a new variety is somewhat conservative. A new variety is defined as a new product that provides a consumption good or service with no existing close substitute. A new cereal brand, such as Lucky Charms, would not constitute a new variety of good. A new cereal with a particular innovation, such as granola, might constitute a new variety, depending on the elasticity of substitution between granola and other types of cereal. A new variety of good would unambiguously include the introduction of cereal as a type of food made of grains that has a long storage life and is eaten in a bowl with milk.

Consumer preference for variety has been given attention in the recent marketing literature (see Gijsbrechts et al. (2000) and references cited therein). The variety of goods and services that people in developed countries can consume has increased, as is documented by Lebergott (1993) and Cox and Alm (1998). For example, Lebergott reports that while the average supermarket in the United States contains eight thousand items, the number of entertainment products added since 1921 is twenty times the number of additional food and drug products. While it seems clear that variety growth has been positive, whether variety growth is accelerating is not clear. Indirect evidence suggesting that variety growth is accelerating in the United States over 1959-1999 is provided by Bils and Klenow (2001). On the other hand, Funke (2000) presents evidence that variety growth in tradeable goods in the United States over 1989-1996 was nearly zero. It is possible that whether one argues that variety growth is or is not accelerating may depend in large part on the standard that defines a new variety. Therefore, this author does not take a view on variety growth other than to argue it is, and has been for past century, positive.

6 Related Theories

6.1 Habit Formation Models

The psychological literature summarized above provides a foundation for habit formation models as developed by Pollak (1978), Abel (1990) and subsequent authors. One of the purposes of using these models has been to provide a theoretical explanation for consumption smoothing over time. As noted by Carroll et al. (2000), the idea behind consumption smoothing is not a new one. The underlying intuition is that consumers do not like large decreases in their consumption pattern and choose to remove volatility in consumption as a result (see Fuhrer (2000)). In these models, the frame of reference $\bar{n}(t)$ in an instantaneous utility function such as equation (1) is a stock of habits that is usually represented as a moving average of previous consumption.[9] Consumption and the habit stock has entered the preference structure as a difference, as in Dynan (2000), or as a ratio, as in Carroll et al. (2000) who use a model of growth with habit formation to provide a rationale for why higher rates of growth may lead to higher rates of savings.

In the case that consumption and the habit stock, or the previous period's consumption, enter the utility function as a ratio, then the utility function is equivalent to (2) . Habit formation models define the trade-off to consumers as between consumption in the current period and consumption in the future. In a model with savings as in that of Carroll et al., consumers use savings to smooth consumption growth.

It would seem natural to use a habit formation model in the current study, possibly with the innovation that there is habit stock associated with each variety of a consumption good. It is, unfortunately, not possible to use a traditional habit formation model in a setting, such as that of this paper, in which the price of a consumption good is determined endogenously by a profit maximizing firm and in which there is innovation of the consumption good generating positive profit for the production sector.[10,11] Essentially, the necessary concavity assumptions to solve utility maximization problem and the profit maximization problem are not mutually consistent. Therefore, an alternative structure that is still well-motivated by the psychology literature is used. This paper's preference structure is complementary to a habit formation framework. The main technical innovation of this paper is the use of a model with many varieties of consumption, and the endogenous growth of variety, as a way to interpret the psychology literature's findings.

However, the interpretation of the preference structure in this paper's model will be somewhat different from that of a habit formation model for two reasons, both having to do with the introduc-

[9] A special case of the frame of reference is the previous period's consumption, providing a hedonic adaptation interpretation.

[10] Positive profit for the production sector is necessary to provide incentive for innovation, as in any growth model with endogenous technological change that requires an allocation of resources to technological change.

[11] The technical details of this claim are laid out in an appendix on the JEBO website.

tion of endogenous variety growth. First, in the model developed below, income is endogenously increasing over time due to technological change, and describing the preference structure as one with habits would be misleading. The steady state level of consumption growth is driven by the technological constraints of the supply side of the economy rather than the formation of habit in consumption. However, the focus of the model's analysis is not just on the steady state, but on a transition path as well. The growth in variety responds to preferences but also the supply-side constraints of the economy. It is not habits that are being formed, but rather changes in consumption choice due to continual adaptation to the growth in the variety of goods available.

The second reason why this paper's model is novel relative to the existing habit formation literature is that, as the psychological evidence suggests that changes in consumption affect well-being, consumers should be willing to pay for experienced changes in the type of consumption. Thus, the growth in the variety of goods available is treated as a tradeable commodity. Consumers are willing to pay a premium for goods that expand their consumption variety to the producers of those new varieties. Their willingness to pay, or the inverse demand function, is derived as a result of their utility maximization problem, and the equilibrium price of the hedonic adaptation commodity can be tracked. As a result, the ability of the supply side of the economy to respond to the preference structure will be limited by technological constraints rather than a missing market.

6.2 Prospect Theory

The Kahneman and Tversky prospect theory uses the concept of decision utility. That is, utility can be inferred from people's decisions. This theory is based on experimental evidence that does not suffer from the criticism that well-being should not measured by surveys. Prospect theory uses an ordinal utility concept. Utility is derived from changes rather than only levels of experience, and those changes are evaluated relative to a reference point (Kahneman (1994)). The close conceptual link with a hedonic treadmill based on a rate of change in consumption is clear.

Kahneman and Tversky support this assertion with experimental evidence. Much of the subsequent work using this theory is concerned with risk and return (for example, see Tversky and Kahneman (1986, 1991) and Thaler, Tversky, Kahneman and Schwartz (1997)). However, Kahneman and Tversky explicitly recognized the connection between the choice of uncertain events and the certainty case, where individuals derive value relative to a reference point of certainty and gains and losses from that reference point. Indeed, their model is motivated by the riskless case.

The implied utility function for events is concave in gains and convex in losses, giving it a S-shape.

6.3 Interpersonal Comparison Theories

Another interpretation of the reference point $\bar{n}(t)$ in an instantaneous utility function such as (1) is as a level of aspiration or the average consumption of some reference group. The intuition is that we compare our consumption to others' to evaluate our well-being. The relative importance of the two types of reference points - interpersonal comparison and hedonic adaptation - has not been empirically resolved (Kahneman (1999)). In principle, the relevance of one does not discount the relevance of the other, and there is evidence supporting both hypotheses. It may be the case that certain types of consumption are more subject to interpersonal comparison than others.

Hirsch (1976) describes certain *positional* goods, and Easterlin (2001) describes *aspirations* as being the frame of reference. In both cases, people determine their well-being by comparing their consumption, or some types of consumption, against desired consumption. This type of comparison would also provide insight into why well-being may be correlated with income across individuals within a period of time. Easterlin argues that within a country and a period of time, people evaluate their well-being relative to a single level of aspiration, with a resulting positive correlation between income and well-being. Over time, aspirations change as income increases (over the lifecycle, in this case). As one becomes richer along with everyone else, the average income increases and thus aspirations increase. Therefore, the measure of well-being will not increase as income increases. A similar type of phenomenon in the case of a positional good, or status good, would hold.

Models of growth with interpersonal comparison are developed by Carroll et al. (1997) and Cooper et al. (2001). The focus of Carroll et al. is to compare savings, growth and utility in models with interpersonal comparison or habit formation in the preference structure. They find that with a negative shock to capital, savings and growth will fall for both preference structures. Utility falls more in the interpersonal comparison case, since individuals do not take into account the effect of their consumption choices on others' utility.

Cooper et al. include in preferences a status good (akin to Hirsch's positional good) on which consumers compete. They show that such a consumption game can lead to non-increasing utility growth despite positive income growth. Cooper, García-Peñalosa and Funk's model predicts that the consumption of the status good will exceed that which is socially optimal.

As in the model of Cooper et al., the model developed here will predict that utility per unit of income is falling. However, aside from the different economic interpretation of the results, the mechanism driving the results is different. In this paper's model, utility does not grow because of a general equilibrium resource allocation trade-off between the hedonic adaptation contribution to utility and the consumption level contribution to utility. The results of this paper have implications regarding the direction and size of technological change that are not present in the interpersonal comparison preference models of growth.

7 Endogenized Variety Growth

A model is presented of endogenous growth with expanding product variety based on that of Grossman and Helpman (1991). The only difference in the present setting from the Grossman and Helpman model will be the preference structure, with consequent effects on the equilibrium pricing structure. The preference structure derives from (3). Hedonic adaptation is interpreted as the rate of addition of the variety of goods available and consumed.[12] Following Grossman and Helpman, new varieties are produced endogenously by an innovation. The innovation sector exhibits decreasing or constant returns to the use of existing varieties as an input for the creation of new varieties. Decreasing returns will be seen to constrain utility growth by constraining the growth rate of new varieties. Population growth is greater than or equal to zero.

The equilibrium growth rate will exhibit properties in accordance with the empirical evidence presented in the Sections 1-5. Consumers in wealthy countries are becoming richer but well-being per unit of expenditure is falling. Further, variety growth is positive and possibly increasing. Economic resources in equilibrium are increasingly devoted to new varieties in equilibrium rather than the level of consumption of each variety.

7.1 Consumers

Intertemporal utility is given by the expression

$$U(t) = \int_t^\infty e^{-\rho(\tau - t)} \log D(\tau)\, d\tau \tag{4}$$

[12] An alternative interpretation might be the rate of change in some measure of quality of goods, but this would be harder to document. Also, at least to some extent, the notion of a rise in quality is subsumed in an increase in variety. For instance, CD players may be better than cassette players in terms of sound quality, but the introduction of CD players did not lead to the disappearance of cassette players. It instead provided a new medium for the enjoyment of music.

$$D(t) = D\left(\lambda(t), \left[\int_0^{n(t)} x(j,t)^{\Omega} dj\right]^{\frac{1}{\Omega}}\right) \tag{5}$$

where $\lambda(t)$ represents hedonic adaptation and will be defined as equal to the rate of variety growth, $\frac{\dot{n}(t)}{n(t)}$. The change in consumption experience is interpreted as not only consisting of an increase in the level of consumption, but also a change in the type of consumption. The level of consumption of variety $j \in [0, n]$ is $x(j,t)$ also enters into utility, as expected. The number of varieties $n(t)$ enters positively into utility, all else equal, under the maintained assumption that $0 < \Omega < 1$. The second term of $D(t)$ combines a degree of variety-loving with a preference for a higher standard of living, as given by the level of consumption. It is assumed that $\frac{\partial D}{\partial \lambda} > 0$ and $\frac{\partial D}{\partial x} > 0$, as is consistent with all three forms of utility structure discussed above. Assume also that D is additively separable in its arguments, in particular,[13]

$$D(t) = \theta\lambda(t)^{\Upsilon} + \left[\int_0^{n(t)} x(j,t)^{\Omega} dj\right]^{\frac{1}{\Omega}}, \tag{6}$$

$\Upsilon \in (0, 1]$.

Instantaneous utility is derived from the introduction of new varieties. It is also derived from the level of consumption of each variety, and the number of varieties available. This formulation is consistent with the psychological evidence reviewed above.

Household expenditure $E(t)$ at each instant of time is an input into the budget constraint

$$E(t) \geq \int_0^{n(t)} p(j,t)\, x(j,t)\, dj + P(\lambda(t))\, \lambda(t) \tag{7}$$

where $p(j,t)$ and $P(\lambda(t))$ are the prices for variety j and λ, respectively. There is a two-tiered price system in which consumers may pay separately for each of the attributes of their utility function. The price $p(j,t)$ is a function of the consumer's willingness to pay for the utility derived from the level of consumption of any variety j.

The utility due to experience of consuming new varieties, captured by the term $\theta\lambda(t)^{\Upsilon}$, implies that producers of new varieties may be able to charge a premium $P(\lambda(t))$ to consumers.

If the premium $P(\lambda(t))$ is charged only at the instant the new variety becomes available, then the number of consumers in the economy is crucial. If the number of consumers is large, such that each consumer is negligible, then any consumer can choose not to consume the new varieties and

[13] A limiting case of this model, where $\Upsilon = 0$, is analytically identical to the Grossman and Helpman (1991) Chapter 3 model.

instead free ride, consuming them starting in the next instant. The utility derived from $\lambda(t)$ would be discounted at rate ρ. Since no premium would be paid, expenditure in both instants would be used entirely toward paying for existing varieties at price $p(j,t)$ for each variety. This free riding is the alternative to that of consuming all new varieties as they are available and paying the premium $P(\lambda(t))$. Such free riding would result, in equilibrium, on the disappearance of the premium in the decentralized economy.[14] In that light, the utility-maximizing problem that is solved next can be interpreted as that by a social planner if free riding is possible. The planner is behaving as a single purchaser of the new varieties when they are first available.[15]

There is another interpretation of the model where, even if each consumer is of negligible size in a decentralized equilibrium. The premium will be charged if the preference for $\lambda(t)$ reflects a preference for novelty, distinct from variety, and that novelty is lost after the instant a new variety is available. Thus, consumers gain utility from the new variety only at the moment it becomes available and cannot free ride. This interpretation of the preference structure is consistent with the empirical evidence. The standard Grossman and Helpman model includes a variety-loving preference structure; what $\lambda(t)$ adds to the preference structure can be interpreted exactly as a preference for novelty.[16]

The reward to a firm that produces a new variety will include $p(j,t)$, paid to all producers of a variety in all periods, as well as a fraction $\frac{1}{\dot{n}(t)}$ of the premium revenue $P(\lambda(t))\lambda(t)$ when the variety is first available. These two elements will be reflected below in the present discounted value of any firm at the instant that it begins producing a new variety.

The intertemporal utility maximization problem is solved in two steps, as is done by Grossman and Helpman. Use of the time-separability of the preference structure is exploited. In the first step, the instantaneous utility maximization problem at time t is solved to determine the allocation of consumption across varieties and between old and new varieties, while holding fixed the level of expenditure at time t. In the second step, the expenditure path that maximizes intertemporal utility is solved(4).

[14] This free-riding equilibrium can be demonstrated by looking at the utility-maximizing choice of consumers in a two-period discrete time example, and then taking the time between the two periods to be arbitrarily small. In that example, free riding will always be chosen over paying the premium.

[15] I thank one of the referees who helped me to clarify this matter.

[16] The premium will also be charged in equilibrium if the producer can charge the premium when the variety is first consumed, as opposed to just when it is first available. A producer would like to do this if possible, but this is probably not realistic.

The Lagrangian for the instantaneous utility maximization problem is

$$\begin{aligned}\mathcal{L} &= e^{-\rho t}\log\left[\theta\lambda(t)^{\Upsilon}+\left[\int_0^{n(t)}x(j,t)^{\Omega}\,dj\right]^{\frac{1}{\Omega}}\right]+e^{-\rho t}\Psi_1(t)\lambda(t)n \\ &\quad +e^{-\rho t}\Psi_2(t)\left[E(t)-P(\lambda(t))\lambda(t)-\int_0^{n(t)}p(j,t)\,x(j,t)\,dj\right]\end{aligned}$$

where first two terms are the Hamiltonian and $\Psi_2(t)$ is the Lagrange multiplier, $\Psi_1(t)$ is the shadow price of $n(t)$, the control variables are $x(j,t)$ and $\lambda(t)$, and the state variable is $n(t)$.

The first order conditions, complementary slackness conditions, and equations for motion of $n(t)$ and $\Psi_1(t)$ are described next. For simplicity these expressions use the results that $x(j,t)=\bar{x}(t)$ $\forall j$ and $p(j,t)=\frac{w(t)}{\Omega}$, where $w(t)$ is the wage paid to each unit of labor, and these results are derived in Section 7.2 below.

$$\Psi_2(t)=\left[\theta\lambda(t)^{\Upsilon}+n(t)^{\frac{1}{\Omega}}\bar{x}(t)\right]^{-1}\frac{\Omega}{w(t)}n(t)^{\frac{1}{\Omega}}; \tag{8}$$

$$\left[\lambda(t)^{\Upsilon}+n(t)^{\frac{1}{\Omega}}\bar{x}(t)\right]^{-1}\theta\Upsilon\lambda(t)^{\Upsilon-1}+\Psi_1(t)n(t)=\Psi_2(t)P(\lambda(t)); \tag{9}$$

$$E(t)=P(\lambda(t))\lambda(t)+n(t)\frac{w(t)}{\Omega}\bar{x}(t); \tag{10}$$

$$\frac{\dot{n}(t)}{n(t)}=\lambda(t); \tag{11}$$

$$\dot{\Psi}_1(t)=(\rho+\lambda(t))\Psi_1(t)-\left[\frac{1}{\Omega}\right]\frac{n(t)^{\frac{1}{\Omega}-1}\bar{x}(t)}{\left[\theta\lambda(t)^{\Upsilon}+n(t)^{\frac{1}{\Omega}}\bar{x}(t)\right]}+\Psi_2(t)\frac{w(t)}{\Omega}\bar{x}(t). \tag{12}$$

Solving for the expenditure path and defining p_D as a composite price of D, the consumer maximizes

$$U(t)=\int_t^{\infty}e^{-\rho(\tau-t)}\left[\log E(\tau)-\log p_D(\tau)\right]d\tau$$

subject to the intertemporal budget constraint.[17] This yields the usual expression

$$\frac{\dot{E}(t)}{E(t)}=r(t)-\rho. \tag{13}$$

If prices are normalized such that E is always equal to one, then $r(t)=\rho\ \forall t$.

[17] The equilibrium expression for p_D is

$$p_D(t)=E(t)\left[\theta\lambda(t)^{\Upsilon}+n^{-\frac{1}{\Omega}}\frac{E(t)-P(\lambda(t))\lambda(t)}{\frac{w(t)}{\Omega}}\right]^{-1},$$

though this expression is not needed in the analysis to follow.

Using $(8), (9), (10)$, and (11), the inverse demand curve for $\lambda(t)$ can be written as

$$P(\lambda(t)) = \frac{\lambda(t)^{\Upsilon} \frac{\theta w(t)}{\Omega} n(t)^{-\frac{1}{\Omega}} \left[\Upsilon \lambda(t)^{-1} + \Psi_1(t) n(t)\right] + E(t) \Psi_1(t)}{1 + \Psi_1(t) \lambda(t)}. \tag{14}$$

To be clear, this expression describes the willingness to pay of the consumer for the commodity $\lambda(t)$, which is interpreted as the experience of the rate of growth of varieties in the consumer's consumption set.

From (14) it can be shown that $\frac{\partial P(\lambda(t))}{\partial \lambda(t)} < 0$ for $\Psi_1(t)$ sufficiently close to zero.[18] Furthermore, $\frac{\partial P(\lambda(t))}{\partial w(t)} > 0$, and $\frac{\partial P(\lambda(t))}{\partial E(t)} > 0$, as one would expect. Finally, it is straightforward to show that $\frac{\partial P(\lambda(t))}{\partial n(t)} < 0$, holding all else equal.

7.2 Production of the Final Goods

Assume that the production of $x(j,t)$ is done using labor as the sole input, and the technology is one-for-one. There is one producer of each variety j. Firms undertake innovation, described below, and then manufacture the variety $x(j,t)$ using the innovation. The producer's problem *after* the initial variety innovation is to maximize profits:

$$\pi(j,t) = p(j,t)\, x(j,t) - w(t)\, x(j,t)$$

where $w(t)$ is the wage paid to labor. Since the varieties enter utility with a constant elasticity of substitution, the profit-maximizing price is $p(j,t) = \frac{w(t)}{\Omega} = p(t)\ \forall j$.

At the instant of innovation, the producer can also earn a premium on its new variety equal to $\frac{P(\lambda(s))\lambda(s)}{\dot{n}(s)}$. Each firm is a monopolistic competitor and considers its own production of one variety small relative to the mass of new varieties $\dot{n}(s)$. Each firm thus takes the total premium and its own share as given. All producers will take the premium as given when choosing the level of production of $x(j,t)$ of new varieties. In other words, producers of new varieties face the same profit maximization problem to determine $x(j,t)$ as all other producers. Therefore, all goods will be demanded equally, and prices will vary only in that new goods receive a premium in addition to $p(t)$.

Using the fact that demand is symmetric and equating supply to demand, demand for each variety at time t, $x(t)$, will be

$$x(t) = \frac{1 - P(\lambda(t))\lambda(t)}{n(t)} \frac{\Omega}{w(t)} \tag{15}$$

[18] Note that $\Psi_1(t) \leq 0$ and that $\lim_{t\to\infty} \Psi_1(t)\, n(t) = 0$ so that $\dot{\Psi}_1(t) > 0$ in equilibrium.

and profits, excluding any premium revenue, will be

$$\pi(t) = \frac{(1 - P(\lambda(t))\lambda(t))(1-\Omega)}{n(t)}. \tag{16}$$

Firm value[19] at the instant of variety innovation, time s, is $v(s)$,

$$v(s) = \int_s^\infty e^{-[R(\tau)-R(s)]}\pi(\tau)\,d\tau + \frac{P(\lambda(s))\lambda(s)}{\dot{n}(s)} \tag{17}$$

where $R(\tau)$ is the cumulative discount factor for profits earned at time τ. The firm will earn profits $\pi(\tau)$ in future periods, and, at the instant of innovation, also earns the premium for expanding variety. Differentiating with respect to time, the no-arbitrage condition is

$$\begin{aligned} \dot{v}(s) &= -\pi(s) + r\int_s^\infty e^{-[R(\tau)-R(s)]}\pi(\tau)\,d\tau \\ &\quad + \frac{1}{n(s)}\left[\dot{P}(\lambda(s)) - P(\lambda(s))\frac{\dot{n}(s)}{n(s)}\right]. \end{aligned} \tag{18}$$

7.3 Technology Production

As discussed above, technological change is conceived in this model as being an increase in the number of available varieties. The technology production function includes both labor and the stock of knowledge (the size of varieties already available):[20]

$$\dot{n} = \frac{L_n n^\Theta}{a} \tag{19}$$

where L_n is aggregate R&D employment and $\Theta \in (0,1]$. The current stock of knowledge, n, is freely available. Innovation creates value $v\frac{L_n n^\Theta}{a}$ so that by free entry,

$$\frac{wa}{n^\Theta} \geq v \tag{20}$$

with equality when $\dot{n} > 0$.

Turning to the labor market, let L denote the total labor supply each period. The labor market clearing condition, using $\frac{w}{\Omega} = p$, (15), and (19) is

$$L = \frac{1}{p} + \frac{\dot{n}}{n}\left[\frac{a}{n^{\Theta-1}} - \frac{P(\lambda)}{p}\right]. \tag{21}$$

[19] This expression for value takes as given that new varieties are consumed as soon as they are created, as is consistent with the discussion earlier.

[20] The time notation is dropped henceforth except as necessary.

7.4 Equilibrium Growth

An equilibrium at each point in time is described by a set of prices $p(j,t)$ $j \in [0,n]$; $P(\lambda(t))$; $w(t)$; $r(t)$; $v(t)$; $\Psi_1(t)$ and quantities $x(j,t)$ $j \in [0,n]$; $\lambda(t)$; $L_n(t)$; $n(t)$ such that:

1. each variety j's good $x(j,t)$ market demand equals supply and firms are profit maximizing,

2. intertemporal utility is maximized subject to the budget constraint,

3. $r(t) = \rho$,

4. the present discounted value of the profits of a firm producing a variety j is $v(t)$, equal to the value of an innovation, and does not exceed the costs of research sector innovation $\frac{wa}{n^{\Theta}}$,

5. total labor market supply equals demand.

It is straightforward to show, using $r(t) = \rho$, (16), (17), (20), and (21), that $\dot{n} = 0$ when $n > \bar{n}$,

$$\bar{n} = \left(\frac{L}{\Omega a}\left[\frac{(1-\Omega)}{\rho} + P(\lambda)\right]\right)^{\frac{1}{1-\Theta}}.$$

If labor supply is low or the price of variety growth is too low, then growth in varieties will be zero.

Turning to the case of $\dot{n} > 0$ to analyze the evolution of growth in the model, we establish expressions for $\frac{\dot{n}}{n}$, $\frac{\dot{v}}{v}$, $\frac{\dot{\Psi}_1(t)}{\Psi_1(t)}$, and $P(\lambda)$. Using $\frac{w}{\Omega} = p$, (20), and (21),

$$\frac{\dot{n}}{n} = \left[\frac{Ln^{\Theta-1}}{a} - \frac{\Omega\left[1 - P(\lambda)\lambda\right]}{vn}\right] \tag{22}$$

if $n \leq \bar{n}$, $v > \bar{v}$ and $\frac{\dot{n}}{n} = 0$ otherwise. Using $r = \rho$, (16), and (18),

$$\frac{\dot{v}}{v} = \rho - \frac{P(\lambda)}{nv}\left[\frac{(1-\Omega)}{P(\lambda)} + \Omega\lambda - \frac{\dot{P}(\lambda)}{P(\lambda)} + r\right]. \tag{23}$$

Using (8), (9), (10), and (12),

$$\frac{\dot{\Psi}_1}{\Psi_1} = (\rho - \lambda) + \left(1 - \frac{\frac{1}{\Omega}}{n}\right)\left[1 + \frac{\theta\lambda^{\Upsilon}}{n^{\frac{1}{\Omega}}}\frac{vn^{\Theta+1}}{\left[1 - P(\lambda)\lambda\right]\Omega a}\right]^{-1}. \tag{24}$$

Using $\frac{w}{\Omega} = p$, (6), (8), (9), (10), and (20),

$$P(\lambda) = \left[1 + \Psi_1\lambda\right]^{-1}\left[\frac{\theta}{\Omega a}\lambda^{\Upsilon}n^{-\frac{1}{\Omega}+\Theta}v\left[\Upsilon\lambda^{-1} + \Psi_1 n\right]\right]. \tag{25}$$

One can use (22), (23), (24), and (25) to analyze whether and how the structure of the utility function affects the growth path of the economy. It is possible to use simulations to examine the evolution of the equilibrium paths of v, n, Ψ_1 and $P(\lambda)$.

Simulation involves setting parameter values for Ω, a, θ, Θ, Υ, $l = \frac{\dot{L}}{L} \geq 0$, and ρ and initial levels of n, $\frac{\dot{n}}{n}$, L, v, Ψ_1, and $\dot{P}(\lambda)$, and taking instants of time to be discrete. As will be discussed further, the main conclusions of the paper are robust to different parameter choices, particularly of l and Θ.

Households experience utility in each instant of time. One important issue is whether the appropriate measure of well-being is $D(t)$, $U(t)$, or $U(0)$. Households have optimized intertemporally with regard to their spending path, summarized in (13). Surveys of well-being are generally interpreted as capturing people's opinion of their well-being as a flow rather than a stock. This interpretation follows that of Blanchflower and Oswald (forthcoming). Thus, $D(t)$ is used to track well-being.[21]

The results for the baseline case $\Theta < 1$ and positive population growth are as follows. Instantaneous utility per unit of expenditure is decreasing over time. To see this, recall expenditure is normalized to one in the model, as detailed in Section 7.1, so instantaneous utility is decreasing under that normalization.[22] The rate of growth of $\frac{\dot{n}}{n}$ is positive and increasing over time toward a constant. These results are summarized in Table 1.

The proportion of expenditure on λ is increasing over time, up to the limit of 1, so the results above are reported only for the sensible value of $n(t)\,x(t) > 0$. This constraint can be interpreted as due to the exogenous minimum consumption of necessities. The increasing expenditure on λ relative to $x(t)$ can be interpreted as an increase in the research sector that is large relative to the increase in the economy overall, as described by Jones (1995). Thus, technological constraints on the supply side of the economy bind the rise in utility over time. A missing market for the hedonic adaption commodity does not alone explain why there would be non-increasing well-being alongside increasing income over time.

[21] Surveys asking about satisfaction may be interpreted as measuring the stock of utility. There are issues about how instantaneous utility may be evaluated differently from remembered utility and anticipated utility, as discussed by Kahneman (1999).

[22] The result that instantaneous utility per unit of expenditure is falling is consistent with rising utility, as long as utility is rising less quickly than expenditure. Since there is some mixed evidence on the direction of utility, as outlined in Section 2, the ratio is the focus of discussion.

Since there is an introduction of an endogenous invention of new varieties, it is to be expected that the results will be at least somewhat dependent on the production technology of that sector. It is important to understand to what extent the result of increasing wages with decreasing utility is dependent upon the decreasing returns assumption of $\Theta < 1$. It turns out that this model's main results, which focus on transition dynamics, are much less sensitive to whether $\Theta < 1$ or $\Theta = 1$ than similar frameworks where the steady state is the focus.

Due to the literature on the absence of scale effects in growth, reviewed by Jones (1999), it is now customary to assume $\Theta < 1$. The earlier literature on endogenous growth did focus on the $\Theta = 1$ case, so that is also considered here. Population is initially taken to be small and positive. However, given the recent population growth rates observed in some European countries, it is also examined how zero population growth may change the results.

In the cases where $\Theta = 1$ and population growth is zero, then variety growth λ increases toward a positive constant.[23] Instantaneous utility decreases. Thus, the pattern of decreasing utility per unit of expenditure remains.

When $\Theta = 1$ and population growth is positive, then λ is increasing without bound. If population growth l is sufficiently small, then utility per unit of expenditure will still be decreasing. Utility is always decreasing over at least a range of the transition dynamics toward a constant and then, for sufficiently large population growth, will begin to rise.[24]

It is only in the case where $\Theta < 1$ and population growth is zero that variety growth λ, though positive, converges toward zero in the limit. Labor is still increasingly allocated toward innovation, as the price of innovation is increasing, though decreasing returns to the level of variety prevents variety growth from increasing. Utility per unit of expenditure is decreasing, as in the other cases.

The four cases are summarized in Table 2.

Therefore, this model's transition dynamics are consistent with the facts set out to be jointly understood in the introduction. First, reported well-being per unit of income, or expenditure, is falling. Second, the variety of consumption goods available and consumed is increasing over time, perhaps at an increasing rate.

The model suggests that utility per unit of expenditure may be increasing under sufficiently large research productivity. Whether there is a role for policymakers to promote reported well-being

[23] This result is equivalent to those of Jones (1995) and the literature on scale effects in growth generally, as one would expect.

[24] It is intuitively clear also that if Θ were larger, the possibility of increasing utility would also be introduced.

is not immediately apparent from the analysis, though the model does indicate that productivity of research is an important factor not only for income growth, but also for trends in instantaneous utility. Subsidies in Jones (1995), for instance, are normally taken to act via the wage on the level of research labor L_n. Instead, suppose a subsidy were interpreted to promote diffusion of knowledge between research firms or between research firms and public R&D agencies. Subsidies to the research sector that decrease the private cost of innovation could act through the parameter Θ to increase productivity of private research. This notion of a subsidy, whose general equilibrium effect would include the efficiency effect of taxation, suggests that certain types of policy intervention might be effective to alleviate the stagnation of well-being.

Baseline Simulation Summary
Assumed Parameter Values
$\Omega : 0.95$ $\Theta : 0.5$ $a : 1000$ $L : 100$ $l : 0.01$ $\rho : 0.05$ $\Upsilon : 0.5$
Assumed Initial Conditions
$v : 5$ $n : 30$ $\frac{\dot{n}}{n} : 1$ $\Psi_1 : -0.01$ $\dot{P}(\lambda) : 1$
Changes in Endogenous Parameters
$\frac{\dot{D}(t)}{D(t)} : < 0$; $\frac{\dot{n}}{n} : > 0$ and $\uparrow$ toward a constant; $P(\lambda) : \uparrow$

Table 1: Summary of Baseline Simulation Results

Θ	l	λ	$D(t)$	$P(\lambda)$
0.5	0.1	$\uparrow$ toward a constant	$\downarrow$	$\uparrow$
0.5	0	$\downarrow$ to zero	$\downarrow$	$\uparrow$
1	0.1	$\uparrow$	$\downarrow$ then $\uparrow$	$\uparrow$
1	0	$\uparrow$ toward a constant	$\downarrow$	$\uparrow$

Table 2: Comparison of Simulation Results

8 Conclusion

Most endogenous growth models focus on the supply-side forces for technological change in the economy. This paper investigates whether such a model produces results consistent with empirical findings on the correlation between income growth and growth of well-being. A model of variety-expanding growth, with a preference structure consistent with psychological studies and consumer surveys of behavior, is used. This preference structure contains a component of hedonic adaptation and of the level of consumption. In the equilibrium, instantaneous utility will be decreasing in the presence of positive growth in variety and income. Hedonic adaptation term is treated as a tradable commodity, but there are decreasing returns in the production of new varieties.

A focus on the supply side in models of growth may be appropriate, historically. These models are consistent with evidence that technology is not, or cannot be, responsive to demand in a way that results in increasing utility over time. Further, as this paper shows, under appropriate preference structure metaphors, the supply side focus yields results consistent with evidence on the correlation between income and well-being. However, a renewed focus on how the direction of technological change and adoption is determined may shed light on how wealthy economies can escape from their stagnation of well-being. In particular, studies of the direction of technological change toward new products or improved existing products as well as the prevalence of variety expansion in the economy would be initial steps. Policies aimed at weakening the diminishing returns to technological change would be helpful possibly by promoting dissemination of knowledge between private R&D agents and between the private and public R&D sectors.

Further empirical research is needed to explore the empirical validity of the emerging explanations of why well-being and income appear to be correlated in the cross-section but not over time. This paper's model as it stands cannot speak to this matter, as consumers are homogenous. Adding heterogeneity, it is conjectured, would result in predictions consistent with this correlation pattern. As mentioned above, an important empirical question is to resolve whether hedonic adaptation or interpersonal comparison, or both, is the main explanatory factor for this pattern in reported well-being.

To test this, longitudinal data would be needed. To see how the test could work, consider the comparison of utility levels of two persons in a large sample. The two theories of comparison are not readily distinguishable when we consider two people who have a history of the same (or similar) levels of consumption, and then one pulls ahead. Both theories predict that the one who pulls ahead would report a higher level of well-being than the other. However, if we consider two people who have a history of different levels of consumption and then one pulls up to the other, the theories differ. Hedonic adaptation is essentially measured by the ratio of this period's consumption to last period's. Hedonic adaptation would predict the person with the historically lower level of consumption will report a *higher* level of well-being in the period of the consumption change. Comparison with others is measured by the ratio of this period's consumption to the level of aspirations common across a group of people (for instance, across a socio-economic group). Aspiration theory would predict that the person with the historically lower level of consumption will report *similar* levels of well-being, or even lower if aspirations are positively correlated with the change in consumption level, as indicated by Easterlin (1999).

Another method to get at the same question, without having to use a cardinal utility concept, would be to run experiments to determine whether individuals' well-being appears to be driven more by interpersonal comparison considerations or by hedonic adaptation. This type of study could be designed similarly to those by Hsee and Abelson (1991) and Hsee et al. (1991), by hedonic comparison of two or more scenarios as in the example described above. Development of the theory should continue alongside empirical exploration.

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9 Appendix: Traditional Habit Formation Models Cannot Be Used

The purpose of this appendix is to demonstrate that a traditional habit formation model of utility cannot be used in models where the price of a consumption good is determined endogenously by a profit maximizing firm and in which there is innovation of new varieties of the consumption good. An example of such a model is that developed by Grossman and Helpman .

The preference structure referred to as a habit formation model is useful in a variety of settings. A typical habit formation model defines utility at a point in time by

$$U(c,z) = \frac{\left(\frac{c}{z^{\Lambda}}\right)^{1-\Omega}}{1-\Omega} \tag{26}$$

where c is the instantaneous consumption flow, z is the habit stock, and Ω is the coefficient of relative risk aversion. The importance of habits for utility is determined by the size of Λ. If $\Lambda = 0$, then only the absolute level of consumption is important; if $\Lambda = 1$, then only the level of consumption relative to the habit stock is important. If $\Lambda \in (0,1)$, as is typically assumed, then both the absolute level of consumption and the level relative to the habit stock matter in determining utility. The habit stock is sometimes simply assumed equal to the previous period's consumption. It is also frequently assumed to evolve according to

$$\dot{z} = \phi(c-z). \tag{27}$$

Detailed analysis of the utility maximization problem using this model is provided by Carroll et al. (1997) and Carroll (2000). Carroll also discusses the alternative of a preference structure in which utility is given by the difference between c and z, rather than by a ratio. He argues that there are technical advantages to using the specification given above in (26) and that this specification appears to be the one used most often in recent studies. Therefore, this is the specification that will be focused on, although results are similar for the alternative specification.

Consider utility specification as (26), in an infinite horizon model for which the present value of the stream of utility is

$$\int_0^\infty e^{-\rho t} U\left(c_t, z_t\right) dt$$

where ρ is the rate of time preference. Taking expenditure as given for each period, the budget constraint is given by

$$E_t = p_t c_t$$

where p_t is the price of the consumption good, taken as given by the consumer. The current-value Hamiltonian for the utility maximization problem is

$$H_t = U\left(c_t, z_t\right) + \psi_t\left[E_t - p_t c_t\right] + \lambda_t \phi\left(c - z\right).$$

The necessary concavity conditions are that H_t is jointly concave in c_t,the control variable, and z_t, the state variable (see Chiang (1992)). $\frac{\partial^2 H_t}{\partial c_t^2} < 0$ if $\Omega > 0$; $\frac{\partial^2 H_t}{\partial z_t^2} < 0$ if $\Omega > 1 + \frac{1}{\Lambda}$. The determinantal test specifies that it must be the case that the determinant of $\begin{bmatrix} \frac{\partial^2 H_t}{\partial c_t^2} & \frac{\partial^2 H_t}{\partial c_t \partial z_t} \\ \frac{\partial^2 H_t}{\partial z_t \partial c_t} & \frac{\partial^2 H_t}{\partial z_t^2} \end{bmatrix}$ is greater than zero. This holds only if $\Omega > \frac{\Lambda}{1-\Lambda}$.

Turn next to the producer's profit maximization problem. As in a typical endogenous growth setting (see Grossman and Helpman (1991) or Aghion and Howitt (1998)), it is assumed that the producer is a monopolist as in the case where the single consumption good is produced using a blueprint for its production and that blueprint is patented. Further, there is a research sector (behind the scenes for our purposes) that invented the blueprint and sold the patent to the consumption good producer.[25]

The consumption good is produced one for one with labor that is paid a wage w_t. The monopolist takes the wage as given, as labor has other employment alternatives outside the model presented

[25] In a model with a variety of consumption goods available and variety-loving consumers, each invention increases the variety of consumption goods available. Producers of consumption goods are monopolistic competitors. All results presented in this note follow through in that setting.

here, so labor markets are competitive. Single-period profits of the monopolist can be written as

$$\pi_t = [p_t - w_t]\, c_t,$$

where the price will be given by the first order condition $\frac{\partial H_t}{\partial c_t} = 0$:

$$p_t = \frac{1}{\psi_t}\left[\lambda_t \phi + (z_t)^{-\Lambda(1-\Omega)}\, c_t^{-\Omega}\right].$$

Thus, the monopolist's profit-maximizing problem can be expressed as a choice of c_t. The monopolist maximizes the present discounted value of profits, recognizing that consumption c_t affects the next instant's habit stock according to (27) . Therefore, the current value Hamiltonian for the producer is

$$\tilde{H}_t = \pi_t + \gamma\left[\phi\left(c_t - z_t\right)\right].$$

Again, joint concavity of c_t and z_t is required. The conditions necessary for the second derivatives $\frac{\partial^2 \tilde{H}_t}{\partial z_t^2} < 0$ and $\frac{\partial^2 \tilde{H}_t}{\partial c_t^2} < 0$ contradict the concavity conditions for the utility maximization problem described above. In particular,

$$\frac{\partial^2 \tilde{H}_t}{\partial c_t^2} = -\Omega\left(1-\Omega\right)\left(z_t\right)^{-\Lambda(1-\Omega)} c_t^{-\Omega-1} < 0$$

only if $-\Omega\left(1-\Omega\right) < 0$. It is necessary and sufficient that either $\Omega < 0$ and $\left(1-\Omega\right) < 0$,or $\Omega > 0$ and $\left(1-\Omega\right) > 0$. If the latter, that contradicts the condition necessary for $\frac{\partial^2 H_t}{\partial z_t^2} < 0$, that $\Omega > 1+\frac{1}{\Lambda}$. If the former, that contradicts the condition for $\frac{\partial^2 H_t}{\partial c_t^2} < 0$, that $\Omega > 0$.

Furthermore,

$$\frac{\partial^2 \tilde{H}_t}{\partial z_t^2} = \frac{\Lambda\left(1-\Omega\right)\left[1+\Lambda\left(1-\Omega\right)\right]}{\psi_t} c_t^{1-\Omega}\left(z_t\right)^{-\Lambda(1-\Omega)-2} < 0$$

only if $\Lambda\left(1-\Omega\right)\left[1+\Lambda\left(1-\Omega\right)\right] < 0$. Since $\Lambda > 0$, either $\left(1-\Omega\right) < 0$ and $\left[1+\Lambda\left(1-\Omega\right)\right] > 0$, or $\left(1-\Omega\right) > 0$ and $\left[1+\Lambda\left(1-\Omega\right)\right] < 0$. The condition necessary for $\frac{\partial^2 H_t}{\partial z_t^2} < 0$ from the utility maximization problem implies $\left[1+\Lambda\left(1-\Omega\right)\right] < 0$, so that $\left(1-\Omega\right) > 0$ if $\frac{\partial^2 \tilde{H}_t}{\partial z_t^2} < 0$. However, the condition $\left(1-\Omega\right) > 0$ contradicts the condition $\Omega > 1+\frac{1}{\Lambda}$ if $\Lambda > 0$.

Therefore, the traditional habit formation model of preferences cannot be used in the endogenous growth model with a monopolist producer outlined above.

Several variations on this model are possible; none of the variations explored overturn the contradictions outlined above. These variations are

1. Introducing variety-loving into the preferences and endogenous innovation of new varieties of the consumption good. There is a habit stock associated with each variety. Producers of the varieties are monopolistic competitors. Instantaneous utility is written as

$$U\left(c_j, z_j,\ j \in [0,n]\right) = \int_0^n \frac{\left(\frac{c_j}{z_j^{\Lambda}}\right)^{1-\Omega}}{1-\Omega} dj$$

where

$$\dot{z}_j = \phi\left(c_j - z_j\right).$$

2. Increasing the flexibility of the preference structure with a parameter Γ such that

$$U\left(c_j, z_j,\ j \in [0,n]\right) = \int_0^n \frac{\left(\frac{c_j^{\Gamma}}{z_j^{\Lambda}}\right)^{1-\Omega}}{\Gamma\left(1-\Omega\right)} dj.$$

3. Adding another term to instantaneous utility that is a function only of the level of consumption, such that

$$U\left(c_j, z_j,\ j \in [0,n]\right) = \int_0^n \frac{\left[\left(\frac{c_j^{\Gamma}}{z_j^{\Lambda}}\right)^{1-\Omega} + c_j^{\Theta}\right]}{\Gamma\left(1-\Omega\right)} dj.$$