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by

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The impact of differential satiation dynamics on changing consumer behavior, wellbeing, and innovative activity*

Leonhard K. Lades‡

Abstract

This paper presents a formal model in which differential satiation dynamics of various consumer needs translate into long-run changes of consumer behavior when income rises. In the model individuals allocate their income to the consumption categories proportional to need deprivation states corresponding to the consumption categories, a decision making process called matching. The paper compares the Engel curves obtained from matching with the Engel curves obtained from traditional constrained maximization. The latter allocation is used as a normative benchmark of the behavior that leads to the highest utility. While superficially both ways to allocate income generate similar results, matching allows to explain some empirical regularities that maximization cannot account for. For example, only by using matching one can reconstruct that income elasticities for food tend to decrease with rising income. Moreover, the comparison of both ways to allocate income shows that the deviations from rational behavior are greater for relatively poor individuals than for richer individuals so that the inequality in terms of welfare can be stronger than the inequality in terms of income. Innovations influencing the satiation patterns can strengthen this effect.

Keywords: Consumer theory, Engel curves, Engel's law, Structural change

JEL classification: B52; C51; D03; D11; D63

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1 Introduction

Over the last few decades, individuals in most industrial nations have witnessed a strong rise of their disposable income.[1] The individuals exploited their increased financial possibilities and consumption expenditures rose nearly as strong as income did. But not only the amount of consumption rose. Also the structure of consumption expenditures changed (Deaton and Muellbauer, 1980). For example, as indicated by income elasticities below unity, the expenditure shares devoted to food consumption decreased with rising income, so that food is commonly classified as a necessity. This empirical regularity was first shown by Ernst Engel and is so strong that it is referred to as Engel's Law (Engel, 1857). To the contrary, the expenditure shares for categories such as housing and recreation increased with rising income so that the measured income elasticities for these categories are typically above unity and these goods are classified as luxuries (Lewbel, 2008). Moreover, with rising income, luxuries can become necessities. Hence, income elasticities are not constant and they can vary when income changes (see for example Banks et al., 1997; Blundell et al., 1993). Although there is ample empirical evidence for such structural change on the demand side (Chai and Moneta, 2010; Deaton and Muellbauer, 1980), there are almost no theoretical models that can explain, rather than solely describe, these empirical findings (Chai and Moneta, 2012). Taking a need-based perspective, and acknowledging the importance of innovations, this paper presents a simple formal model that can account for some of the described long-run changes of expenditure shares when income rises.

Most existing neoclassical approaches that aim at formally describing long-term changes on the demand side assume that rational individuals maximize their subjectively defined utility under given constraints. In these models, changing consumer behavior is mostly understood as the result of changing constraints. The model presented in this paper differs from these neoclassical models in at least three ways. First, the model follows research suggesting that preferences can, at least partly, be understood on the basis of needs instead of assuming that preferences are exogenously given, stable, and solely subjective. More precisely, in line with a long tradition in economics (Pasinetti, 1981; Scitovsky, 1992; Witt, 2001), the paper assumes that need deprivation states are the key driver of consumer behavior. Since with rising income, need deprivation/satiation dynamics differ across needs, this need-based perspective is particularly valuable for investigating long-run changes of consumer behavior. The need-based perspective suggests, for example, that expenditure shares for food decrease with rising income because the need for food is easier to be satiated than many other consumer needs such as those for social status, arousal, and positive self-images. Accordingly, these other needs gain importance for consumer behavior over time when income rises (Witt, 2001). Satiation and hence decreasing market shares, however, trigger innovative responses on the supply side. These innovations can change the degree to which different goods are satiable, and hence have to be considered in model

[1] See for example Maddison (2001).

explaining structural change on the demand side based on differential satiation dynamics.

The second difference to neoclassical models is that the paper does not *a priori* assume that individuals allocate their income in a way that maximizes their utility. Neither does the paper start with the assumption that rational utility maximization is the best approximation for describing the way consumer behavior changes in the long run. Instead, the paper proposes to use an alternative decision making process in order to approximate individual consumer behavior. This decision making process is inspired by Herrnstein et al.'s (1997) matching law which has proven to be a good approximation for human and animal behavior driven by need deprivation states. The paper shows that by assuming that individuals allocate their income according to the matching law, some empirical regularities can be reconstructed that most classical utility maximization models have great difficulties to reconstruct. However, although the paper challenges the assumption that constrained maximization is the best approximation to model changing consumer behavior in the long run, the paper assumes that constrained maximization is the best normative benchmark available with which the consumer behavior that is obtained from the matching model can be compared in a welfare analysis.

The third difference to neoclassical models is that the paper does not assume that choices reveal the individuals' "true" preferences. Since in the model, individuals are not assumed to be rational utility maximizers, it is possible that their motivation to consume (wanting) differs from the well-being (liking) they expect to obtain from consumption. This dissociation of utility into components of wanting and liking corresponds to recent approaches in neuroscience and behavioral economics (Berridge, 1999; Kahneman, 2003) and becomes important when analyzing the welfare implications of the decision making process suggested here.

The rest of the paper is organized as follows. Section 2 presents the theoretical background from which the model's assumptions are derived. Section 3 presents the model in which differential need satiation patterns translate into long-run changes of consumer behavior when income rises. For two consumption categories, namely food and status symbols, the development of consumer behavior with rising income is shown by means of Engel curves and income elasticities. Section 4 compares the income allocation of individuals who match with the income allocation that maximizes individual utility. In particular, section 4 shows which individuals in the income distribution suffer more than others from their possibly non-optimal allocation of income when they match and do not maximize. Section 5 investigates the impact of an innovation that adds an additional symbolic component to the food product, and shows that this innovation affects both structural change on the demand side and the welfare of the consumers. The last section concludes.

2 Theoretical background

Neoclassical economists usually explain consumer behavior by assuming that individuals rationally maximize a utility function containing consumer goods under given constraints. The maximization of this function leads to demand functions which can be tested empirically. To identify the utility functions that, when maximized, lead to empirically testable demand functions, economists typically assume that preferences, i.e. the expectations about how much utility consumption will provide, are revealed by choices. In other words, utility functions can be derived from observing demand functions. Hence, what economists typically do is to identify demand functions that are good descriptions for observed consumer behavior and, in a second step, identify the utility functions that, when maximized, lead to these demand functions. Utility functions themselves are unobserved. To the contrary, the utility functions, which are maximized to obtain the demand functions, are themselves inferred from the demand functions.

To fit the concept of the *homo oeconomicus*, from a theoretical point of view all that is needed from these inferred utility functions is that they satisfy certain axioms (such as transitivity, independence, and non-satiation) that make sure that the maximization process works well. Besides these axioms of decision making, neoclassical economists make no further assumptions, for example about the content, rather than the mathematical structure, of the utility functions. Preferences are assumed to be solely subjective. More than that, inquiring into individual preferences, i.e. understanding the content of individual utility functions, is argued not to be of economists' business (Friedman, 1962; Samuelson, 1937). Accordingly, research in economics has long searched for demand functions that are, on the one hand, the result of the maximization of well-behaved utility functions and, on the other hand, flexible enough to describe various patterns of consumer behavior without needing any information about the content of preferences (Banks et al., 1997; Barnett and Serletis, 2008; Deaton and Muellbauer, 1980).

Consumer behavior can change (more quickly) over situations and (more slowly) over time. In neoclassical economics, changing consumer behavior is usually understood as being the result of changes in exogenous variables such as price, income, or, when these aspects are not sufficient, changes in preferences. Partly due to the fact that in economics preferences are usually regarded as solely subjective, however, the discipline has so far failed to provide a unifying model that is able to explain a good deal of changing consumer behavior over time and/or situations. As a result of this failure, certain subfields within economics have emerged that aim at, among other things, understanding more thoroughly individual preferences and the ways preferences change over time and/or situations. One of these subfields is behavioral economics. Behavioral economics tends to focus on changing preference due to situational factors (Camerer, 2004; Lewis, 2008). This paper, to the contrary, is interested in the relatively slow change of consumer behavior that occurs over time and is less dependent on the context of the decision making situation. This slower change of consumer behavior becomes apparent, for example, in the changing allocation of income over time. To the author's knowledge, in economics there is currently no formal model that provides an explanation for the fact that over time and with rising income, the expenditure shares devoted to some goods evolve differently than the expenditure shares devoted to other goods.

Empirical evidence for such structural change, however, is ample (Deaton and Muellbauer, 1980). To describe long-run changes of consumer behavior economists usually use Engel curves and income elasticities (Lewbel, 2008). Engel curves describe the relationship between consumption in a particular consumption category, on the one hand, and income, on the other hand. With the Engel curves at hand, one can easily calculate income elasticities. Income elasticities depict the ratio of the percentage change of consumption in a particular consumption category to the percentage change in income. Goods with income elasticities below zero, between zero and unity, and above unity are called inferior goods, necessities, and luxuries respectively. While the expenditure shares devoted to necessities decrease with rising income, the expenditure shares devoted to luxuries increase. Inferior goods are consumed less frequently with rising income (Lewbel, 2008). While in almost all empirical studies food turns out to be a necessity, other consumption categories, such as recreation, transport, and housing, usually have income elasticities above unity and are called luxuries (Deaton and Muellbauer, 1980; Kaus, 2012). Moreover, empirical evidence suggests that Engel curves are close to linear in some consumption categories but non-linear in others (Banks et al., 1997). Also, income elasticities can change with income so that a good can be a luxury for poor individuals but a necessity for rich individuals (Lewbel, 2008). For example, Blundell et al. (1993) show that income elasticities for food decrease with rising income from 0.788 for the poorest 5 percent to less than 0.5 for the richest 25 percent.

This paper argues that the neoclassical strategy to identify utility functions whose maximization leads to empirically testable demand functions was not particularly successful in offering an *explanation* for the described changes of consumer behavior. In particular, the neoclassical approach has failed to explain why some goods are necessities and other goods are luxuries, and why income elasticities change with rising income in the way they do. The paper identifies three reasons for this: (1) the lack of a motivational foundation of utility functions, (2) the focus on constrained utility maximization without acknowledging the possibility of other decision making processes, and (3) the assumed coherence between the motivation to consume and the well-being obtainable from consumption, inherent in the concept of revealed preferences.

The first problem of neoclassical research on consumer behavior, i.e. the lack of a motivational foundation of economic preferences in favor of the assumption that preferences are solely subjective, makes it difficult to separate one product category from another and to describe the factors that differentiate these categories (Witt, 2001, 2012). The idea of solely subjective preferences is contested by several subdisciplines within economics. For example, socio-economic and behavioral economic approaches argue that individuals are influenced by the social context in predictable ways. Individuals' decisions about how much to spend for status symbols, for example, depend on how much other individuals spend for these goods (Frank, 1985). Other research in behavioral economics investigates predictably changing preferences due to adaptation effects or hedonic treadmills (Frederick and Loewenstein, 1999; Scitovsky, 1992). In the latter approaches, individuals are argued to adapt to the goods they bought so that these goods lose their entertaining value and ever new goods are needed to keep the individuals satisfied. More generally, in psychology there is much research on human motivation. Particularly salient in this literature is the motivation related to individuals' self-images (Gaertner et al., 2008; Gollwitzer and Kirchhof, 1998). Also economists have recently integrated self-images into neoclassical utility functions (Akerlof and Kranton, 2000; Benabou and Tirole, 2011), and Cordes (2009) argues that social self-images, and hence identity-related preferences, can change systematically with rising income.

This paper follows Witt (2001) who suggests to capture such insights on human motivation in an integrative framework understanding human preferences in terms of basic needs, acquired wants, and cognitively determined motives.[2] It has long been argued that consumer behavior is driven by the desire to satisfy needs (Engel, 1857; Pasinetti, 1981; Scitovsky, 1992). By recognizing that human behavior is driven by a finite number of basic human needs, preferences become partly objective and the traditional economic assumption that one cannot say anything about human preferences, because preferences are purely subjective, can be softened. To the extent that consumption goods and consumer needs can be related to each other, one can understand the reasons why individuals consume. However, since consumption goods usually have several characteristics and therefore can appeal to different needs at the same time (Witt, 2001), the need-based approach to preferences can only explain a limited subset of consumer behavior.

Nevertheless, for certain types of consumer behavior the need-based explanation of preferences is valuable as shown by Kaus (2012). This is especially true when being interested in long-term changes of consumer behavior. Witt (2001) argues that need deprivation states correspond to physiological or psychological discomfort and therefore motivate behavior to reduce the discomfort. Over time and with rising income, it becomes important that the satiation/deprivation patterns across needs differ. With rising income and accordingly more consumption in most categories, the motivation to consume decreases faster for needs that are relatively easy to be satiated than for needs that are relatively difficult to be satiated. Homeostatic needs, such as hunger and thirst, are easier to be satiated with sufficiently high income than other, non-homeostatic needs, such as the need to signal social status, the need for arousal, and the need for positive and consistent self-images. Moreover, besides innate needs which are sometimes easy and sometimes difficult to be

[2] The paper is limited to the analysis of basic needs, and their changing degrees of importance for consumer behavior. For complementary analyses of, for example, skill acquisition through learning by consuming and consumer socialization process see Babutsidze (2011).

satiated, acquired wants and higher order cognitive motives are relatively difficult to be satiated (for a more detailed discussion see Witt, 2001).

As a result of these differential satiation dynamics, individuals shift their expenditures from the needs that are easy to be satiated to those where the need's motivation has not yet vanished due to high satiation levels. Hence, based on knowledge about differential satiation/deprivation patterns of various needs underlying consumer behavior, it is possible to explain why, with rising income, the allocation of income to various expenditure categories changes. The need-based framework suggests that when very poor individuals gain additional income, they use most of this income to consume basic goods such as food, clothes, or housing. When rich individuals get even richer, they use most of the additional money to consume products corresponding to needs that are relatively difficult to be satiated, such as expensive watches or television sets, bigger cars, or mobile phones.[3]

Regarding the second problem of neoclassical economics, namely the imperative use of constrained utility maximization, one has to acknowledge that this way to formalize economic decision making is not problematic per se. The view that individuals rationally maximize their utility under given constraints has been greatly beneficial in explaining a multitude of economic phenomena and lies at the core of the success of economics as a discipline. Constrained utility maximization, however, becomes problematic when it generates predictions that are not consistent with the data, or when great efforts have to be taken to get the predictions consistent with the data. The paper argues that such problems occur when one uses constrained utility maximization as a tool to explain long-run changes of consumer behavior that are driven by rising income. More specifically, many common utility maximization models predict Engel curves and income elasticities that are not in line with common empirical findings (Deaton and Muellbauer, 1980).

As an example, consider quasi-homothetic preferences such as the Stone-Geary specification of the utility function (Geary, 1950; Stone, 1954). In this specification, consumers obtain utility from consumption in excess of subsistence levels. The maximization of these utility functions leads to Engel curves locally linear in income and income elasticities that tend to unity when income rises. Some even more restrictive specifications of the utility function (for example the Cobb-Douglas utility function and the CES utility function) assume that preferences are homothetic so that Engel curves are straight lines starting in the origin and income elasticities are always, and per definition, unity for all categories at all income levels. This implies that all expenditures are linear in income and that expenditure shares are similar at all income levels. These predictions contradict Engel's law and are clearly proven wrong by many empirical studies (e.g. Blundell et al., 1993).

Other models, such as the AIDS (Deaton and Muellbauer, 1980) and the basic translog

[3]Though this approach is somewhat akin, it does not exactly mimic Maslow's (1943) notion of a hierarchy of needs. In the need-based perspective taken here, the satiation of more basic needs is not a necessary condition for behavior that satisfies needs located at higher levels of Maslow's pyramid. To the contrary, in Witt's approach it is possible that even with very low income every expenditure category obtains a (potentially small) fraction of income (see Chai and Moneta (2012)).

(Christensen et al., 1975), assume that expenditures are linear in the logarithm of total expenditure. However, these models still do not have enough flexibility to account for the curvature of Engel curves occurring with large income changes (Barnett and Serletis, 2008), nor do they offer theoretical explanations or predictions for the curvature of Engel curves. The quadratic specification for estimating Engel curves (QUAIDS) suggested by Banks et al. (1997) can account for various types of Engel curves, so that their model can be regarded as the best specified model describing the relationships between individual budget shares and the log of individual incomes. Nevertheless, Banks et al.'s (1997) model involves many parameters which makes it numerically difficult and intractable to implement. Moreover, although Banks et al.'s (1997) model can be used to calculate various types of income elasticities, it is not able to generate predictions about which categories are characterized by which income elasticities and why this is the case (Chai and Moneta, 2010).

Overall, when relatively simple utility functions (Stone-Geary, CES) are used, basic empirical regularities cannot be replicated. When more complicated types of utility functions are used to obtain (more complicated) demand functions (AIDS, basic translog, QUAIDS), these models are flexible enough to capture many empirical regularities, but they also become difficult and intractable to implement. Most importantly, although these models are able to *describe* long-run changes of consumer behavior, they have not been successful in *explaining* why these changes occur and of which type they are.

Research mainly in behavioral economics has shown that in many decision making situations, rational utility maximization is not the best approximation of human behavior (see for example Camerer, 2004; Lewis, 2008). In an early contribution already Simon (1955) suggested to use the concept of bounded rationality to approximate human behavior, and recent evolutionary economic approaches have used this concept to better understand consumer behavior (Nelson and Consoli, 2010; Valente, 2012). This paper supports the idea that utility maximization leads to unsatisfying predictions regarding long-run changes of consumer behavior. It may be the case that for investigating these long-run changes of consumer behavior, the assumption of rationality has limited applicability.[4] There may be better ways to obtain the correct predictions when one departs from the traditional utility maximization framework.

Following Witt (2001), this paper suggests to use a variant of Herrnstein et al.'s (1997) matching law to formalize consumer behavior when one aims at understanding long-run changes of consumer behavior and utilizes the idea that preferences are based on needs. The matching law has proven to be a good approximation for behavior driven mainly by basic need deprivation states which are related to what Witt (2001) calls innate needs (Herrnstein et al., 1997). The matching law is considered to be one of the most robust

[4]As Chakrabarty and Hildenbrand (2011) note, linking the development of expenditure shares to microeconomics was never in the spirit of Engel who was one of the first economists investigating long-run changes of consumer behavior. Nowhere in Engel's thinking or writings does the concept of an individual demand function appear.

experimental findings in behavioral sciences at the level of behavior with little or no cognitive intervention (Davison and McCarthy, 1988). In various studies, mainly with animals but also with humans, where deprived subjects allocate their behavior to obtain a reduction of their deprivation states, a robust finding emerged: Subjects allocate their behavior so that the relative rate of response is proportional to the relative rate of reinforcement. Herrnstein and colleagues call this behavior matching. Formally the matching law for two behaviors and two corresponding forms of reinforcement can be written as

$$\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2}, \tag{1}$$

where B_i depicts the behavior that leads to the reward or reinforcer R_i. R_i can be interpreted as the (motivational) value attached to reward i (Rachlin et al., 1981). In the matching law literature, it is commonly argued that individuals keep track of the average reward that a particular type of behavior generates so that R_i commonly depicts the average reward of need i. Individuals are assumed to shift their behavior to those alternatives which provide the highest average reward without considering that their choices change the average rewards obtainable from consumption in the future. Herrnstein and Prelec (1991) call this way of allocating behavior without considering the future consequences of the behavior melioration. In the equilibrium, melioration leads to matching. When the average reward R_i does not change as a result of behavior B_i, matching and maximization lead to the same outcome. However, when the reward R_i obtainable from B_i changes as a result of behavior B_i, melioration leads to a different allocation of behavior compared to maximization. Accordingly, when reward is understood in terms of a reduction of a need deprivation state, and consumption choices are distributed over many consumption instances, melioration and matching imply different allocations of behavior. Matching is thus likely to be a good approximation for consumption in categories such as food where the complete expenditure is the sum of many single purchases and where not too much cognitive deliberation is involved. For consumption in other categories such as cars where usually just one single and very deliberative purchase is made in a given period, matching and maximization are likely to lead to similar behavior (Herrnstein and Prelec, 1991).

The matching law, however, usually describes behavior in experiments. Outside of experiments, it is difficult to define what R_i stands for (Witt, 2001). To transfer the matching law into the context of human consumer behavior on the population level, and to keep the model as simple as possible, this paper deviates from the classical literature on the matching law. In the model presented in this paper, R_i depicts the motivational value of need i corresponding to the need deprivation state that individuals face at the beginning of each period when they have not consumed anything yet. At the beginning of each period, individuals compare these need-deprivation states and then devote their income to the various consumption categories proportional to the deprivation states. Hence this variant of matching suggests that the income to be allocated is divided proportional to the strengths of the need deprivation states in each consumption category. More money is spent in those categories where, at the beginning of the period, deprivation is higher than in those categories where deprivation is relatively low. This way of allocating behavior implies that individuals are not forward looking in the sense that they do not consider which ways of satiation are potentially obtainable and how their consumption changes the pleasure obtainable from future consumption. To the contrary, individuals act solely driven by current states of discomfort caused by deprivation of certain needs.

The third problem that arises when economists aim at explaining Engel curves and income elasticities using constrained maximization models is that no distinction is made between descriptive and normative aspects of utility. The concept of utility subsumes the notions of motivation to consume (wanting) and the well-being obtainable from consumption (liking) in one concept. When individuals are rational, this is not a major problem, because rational individuals want what they like and like what they want. Hence, their behavior reveals their true preferences. However, since behavioral economics and neuroscientific research show that in many situations individuals are not rational, it is not necessarily the case that wanting and liking cohere (Gilbert and Wilson, 2000; Kahneman, 2003). Neuroscientific findings, for example, suggest that wanting and liking correspond to different areas in the brain (Berridge, 1999). In behavioral economics and economic psychology, studies such as Litt et al. (2010) and Dai et al. (2010) show that wanting and liking can also differ when measured behaviorally. As a result, when one departs from the assumption that individuals are rational actors, one cannot use the same utility function to depict motivational aspects of utility and well-being aspects of utility at the same time.

3 The model

The model assumes that need deprivation states are the key motivator of consumer behavior. For each consumer need i, the need deprivation state is defined as the difference between the need's satiation point $\theta_{i,t}$ and the satiation level that is present when nothing has been consumed yet. When individuals consume and thereby increase their satiation level up to the satiation point $\theta_{i,t}$, no discomfort of deprivation is present anymore. Each unit of consumption reduces the deprivation state by a need-specific factor depicting the effectiveness of consumption. The paper will assume this factor to be unity for all needs.[5]

The motivation to consume in category i at time t is depicted by $v(p_{i,t}c_{i,t})$, where $p_{i,t}$ is the average price of consumption good $c_{i,t}$. The model assumes that this motivation to consume is independent of the consumption in previous periods, i.e. there are no lasting satiation effects from one period to the next period.[6] Therefore, for each need i at the

[5]The effectiveness of consumption is tied to the means, i.e. consumption goods, by which deprivation can be reduced in the various categories. This effectiveness can be modeled as a function that decreases with consumption in the same category, approaching zero from above so that total satiation will never be reached.

[6]Baucells and Sarin (2007) present a model in which satiation is persistent over time and decays at a constant, need-specific rate per period.

beginning of every time period where consumption is still zero ($c_{i,t} = 0$) also the satiation level is zero. Hence, at the beginning of each period, the deprivation state as well as the motivation to consume is completely determined by $\theta_{i,t}$. Note that this also implies that the motivation to consume is independent of the effectiveness of consumption.

The model assumes that at the beginning of each period, individuals allocate their income by comparing the various values of $v(p_{i,t}c_{i,t})$ with each other. More precisely, in every period individuals allocate their income proportional to the motivational strengths of the need deprivation states. That is, individuals match the various motivational values of their consumer needs with the money they spend in the consumption categories. The money spent in category i relative to the overall money spent is matched to the motivational value of need i relative to the sum of all motivational values of all needs. Hence, income is allocated according to

$$\frac{p_{i,t}c_{i,t}}{I_t} = \frac{v(p_{i,t}c_{i,t})}{\sum\limits_{j=1}^{n} v(p_{j,t}c_{j,t})} = \frac{\theta_{i,t}}{\sum\limits_{j=1}^{n} \theta_{j,t}}, \tag{2}$$

where $I_t = \sum_{j=1}^{n} p_{j,t}c_{j,t}$. Rearranging equation (2) leads to the demand function for good i

$$c_{i,t} = \frac{I_t}{p_{i,t}} \times \frac{\theta_{i,t}}{\sum\limits_{j=1}^{n} \theta_{j,t}}. \tag{3}$$

This decision making process implies that individuals shift their consumption to those alternatives where at the beginning of the period the deprivation is more pressing. To give an example, assume that in an artificial economy only two goods (A and B) exist. Both goods have stable satiation points and average prices are given by $p_A = p_B = 1$. Assume that the motivation to consume good A is 5, and the motivation to consume good B is 3. Matching implies that for any given amount of income below 8, the fraction 5/8 of income is allocated to good A and the fraction 3/8 is allocated to good B. This means that for all levels of income below 8, the percentage of deprivation for both needs is equal. For example, when income is 4, need A obtains 5/2 and need B obtains 3/2 which corresponds in both cases to 50% deprivation. When income increases beyond 8, the motivation to allocate additional income vanishes because an income of 8 is sufficient to satiate both needs. In this case, individuals use their discretionary income that is not needed for need satiation to save for future consumption activities and corner solutions emerge.

In the example above, it is assumed assumed that satiation points are stable. However, for some needs this assumption is not warranted. Following Pollak (1970) the model suggests that satiation points are determined by physiological factors (θ_i^{ph}) and by psychological factors ($\theta_{i,t}^{ps}$), so that

$$\theta_{i,t} = \theta_i^{ph} + \theta_{i,t}^{ps}. \tag{4}$$

Physiological factors are exogenously given by biology and thus are constant over time. For example in the case of the need for nutrition, the physiological satiation point is arrived when hunger does not motivate eating anymore. Since the amount of income that is needed to achieve this satiation point does not change dramatically over time, needs with a constant satiation point are relatively easy to be satiated with sufficiently high income. Most needs with constant satiation points can be satiated by the products' functional values (instead of the products' possibly existing symbolic meanings). For example in the case of the need for nutrition, the products' calories are the satiating component.[7]

Psychological factors, however, can change the satiation points. Oftentimes these changes are driven by rising individual income or increasing affluence in whole societies. One psychological factor that can change the satiation point and that has received some attention in economics is the social comparison level (Charles et al., 2009; Frank, 1985; Heffetz, 2011; Kaus, 2013; Leibenstein, 1950; Veblen, 1899). Social comparison levels play an important role regarding the human need to signal one's status to others. When one's social comparison group spends a lot for status symbols, individuals who want to signal their status as well have to spend a lot of money, too. Given that one does not want to fall short in a social comparison with one's neighbors, say the Joneses, who have recently bought a new and more expensive car, one has to buy a new and more expensive car as well (Frank, 1985). Individuals choose their social comparison levels partly by themselves, and these choices depend on the individuals' income. Poor individuals tend to have relatively poor peer-groups and richer individuals tend to have richer peer-groups. In line with this argument, Cordes (2009) argues that social self-images change systematically with rising income and material markers of one's social identity become increasingly expensive. Hence, it can be safely assumed that the psychologically satiation point for the need to signal status is a function of one's income.[8] In the following, the paper assumes that the psychological satiation point increases linearly with one's income with the factor α_i. Hence, the satiation point can be written as $\theta_{i,t} = \theta_i^{ph} + \alpha_i I_t$.

Including the possibility of changing satiation points, equation (3) becomes

$$c_{i,t} = \frac{I_t}{p_{i,t}} \times \frac{\theta_i^{ph} + \alpha_i I_t}{\sum_{j=1}^{n} (\theta_j^{ph} + \alpha_j I_t)}. \tag{5}$$

[7]Individuals today, though, spend more for food than hundred years ago. It is, however, likely that this does not hinge on the need for nutrition alone, but additionally on needs for variety, health, status, or ethical considerations. In section 5, the paper will come back to this point.

[8]Another psychological factor that can change the satiation points and has received considerable attention in economics is adaptation. Adaption plays a role when needs such as the need for arousal are considered. Spending the same monthly amount of money does not mean that one gets the same amount of entertainment in each time period. Rather, this year one has to spend more than last year, to reduce the need deprivation down to the same level as yesterday, because individuals adapt and the same television set loses its entertaining value when time goes by. To keep their deprivation state of the need for arousal at a constant level, individuals thus have to consume ever new and more entertaining products (Frederick and Loewenstein, 1999; Scitovsky, 1992).

Given that all prices are unity, the income elasticity for good i is given by[9]

$$\epsilon_{i,t} = 1 + \frac{\alpha_i I_t}{\theta_i^{ph} + \alpha_i I_t} - \frac{\sum\limits_{j=1}^{n} \alpha_j I_t}{\sum\limits_{j=1}^{n} (\theta_j^{ph} + \alpha_j I_t)}. \tag{6}$$

Equation (6) shows that whether a good is a luxury ($\epsilon_{i,t} > 1$) or a necessity ($\epsilon_{i,t} < 1$) depends on the various ratios of $\alpha_i I_t$ and $\theta_i^{ph} + \alpha_i I_t$. $\frac{\alpha_i I_t}{\theta_i^{ph}+\alpha_i I_t}$ depicts the influence of psychological factors on the satiation point of need i, and $\frac{\sum_{j=1}^{n} \alpha_j I_t}{\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)}$ depicts the influence of all psychological influences combined on the sum of all satiation points. If for need i the influence of psychological factors on the satiation point is higher (lower) than the influence of all psychological influences combined on the sum of all satiation points, need i is a luxury (necessity). Moreover, with rising income, differences across goods in θ_i^{ph} become less important, but differences of the α_i across needs become more important. Hence, to determine whether a good is a luxury or a necessity, with low income it is more important to look at physiological impacts on the satiation point, and with higher income it is more important to look at psychological impacts on the satiation point.

To understand the matching dynamics with unstable satiation points more thoroughly, consider an economy in which only two goods exist that correspond to the only two needs that the consumers in the economy have. The first good depicts all necessities. For illustrative purposes, call this good “food”. The need corresponding to food, i.e. the need for nutrition, has a positive and constant physiologically satiation point ($\theta_f^{ph} > 0$) and no psychological component effects the satiation point ($\alpha_f = 0$). The second good stands for all goods corresponding to needs that are more difficult to be satiated.[10] This good, say a “status symbol”, has no physiologically satiation point ($\theta_s^{ph} = 0$), but the psychologically satiation point is influenced by social comparisons. To keep it simple, the model again assumes that social comparison levels linearly increase with one’s income so that also the satiation point of the need to signal status linearly increases with income ($\theta_{s,t}^{ps} = \alpha_s I_t$). Hence, $\theta_f = \theta_f^{ph}$ and $\theta_{s,t} = \alpha_s I_t$.

According to equation (5) the demand function for food is

$$c_{f,t} = \frac{I_t}{p_{f,t}} \frac{\theta_f^{ph}}{\theta_f^{ph} + \alpha_s I_t}. \tag{7}$$

Analogously, the demand function for status symbols is

$$c_{s,t} = \frac{I_t}{p_{s,t}} \frac{\alpha_s I_t}{\theta_f^{ph} + \alpha_s I_t}. \tag{8}$$

[9] See Appendix.
[10] It is also possible to think of the two goods as being “food” and “everything else”.

To see the effects that different dynamics of satiation points have on long term changes of consumer behavior, it is helpful to look at income elasticities of the two goods. The income elasticity for food is $\epsilon_f = 1 - \frac{\alpha_s I_t}{\theta_f^{ph} + \alpha_s I_t}$. Hence, as long as α_s is positive, consistent with empirical findings (Blundell et al., 1993), with very low income the income elasticity for food is close to unity and with rising income, the income elasticity for food decreases. The income elasticity for status symbols is $\epsilon_s = 1 + 1 - \frac{\alpha_s I_t}{\theta_f^{ph} + \alpha_s I_t}$. Hence, as long as α_s is positive, the income elasticity for status symbols is always above unity and decreases with income.

Figure 1 graphically illustrates the dynamics of the matching model. For this illustration, it is assumed that the satiation point of the need to eat is 2 so that this need is satiated when $c_{f,t} = \theta_f^{ph} = 2$, and the satiation point of the need to signal social status depends linearly on income and is given by $\theta_{s,t} = (2/3)I_t$. Hence, to reduce the discomfort of having not enough social adoration, individuals have to devote two thirds of their income to status symbols. Both prices are assumed to be unity. Given these specifications, according to equations (7) and (8), the demand functions when individuals match are $c_{f,t} = \frac{3I_t}{3+I_t}$ and $c_{s,t} = \frac{I_t^2}{3+I_t}$ for food and status symbols, respectively.[11]

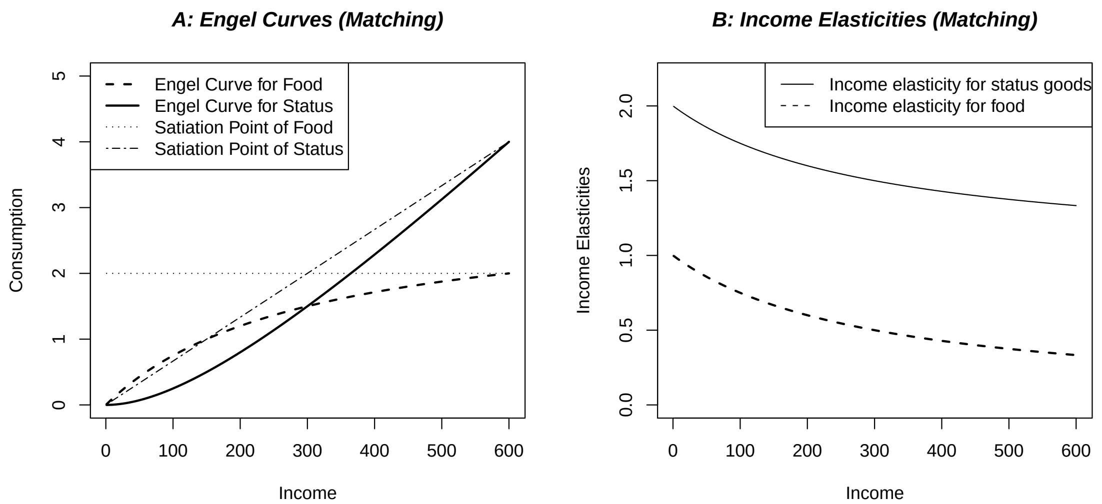

Figure 1: Figure 1a depicts the (inverted) Engel curves of food and status goods. Figure 1b shows the income elasticities for food and status goods. In all figures, income is depicted in the next smaller money unit so that an income of for example 6 is depicted as 600. All figures are created using the software environment R.

As illustrated in figure 1a, with relatively low income, most income is devoted to food. With rising income, individuals consume more food. However, the increase of food consumption becomes smaller as the satiation level of food approaches its satiation point. Consumption of status symbols is relatively low for poor individuals and increases more than proportionally with rising income. When income reaches 6 units, the individuals are

[11] According to equations (7) and (8), $c_{f,t} = I_t \times \frac{2}{2+(2/3)I_t} = \frac{3I_t}{3+I_t}$, and $c_{s,t} = I_t \times \frac{(2/3)I_t}{2+(2/3)I_t} = \frac{I_t^2}{3+I_t}$

rich enough to satisfy both needs. When income gets above 6, corner solutions are present because the model assumes that individuals do not consume more than it is needed to arrive at their satiation points. Hence, when income is above 6, food consumption stays constant at 2 and consumption of status goods increases with 2/3 for each unit of increasing income.[12]

Figure 1b depicts the income elasticities for food and status goods. It is straightforward to see that in our example the income elasticity for food is $\epsilon_f = 1 - \frac{I_t}{3+I_t}$ and the income elasticity for status symbols is $\epsilon_s = 1 + 1 - \frac{I_t}{3+I_t}$. As can be seen in figure 1b, income elasticities for both goods decrease with rising income. This is consistent with empirical findings from, for example, Blundell et al. (1993) who find that income elasticities for food decrease with rising income; a finding that traditional maximization models have difficulties to predict.

4 Welfare implications

This section analyzes to what extent consumer behavior following the matching law deviates from consumer behavior that maximizes utility. To compare both types of income allocation, first the section defines a utility function that takes account of satiation points. An additively separable utility function is used which is commonly assumed in textbook economics when the effects of the existence of bliss points are to be understood.[13] Bliss points depict the optimal levels of consumption corresponding to zero (dis-)utility. When consumption is below or beyond these bliss points, utility is negative. Bliss points can be interpreted as satiation points so that minimizing deprivation maximizes utility. In order to be able to compare the utility function with the model presented in section 3, again it is assumed that only two goods, food and status goods, exist in the economy. Hence, the utility function with the two bliss points is

$$U(c_{f,t}, c_{s,t}) = -\frac{1}{2}(\theta_f - c_{f,t})^2 - \frac{1}{2}(\theta_{s,t} - c_{s,t})^2. \tag{9}$$

As above, the bliss point for food, i.e. θ_f, is defined as 2 and the bliss point for status goods is a function linearly increasing with income ($\theta_{s,t} = (2/3)I_t$). Rational individuals do not consume more than is needed to arrive at their bliss points. In the paper the con-

[12] Corner solutions are always problematic because they can be modified by ad hoc assumptions to fit the model to the observed data. In this case, the paper assumes that it is unlikely that a situation will occur where indeed all needs are satisfied. The paper presents a simple two goods/two needs model. However, in reality, much more needs drive consumer behavior. It is likely that some satiation dynamics are related to individual income in more complicated ways than by simple linear relations. Hence, it is not unrealistic to assume that satiation points are never reached. Moreover, a "need to save" can be defined which is insatiable so that satiation is never reached in the model. Another possibility to make sure that the satiation points are never reached is to add the effectiveness of consumption to the model as described in footnote 5.

[13] Although intuitively appealing, utility functions with bliss points are not often used in neoclassical economics partly because the assumptions of monotonicity and non-satiation do not hold for these functions so that the optimization calculus does not necessarily operate well and corner solutions can emerge.

sumer behavior following from the maximization of this utility function will be used as the normative benchmark with which the consumer behavior following from the matching law is compared. That is, the paper assumes that although constrained utility maximization is not a proper means for a descriptive analysis of structural change on the demand side, it is the most tractable normative benchmark available.[14] Note that since rational individuals always want what they like and like what they want, traditionally this utility function is related to both the motivation to consume and the pleasure that can be obtained from consumption.

Maximizing the utility function (9) under the constraints $c_{f,t} + c_{s,t} \leq I_t$, $c_{f,t} \geq 0$, and $c_{s,t} \geq 0$ leads to the demand functions $c_{f,t}^{max} = min(c_{f,t}, 1 + (1/6)I_t)$ and $c_{s,t}^{max} = max(0, -1 + (5/6)I_t)$ for $I_t < 6$, where corner solutions are present when income is below 6/5.[15] When income is below 6/5, individuals spend all their income on food, because even when already some income is devoted to food, a marginal unit of additional food consumption provides more utility than the first marginal unit of status consumption. When income is 6/5 and all this income is devoted to food, the utility obtainable from one more unit of food equals the utility from the first unit of the status good. Hence, only starting with an income of 6/5, rational individuals consume status goods. When income is 6, individuals can reduce their disutility to zero by spending 2 on food and $4 = (2/3)6$ on status symbols. When income increases beyond 6, individuals do not increase the income allocated to food consumption any further, but still use (2/3) of their additional income to satiate the need to signal social status. Hence, there is another structural break of the Engel curves at $I_t = 6$. For the same reasons as described in section 3, however, income is assumed to be below 6. When income is below 6/5, the income elasticities for food and status objects are unity and zero, respectively. When income is above 6/5, the income elasticity for food is $\epsilon_f^* = \frac{I_t}{6+I_t}$ and the income elasticity for status symbols is $\epsilon_s^* = \frac{5I_t}{5I_t-6}$.[16] Both income elasticities tend to unity as income rises. In the case of status consumption this is in line with the data. For food, however, empirical studies suggest that income elasticities decrease with rising income (Blundell et al., 1993).

Figure 2 compares the Engel curves that arise from matching with the Engel curves arising from maximization. One can see that both the optimization calculus and the matching approach predict relatively similar curvatures of the Engel curves for rich individuals, given that comparable assumptions about bliss points and satiation points are made. Even if one assumed that individuals match their expenditures, as can be seen in figure 2, maximization is a not too bad approximation for the change of consumer behavior of relatively rich individuals who become even richer. For rich individuals, the existence of bliss points or satiation points seems to be more important for the descriptive analysis

[14]However, there are also other approaches to normative economics that take account of the fact that preferences can change (see Witt (2005); Witt and Schubert (2010)).

[15]See Appendix.

[16]The income elasticities are $\epsilon_{c_{f,t}^{max}} = \frac{\partial c_{f,t}^{max}}{\partial I_t} \frac{I_t}{c_{f,t}^{max}} = \frac{1}{6} \cdot I_t \cdot \frac{6}{6+I_t} = \frac{I_t}{6+I_t}$ and $\epsilon_{c_{s,t}^{max}} = \frac{\partial c_{s,t}^{max}}{\partial I_t} \frac{I_t}{c_{s,t}^{max}} = \frac{5}{6} \cdot I_t \cdot \frac{6}{5I_t-6} = \frac{5I_t}{5I_t-6}$ for food and status, respectively.

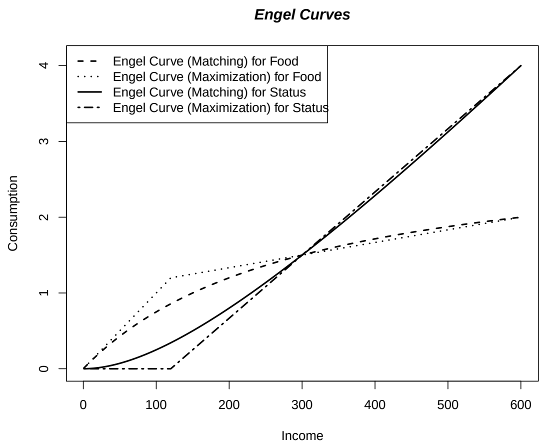

Figure 2: This figure shows the Engel curves for food and status goods obtained from matching and from maximization.

of long-run changes on the demand side than the question which decision making calculus individuals use.

However, for relatively poor individuals, differences between Engel curves obtained from utility maximization and the matching law are obvious. One obvious difference between both Engel curves is the consumer behavior of individuals who have an income below 6/5. They maximize their utility by not consuming status goods at all. Matching, however, suggests that these individuals do consume status goods. More generally, relatively poor individuals ($I_t \leq 3$) spend more on status goods and less on food than it is rational, and richer individuals ($3 \leq I_t \leq 6$) spend slightly too much on food and to little on status goods. The deviation from rational behavior, however, is larger for poor individuals than it is for rich individuals.

These differences can play a role in the normative welfare analysis. Assumed that individuals indeed match expenditure shares to need deprivation states, welfare losses can be computed by subtracting the utility corresponding to matching from the utility corresponding to maximization. Figure 3a shows the utility that is generated by individuals who either match or maximize to allocate their income. Formally, to obtain figure 3a, the various demand functions were inserted into the utility function (9). Figure 3b plots the welfare reductions from matching compared with maximization for various income levels. As can be seen, the welfare reduction is higher for relatively poor individuals than it is for richer individuals. Individuals with a relatively high income (above 2)have only a very small welfare loss compared to the poorer individuals. Hence, when all individuals follow the matching principle to allocate their income, this behavior leads to a higher welfare loss for the poor than for the rich. This can have consequences for the evaluation of various redistributive policy interventions. Redistribution of income from the rich to the poor may have a smaller effect in terms of welfare that it has in terms of pure income. Hence,

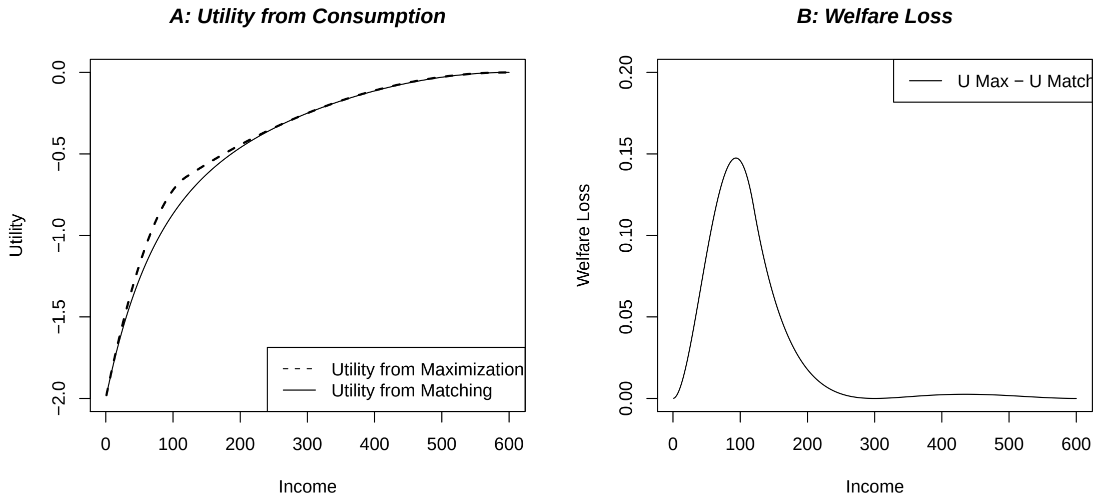

Figure 3: Figure 3a shows the (dis-)utility from consuming less that it is needed to arrive at the bliss point in the case of maximization and at the satiation point in the case of matching. 3b shows the difference between the (dis-)utility obtained from maximization and the (dis-)utility obtained from matching.

a higher degree of redistribution than utility maximization would suggest may be needed to arrive at a predefined reduction of inequality.

5 Innovative activity

The model presented in section 3 analyzed differential satiation patterns as one reason for structural change on the demand side when income rises. However, although important, differential satiation is only one of several reasons for such structural change. Another reason is the innovative activity of producers who try to increase the demand for their products (Witt, 2001). One reason for this innovative activity is the reduced demand caused by high satiation levels corresponding to high consumer income. Innovators oftentimes aim at changing the satiation characteristics of consumer goods to generate more consumption. These innovations occur in various forms. For example, Witt suggests that producers sometimes reduce the satiating components of consumer goods, as in the case of diet products, alcohol free beer, and decaffeinated coffee. These innovations reduce the effectiveness of consumer goods to increase satiation levels. Other innovations increase the price of certain products by using rarely occurring and hence more expensive ingredients.

A third type of innovation is to add new characteristics that appeal to less easily satiable needs to the consumer goods. Innovators sometimes add new symbolic characteristics to consumption products, thus providing additional reasons to consume these products. Food items can, for example, be used to signal social status and/or communicate with oneself or with others. Moreover, food consumption is oftentimes seen as being driven by self-image

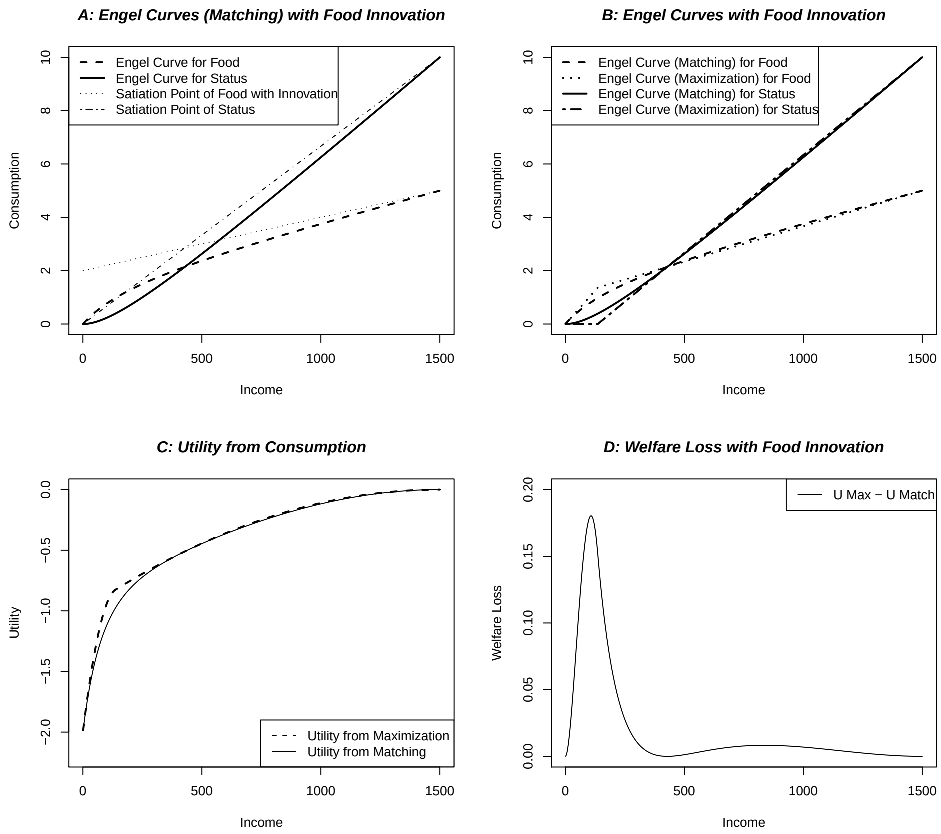

Figure 4: All graphs describe the economy with the innovation in the food domain. For food and status goods, figure 4a plots the Engel curves for individuals who match as well as the change of the satiation points when income rises. Figure 4b shows the Engel curves for food and status goods obtained from matching and from maximization. Figure 4c shows the (dis-)utility from consuming less that it is needed to arrive at the bliss point in the case of maximization and at the satiation point in the case of matching. Figure 4d shows the difference between the (dis-)utility obtained from maximization and the (dis-)utility obtained from matching.

motives such as in the case of ethical food consumption. Individuals consume ethical food products to obtain positive and stable self-images of being responsible individuals. These symbolic characteristics can show systematical relationships with rising income as described in section 2.

Formally, adding a symbolic meaning to the food item changes the satiation point from θ_f to $\theta^*_{f,t}$. $\theta^*_{f,t}$ now is determined by the physiological satiation point θ_f^{ph} and a psychological factor that changes linearly with income $\theta_{f,t}^{ps} = \alpha_f I_t$, where α_f depicts the degree to which the symbolic motivation to consume the food product varies with income. Hence, the satiation point corresponding to the two needs that food items can satiate after the innovation is given by $\theta^*_{f,t} = \theta_f^{ph} + \alpha_f I_t$. Accordingly, when individuals match, i.e. according to equation (3), the demand function for food is $c^*_{f,t} = \frac{\theta_f^{ph} I_t + \alpha_f I_t^2}{\theta_f^{ph} + \alpha_f I_t + \alpha_s I_t}$ and the demand function for status goods is $c^*_{s,t} = \frac{\alpha_s I_t^2}{\theta_f^{ph} + \alpha_f I_t + \alpha_s I_t}$. Figure 4a shows these demand functions as well as how the satiation points for food and the status good change with rising income. Figure 4b compares the matching Engel curves with the Engel curves obtained when equation (9) is maximized with $\theta_f = \theta_f^{ph} + \alpha_f I_t$ and $\theta_s = \alpha_s I_t$ under the constraints $c_{f,t} + c_{s,t} \leq I_t$, $c_{f,t} \geq 0$, and $c_{s,t} \geq 0$ (see Appendix). Figure 4c shows the utility obtained from both ways of allocating income to the two consumption categories, and figure 4d plots the welfare loss generated by matching instead of maximization. Comparing figure 3b with figure 4d shows that the innovation increased the welfare loss of relatively poor individuals so that their behavior deviates more strongly from the rational benchmark.

6 Concluding remarks

Nelson and Consoli (2010) argue that evolutionary economics needs a behavioral theory of consumer behavior. Based on the need-based explanation of preferences by Witt (2001), this paper sketches a formal model of changing consumer behavior. In the model, individuals allocate their income using a simple matching calculus so that differential need satiation dynamics across needs translate into long-run changes of consumer behavior. The model is able to reconstruct some empirical regularities that traditional maximization models have difficulties to generate. For example, the empiric regularity that income elasticities for food decrease with rising income is difficult to be generated in most maximization models, but the matching model can reconstruct this regularity. Furthermore, the paper compares the allocation of income generated by the matching model with the allocation of income generated by a utility maximization calculus. Both decision making processes generate relatively similar Engel curves for rich individuals. For poor individuals, however, the two types of Engel curves are quite different. When relatively poor individuals match, they spend more than it is optimal on luxury products such as status goods and less than it is optimal on necessities such as food. The deviations from optimal behavior when individuals match are thus larger for poor individuals than they are for rich individuals. Accordingly, the model suggests that the inequality in a society measured in terms of well-being can be higher than the inequality measured in terms of income. This can have implications for the evaluation of redistributive policy interventions. To arrive at a target value in terms of reduction of inequality, more redistribution than rational utility maximization models suggest may be needed. Future research can investigate the effects of such redistributive interventions. Moreover, the paper shows that an innovation that adds a symbolic component to a basic good can increase the welfare loss of poor individuals that emerges when individuals match instead of maximizing. Future research can investigate the effects that other types of innovations have on structural change and individual well-being. Finally, since matching and maximization lead to particularly different allocations of income for poor individuals, future empirical research can investigate which decision making process leads to Engel curves that are better approximations of the behavior of poor individuals.

7 Mathematical Appendix

7.1 Calculation of income elasticities in section 3:

The demand functions are given by $c_{i,t} = \frac{I_t\theta_i^{ph}+\alpha_i I_t^2}{\sum\limits_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)}$. Hence,

$$\begin{aligned}
\epsilon_{i,t} &= \frac{\partial c_{i,t}}{\partial I_t}\frac{I_t}{c_{i,t}} \\
&= \frac{[(\theta_j^{ph}+2\alpha_j I_t)(\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)) - (I_t\theta_j^{ph}+\alpha_j I_t^2)\sum_{j=1}^{n}\alpha_j]\cdot I_t\cdot\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)}{(\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t))^2\cdot(I_t\theta_j^{ph}+\alpha_j I_t^2)} \\
&= \frac{(\theta_j^{ph}+2\alpha_j I_t)(\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_j)) - (I_t\theta_i^{ph}+\alpha_i I_t^2)\sum_{j=1}^{n}\alpha_j}{\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)\cdot(\theta_i^{ph}+\alpha_i I_t)} \\
&= \frac{\theta_i^{ph}+2\alpha_i I_t}{\theta_i^{ph}+\alpha_i I_t} - \frac{I_t\sum_{j=1}^{n}\alpha_j}{\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)} \\
&= 1 + \frac{\alpha_i I_t}{\theta_i^{ph}+\alpha_i I_t} - \frac{\sum_{j=1}^{n}\alpha_j I_t}{\sum_{j=1}^{n}(\theta_j^{ph}+\alpha_j I_t)}.
\end{aligned}$$

7.2 Maximization calculus in section 4:

Maximizing the utility function

$$U(c_{f,t}, c_{s,t}) = -\frac{1}{2}(2-c_{f,t})^2 - \frac{1}{2}((2/3)I_t - c_{s,t})^2 \tag{10}$$

under the constraints $c_{f,t} + c_{s,t} \leq I_t$, $c_{f,t} \geq 0$, and $c_{s,t} \geq 0$ using the Lagrange method

$$L = -\frac{1}{2}(2-c_{f,t})^2 - \frac{1}{2}((2/3)I_t - c_{s,t})^2 + \lambda[I_t - c_{f,t} + c_{s,t}] \tag{11}$$

leads to the first order conditions

$$\frac{\partial L}{\partial c_{f,t}} = 0 \Leftrightarrow 2 - c_{f,t}^{max} = \lambda \tag{12}$$

and

$$\frac{\partial L}{\partial c_{s,t}} = 0 \Leftrightarrow (2/3)I_t - c_{s,t}^{max} = \lambda. \tag{13}$$

Hence, $2 - c_{f,t}^{max} = (2/3)I_t - c_{s,t}^{max}$ and with $c_{f,t}^{max} + c_{s,t}^{max} = I_t$, $c_{f,t}^{max} = 2 - (2/3)I_t + I_t - c_{f,t}^{max}$ so that $c_{f,t}^{max} = 1 + (1/6)I_t$. However, since $c_{f,t} + c_{s,t} \leq I_t$, the solution is

$$c_{f,t}^{max} = min(c_{f,t}^{max}, 1 + (1/6)I_t). \tag{14}$$

Since, $c_{s,t} = I_t - c_{f,t}$, $c_{s,t}^{max} = I_t - 1 - (1/6)I_t$ so that $c_{s,t}^{max} = -1 + (5/6)I_t$. Due to $c_{s,t} \geq 0$, the solution is

$$c_{s,t}^{max} = max(0, -1 + (5/6)I_t). \tag{15}$$

7.3 Matching and maximization with innovation in section 5:

The demand functions when individuals match after the innovation for food and status are $c_f^* = I_t \cdot \frac{\theta_f^{ph} + \alpha_f I_t}{\theta_f^{ph} + \alpha_f I_t + \alpha_s I_t} = \frac{\theta_f^{ph} I_t + \alpha_f I_t^2}{\theta_f^{ph} + \alpha_f I_t + \alpha_s I_t}$ and $c_s^* = I_t \cdot \frac{\alpha_s I_t}{\theta_f^{ph} + \alpha_f I_t + \alpha_s I_t} = \frac{\alpha_s I_t^2}{\theta_f^{ph} + \alpha_f I_t + \alpha_s I_t}$. With $\theta_f^{ph} = 2$, $\alpha_s = (2/3)$, and $\alpha_f = (1/5)$: $c_f^* = \frac{2I_t + (1/5)I_t^2}{2 + (1/5)I_t + (2/3)I_t} = \frac{2I_t + (1/5)I_t^2}{2 + (13/15)I_t}$ and $c_s^* = \frac{(2/3)I_t^2}{2 + (1/5)I_t + (2/3)I} = \frac{I_t^2}{3 + (13/10)I}$.

Maximizing the utility function

$$U(c_f^*, c_s^*) = -\frac{1}{2}(\theta_f^{ph} + \alpha_f I_t - c_f^*)^2 - \frac{1}{2}(\alpha_s I_t - c_s^*)^2 \tag{16}$$

under the constraints $c_f^* \geq 0$, $c_s^* \geq 0$, and $c_f^* + c_s^* \leq I_t$ using the Lagrange method leads to the first order conditions

$$\theta_f^{ph} + \alpha_f I_t - c_f^{max,*} = \lambda \tag{17}$$

and

$$\alpha_s I_t - c_s^{max,*} = \lambda, \tag{18}$$

so that with $c_f^* + c_s^* = I_t$,

$$c_f^{max,*} = \frac{1}{2}(\theta_f^{ph} + (1 + \alpha_f - \alpha_s)I_t) \tag{19}$$

and

$$c_s^{max,*} = -\frac{1}{2}\theta_f^{ph} + \frac{1}{2}(1 - \alpha_f + \alpha_s)I_t. \tag{20}$$

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