Material needs and aggregate demand

Eric Kemp-Benedict

Stockholm Environment Institute

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Eric Kemp-Benedict[a]

[a]*Stockholm Environment Institute, 11 Curtis Avenue, Somerville, MA 02144, USA*

Abstract

A central conclusion of the standard theory of consumption is that consumers' preferences can be taken as theoretical primitives. Special categories of consumption, such as "basic needs", or of goods, such as "subsistence goods" are seen as extra theoretical baggage that add few, if any, insights. This theoretical orientation has been absorbed into the theory of aggregate demand, but the aggregate theory has a serious problem that is not shared by the individual-level theory: no matter how well-behaved the individual-level demand functions may be, the aggregate-level function can take on almost any form. This result follows from the SMD theorem, named after Sonnenschein, Mantel, and Debreu, who developed the theory; Kirman and Koch strengthened the results, and the SMD-KK theorem poses a fundamental challenge to models linking micro and macroeconomics. A standard response to the aggregation problem is to introduce a representative agent, but this merely sidesteps the problem. We argue that the aggregation problem arises, in part, because of the exclusion of needs from the theory. Specifically, we argue that material needs—such as basic needs for energy, water, food, and shelter—must be included as theoretical primitives because both the needs and the satisfiers of those needs are universal. We construct a microeconomic model with material needs and show that the form of the aggregate excess demand function is not completely arbitrary, so the SMD-KK theorem does not apply. We discuss the implications of this result.

Keywords: Sonnenschein-Mantel-Debreu theorem, micro-foundations, aggregation, needs-based consumption, hierarchical consumption, consumer demand

1. Introduction

Near the middle of the last century the theory of individual consumer demand reached a peak, as the work of Houthakker (1950) and Samuelson (1950) closed the theoretical loop between utility-based theories and the theory of revealed preference. By that time, needs, which had been an important consideration in economic theory, had all but disappeared as a fit subject of research,

Email address: eric.kemp-benedict@sei-international.org (Eric Kemp-Benedict)

because they were thought to add no additional insights to the micro-level theory of individual or household consumption (Seeley, 1992). Since then, the standard micro-level theory has been criticized for having unrealistic hypotheses about human behavior (Ackerman, 1997; Kirman, 1989; Simon, 1984), and alternative micro-level theories have been proposed that correct some of the deficiencies (Lancaster, 1966; Stigler and Becker, 1977; Seeley, 1992). At the same time problems with the macro-level theory of aggregate consumption appeared. The aggregation problem[1] is by now a widely understood but also widely unacknowledged problem within standard economic theory (Kirman, 1989, 2006; Janssen, 1993; Chipman, 2006). The situation is serious because a major tool of economic policy analysis—the computable general equilibrium model—is premised on the ability to meaningfully aggregate individual-level demand to an economy-wide demand function (Dixon et al., 1996; Ackerman, 2001; Ginsburgh and Keyzer, 2002).

The aggregation problem is captured in the so-called SMD theorem (Rizvi, 2006), named after Sonnenschein (1972), Mantel (1974), and Debreu (1974), who built up the essential argument in a series of papers. The SMD theorem shows that nearly any continuous function satisfying Walras' Law can be expressed as a sum of well-behaved individual demand functions; thus the individual theory of consumption places almost no restrictions on aggregate excess demand. Because the theorem is proved by construction, it could be, and was, criticized for the specific form of the demand functions used in the construction. This critique was strongly refuted by Kirman and Koch (1986), who showed that the theorem holds even in the case of identical preferences and almost any initial relative income distribution. In their own words, they showed that, "...any arbitrary excess demand function may be generated by an exchange economy with any fixed price independent relative income distribution and identical preferences for all agents." The Kirman and Koch result, which, with Chipman (2006), we call the SMD-KK theorem, is a strong challenge to aggregation. At present there is no known way around it aside from assuming a representative agent—that is, assuming that the aggregate demand function looks like an individual demand function (Kirman, 2006; Chipman, 2006). However, there is no theory that justifies this approach (Kirman, 1992; Janssen, 1993), and the representative agent is perhaps best viewed as a practical device to generate candidate forms for aggregate demand functions that can then be tested empirically.

In this paper we argue that the introduction of human needs into the theory provides a solution to the aggregation problem, although we do not think that the solution is unique. We restate Kirman and Koch's result in a way that is more appropriate for our argument:

[1]The term "aggregation problem" is sometimes used to label a particular mathematical problem of finding the conditions under which the structure of a micro-scale economic relation is reproduced at the aggregate level (Janssen, 1993). In this paper we use it more generally to mean the problem of explicitly deriving a macro-economic model from a micro-economic model by aggregating over a population.

> Given an arbitrary excess demand function f and a relative income distribution with a lower bound well above zero,[2] it is always possible to construct a single, well-behaved, preference function that is shared by all consumers such that the aggregate excess demand generated by the specified income distribution and preference function is equal to f.

In this paper we show that when basic needs are introduced into individuals' consumption decisions, one avoids the implications of Kirman and Koch's result, for two reasons. First, we argue that theories of human needs suggest that, for a class of "material" needs, people within a given society have very similar preferences and, moreover, the form of those preferences is not arbitrary, as the SMD-KK theorem requires (Chipman, 2006). Second, we argue on empirical evidence provided by Jackson and Marks (1999) that, even in highly industrialized societies, expenditure on these categories of needs is a large part of many household budgets. By the first argument we place both a weaker and a stronger constraint on the form of the excess demand function than assumed by Kirman and Koch. It is weaker because individual preference functions differ for some goods, but are identical for other goods; it is stronger because it fixes the form of the individual preference function for goods that satisfy material needs. From the second argument we conclude that even if material needs provide only a portion of household expenditure, it is a large enough portion to significantly constrain aggregate demand.

2. Human Needs and Consumption

There is a long history within economics of hierarchical, needs-based approaches to consumption (Drakopoulos and Karayiannis, 2004). Indeed, Alfred Marshall, one of the early theorists of the current consumption model, proposed a hierarchy of needs (Drakopoulos and Karayiannis, 2004; Haines, 1982). Outside of mainstream economics there has been continued interest in human needs. Perhaps the best-known psychological theory is that of Maslow (1943), who proposed a hierarchy of needs that is similar to that of Marshall. Needs lower in Maslow's hierarchy, such as physiological and safety needs, must be satisfied before people can pursue higher needs, such as belonging or "self-actualization".

There have been few attempts to construct quantitative needs-based consumption models, mainly because hierarchical utility functions have "kinks" in them, which interferes with substitutability. However, limited substitutability is a direct implication of needs-based theories of consumptions; if people do indeed choose partly based on hierarchical needs, then it is the task of the theorist to accommodate this behavior within the theory. Seeley (1992) offers a notable

[2] The assumption of an income distribution bounded far away from zero is not emphasized in the body of Kirman and Koch's paper, but appears in the appendix, where they write, "We may further assume that the endowments are large enough to make the individual demand $\phi_i(p) \gg 0$ for every $p \in S_\epsilon$ and every consumer i."

example of an explicit mathematical consumption model based on Maslow's theory. In Seeley's model, there is a satiable basic need A_1 that takes precedence over a higher-order need A_2. Satiability and precedence together suggest that the consumer's utility function $U(A_1, A_2)$ is insensitive to changes in A_2 when A_1 is below an "aspiration boundary" $\bar{A}_1$, and insensitive to changes in A_1 when A_1 is above a "satiation boundary" A_1^*. Between the aspiration and satiation boundaries is a transitional region in which the consumer trades off between A_1 and A_2. In keeping with recent thought about household consumption (e.g., Ironmonger, 1995; Stigler and Becker, 1977), Seeley assumes that people can meet their needs either through economic or non-economic goods; we do not explicitly include this in our model, but do accept it as a basic fact of economic life.

Recent studies on the behavior of people in poor communities (Bebbington, 1999; Guillen-Royo, 2008), while supporting the idea that some needs are more basic than others, have cast some doubt on strict, "lexicographic" preferences; the hierarchy of needs is a relative rather than an absolute concept. Jackson and Marks examine consumption data in the UK in a frame drawn from Max-Neef's theory of needs (Max-Neef et al., 1991), which does not impose a hierarchy, although some of its categories (e.g., "subsistence") are clearly more basic than others. Max-Neef makes an important contribution to the theory of human needs by distinguishing "needs" from "satisfiers" of those needs, a distinction we maintain in this paper. Jackson and Marks build upon Max-Neef's framework by distinguishing "material" needs (those that cannot be met without some material consumption) from "non-material needs" (those that can in principle be met without any material consumption). They also distinguish needs from structural factors, such as the amount of travel required to meet needs. Examining aggregate UK data, they argue that, from 1954 to 1994, expenditure for material needs barely increased, while expenditure for non-material needs and travel increased significantly. They interpret their results to mean that over that time people in the UK were mostly increasing their expenditure either to maintain their levels of material needs or to meet non-material needs through material means. Importantly, by their classification, expenditure to meet material needs accounted for roughly one-half of total household expenditure in 1954 and nearly one-third of total expenditure in 1994; meeting material needs takes up a great deal of household budgets, even in a highly industrialized country.

In a separate study of UK consumption data, Baxter and Moosa (1996) contrasted the statistical properties on expenditure to meet basic needs—food, energy products, clothing and footwear, and housing—and expenditure on other non-durable goods. They found that both the time-series and cross-sectional statistical properties of their basic-needs category were distinct from those of other non-durable goods, and concluded that "basic needs" is a meaningful economic concept with observable characteristics in aggregate economic data. Baxter and Moosa also provided a list of criteria to identify basic needs, saying they are: *universal*; *hierarchical* (in that they are essential to survival); *satiable*; *measurable*; *irreducible* (below a minimum level); *continuing* (over every consumer's lifetime); *stable*; *additive* (in that total expenditure should be roughly proportional to population); and *absolute*. We will revisit their list later in this paper.

2.1. Quantifying basic material needs

Baxter and Moosa use only food as an example of quantifying basic needs, while surmising that other basic needs could be similarly quantified. They are correct, as a short survey will show. In this survey we consider basic material needs for water, food energy, useful energy, and living space. We make no attempt at completeness and consider only one or two sources for each of these needs.

2.1.1. The need for water

In a well-known paper, Gleick (1996) quantified basic needs for water. He considered drinking water, water for sanitation and bathing, and water for food preparation. While these needs vary somewhat with the types and levels of household activities and with climate, he proposed a uniform daily minimum of 50 liters per person. In fact, people do get by on less than that amount, so rather than a minimum for survival, his value is a minimum for supporting a normal level of activity. Below this minimum people experience a higher risk of disease and an impaired ability to carry out daily tasks.

2.1.2. Food energy intake: Metabolic needs for food

Similarly to Gleick's minimum for water, there are minimum standards for food energy intake to support normal activity (FAO, 2008, 2011). Also as with water, food energy needs vary with circumstances, depending on age, gender, and level of activity; the standards for food energy take these factors into account. "Food energy" refers to the useful (metabolizable) calories derived from food after digestion and excretion have been accounted for. People also need vitamins, minerals, and proteins, but the Food and Agriculture Organization of the United Nations (FAO) has identified food energy as the best single benchmark to measure undernutrition.

While people can and do live with food energy intake below minimal levels, it impairs their ability to carry out normal tasks. According to the FAO's last estimate (FAO, 2011), about 13 per cent of the world's population could not meet its food energy needs.

2.1.3. The need for (useful) energy

Estimating basic needs for energy is more complex than for water or food. Pachauri and Spreng (2004) consider three different approaches to estimating basic needs for energy—a poverty-line measure, an engineering-based measure, and a two-dimensional access vs. useful energy measure. They conclude that measuring energy in terms of useful energy—that is, the energy that contributes towards supplying an energy service—and taking access into account is the best approach. An even more basic concept than useful energy is that of an energy service, such as "illumination", in contrast to the energy output of a light source, but it is difficult to construct comparable measures of energy services. To calculate useful energy, the energy input (e.g., the energy supplied by complete combustion of wood, coal, or kerosene) is multiplied by a conversion efficiency factor.

Pachauri and Spreng's analysis is focused on India. They find a clear hierarchy of energy use, echoing earlier work on the "energy ladder" in developing countries (Hosier and Cleveland, 2004), and argue that there are minimal and quantifiable needs for energy, although they interact with level of access to different energy carriers. Moreover, energy needs may vary from one society to another.

2.1.4. The need for living space

In long-term historical perspective, it is clear that people do not need much space. Brown and Deaton (1972), updating an earlier estimate by Naroll (1962), argued that a value of 6 square meters per capita is a reasonable worldwide population constant for estimating long-term historical populations from archaeological measurements of living space. In contrast, considering contemporary Portugal, Pedro (2009) argues that below 8 square meters of habitable space per capita living conditions are "pathological", neutral satisfaction is achieved at 14 square meters per person, and positive satisfaction only at 20 square meters per person. As with energy, need for living space is most likely society-specific, but within that society it is measurable.

2.2. Prices of satisfiers of material needs

Prices for water, food, useful energy, and living space show quite distinct patterns from one another. In this section we survey some empirical results on prices for material needs. We are interested in countries across a wide range of income levels, but most of the studies we refer to in this section are for India; this is partly because of the intrinsic research interest of a populous country undergoing rapid economic change, but also because the National Social Survey (NSS) of India provides several waves of micro-level data that can support analysis.

A global survey found that water prices are typically regulated, but informal and non-municipal water vendors appear where there are either no services or inadequate services. The prices from informal sources can be much higher than the price of municipal piped water, either because the vendors have an effective monopoly or because of high costs for supplying water (Dagdeviren and Robertson, 2009).

Food prices per calorie are also highly variable. Subramanian and Deaton (1996), in a study in Maharashstra state, found a wide range of prices on a per calorie basis, with prices for meat 26 times that for cereals. They found that, as incomes rise, people purchase "more expensive calories", substituting between food groups (e.g., meat over cereals) rather than within groups.

In contrast to water and food, prices per unit of useful energy are remarkably even. Pachauri and Spreng (2004) found, for their sample, that in 11 of their

14 categories of consumer the average price paid for useful energy ranged from 0.28 to 0.37 Rs per kWh—a ratio of 1.3. In only three categories did they find higher values: urban kerosene and LPG (0.43 Rs per kWh) and rural and urban biomass (0.46 and 0.68 Rs per kWh). Urban consumers with access to electricity faced lower prices than those without, and those relying solely on biomass were among the poorest households. As with water, the poor in their data set paid more than the non-poor for equivalent energy services.

Prices for living spaces vary considerably, and depend on the characteristics of the housing. In a study of housing demand in Delhi, Ahmad et al. (2012) found that, outside of slums, housing demand is relatively responsive to income, and less responsive to changes in price. Within slums, the opposite is true, suggesting that slum dwellers have to prioritize other consumption as their incomes rise, consistent with a hierarchical model of consumption. What is more, slum dwellers are responsive only to differences in the quantity of housing, and not quality, while outside of slums households respond to differences in both the quantity and quality of their living space.

The overall patterns of prices suggest the following observations:

1. Limited access to satisfiers of material needs leads to higher prices per unit of service, either because of higher supply costs or an effective monopoly;
2. When access is not limited, price per unit of service is roughly equal across different satisfiers unless they also satisfy non-material needs;
3. When satisfiers of material needs also satisfy non-material needs, they command a premium.

We do not consider the first item, although it has important welfare implications. We incorporate the second and third items in the model presented later in this paper.

2.3. Satisfiability and satiability

The brief survey above confirmed that basic material needs can, to a greater or lesser degree, be quantified, either for humanity in general (water and food), or within the context of a particular society (energy and living space). It is instructive at this point to reconsider Baxter and Moosa's criteria for basic needs (Baxter and Moosa, 1996). Most items on their list appear to hold true of basic material needs, with some qualifications. Basic needs are universal, in that everyone must satisfy them at some level, although that level may differ with circumstances and from one society to another. Basic needs may be at least partly hierarchical, although this is less clear: for example, as noted above, people living in slums in Delhi prioritized other expenditure over living space when their incomes increased. Basic material needs are measurable, although the measurement can be quite involved; in the case of energy it is difficult to set an absolute measure without taking access into account. Most basic needs are irreducible, in that there is an absolute minimum below which people cannot survive; for some needs there is also an identifiable and irreducible level for carrying out normal activities. Finally, basic needs are continuing, stable, and absolute.

Two of the criteria on Baxter and Moosa's list are less clearly supported by the examples listed above. First, it is not obvious that expenditure on basic needs satisfiers is additive, because some material satisfiers can be consumed in excess, prices can vary per unit of material satisfier delivered, and some people may consume the material satisfier at rates below the minimum. Second, and related to the first, basic material satisfiers may not be satiable. An example of a satiable need is the need for food. Beyond a certain level of consumption, additional calories become deadly; only waste is a survivable use of calories beyond what the body can accommodate. While high-income countries do waste a great deal of food, even their calorie consumption is expected to saturate in coming decades (FAO, 2006). This conclusion is consistent with Subramanian and Deaton's observation that the people in their sample appeared to buy more expensive calories as their incomes increased; increases in their caloric intake rose more slowly than their food expenditure. Similarly, although domestic water use can be much higher than basic needs, this is partly because of leakage and inefficient water use. Efficiency measures can reduce total water consumption, suggesting that price is not a limiting factor, while high-income countries can have quite modest domestic water consumption (Gleick, 2003); also, standard models of water demand assume satiation at low price levels (Arbus et al., 2003).

In contrast to food and water, there are many uses for energy beyond basic needs, and demand for useful energy does not saturate. There is also no natural saturation point for living space. Pedro (2009) categorizes responses to different amounts of living space as "pathological", "negatively satisfied", "neutral", and "positively satisfied". His categories provide a useful frame for thinking about these non-satiable but necessary material satisfiers, while Ahmad's study of housing demand (Ahmad et al., 2012) provides insights into different consumer responses at different levels of satisfaction. It is plausible that Ahmad's slum residents, who were much more responsive to quantity of living space than quality, were somewhere in the range from pathological to negative satisfaction. In that range it is reasonable that households will, if they are not trying to satisfy other material needs, try to improve the material satisfaction of their need for living space at the expense of non-material needs. Above that range, where consumers become neutral to changes in the provision of a good, they can focus more on non-material needs; for non-satiable goods, they may meet those needs through material means, moving into the range of positive satisfaction.

These observations suggest that some satisfiers of basic material needs are satiable, but all are "satisfiable". Below the level of satisfaction, consumers seek to meet their basic material needs. Beyond that level they may increase their consumption of material satisfiers, but may also diversify into other goods that provide for their non-material needs. Consumption of satiable goods eventually saturates, perhaps increasing beyond a level of neutral satisfaction, but saturating not far above that level.

3. The Model

In this paper we propose a needs-based model for individual or household-level consumption and then explore the implications at the aggregate level. In light of the survey in the previous section the model is much simpler than the reality, but also has some interesting behavior. We make the following assumptions:

1. Needs are universal and partly hierarchical, in that physiological needs must be met to some degree before they can be traded off against other needs. While other needs can be met even when physiological needs are not fully met, consumers will choose not to meet them at the expense of physiological needs.
2. Everyone agrees on the satisfiers of material needs (e.g., calories of food, liters of water, kilowatt-hours of useful energy, square meters of living space). Also, everyone agrees on how much of a material satisfier is provided by any particular good.
3. The relationship between goods and satisfiers is strictly linear, although the level of satisfaction is not; for example, ten chickens will provide ten times the calories of one chicken, but—if one attempts to eat them all in one sitting—less satisfaction.
4. Any good, including goods that provide for material needs, can also satisfy non-material needs. But the translation of goods to non-material needs can vary considerably from one consumer to another.

We implement these assumptions in a mathematical model through the following definitions and assumptions:

1. We denote the set of material satisfiers by a vector $\boldsymbol{y}$ with n elements. We use an index $k = 1, \ldots, n$.
2. We denote the set of goods by a vector $\boldsymbol{x}$ with ℓ elements; each good has a price p_i. We use an index i for goods, with $i = 1, \ldots, \ell$.
3. We relate goods and material satisfiers through a set of linear coefficients b_{ki}: $y_k = \sum_{i=1}^{\ell} b_{ki} x_i$.
4. All consumers share a preference function $\varphi(\boldsymbol{y}, z)$, where z captures the satisfaction of non-material needs. However, each consumer $r = 1, \ldots, m$ maps goods to non-material needs in a way that other consumers may not share, denoted by a function $z_r(\boldsymbol{x})$.
5. Each consumer has a budget I_r that can, as is standard in the theory of excess demand, be represented as the value of an endowment bundle $\boldsymbol{\omega}_r$: $I_r = \sum_{i=1}^{\ell} p_i \omega_{ri}$.
6. The preference function is insensitive to changes in z when $y_k \leq \beta_k$ for any material satisfier k, where $\boldsymbol{\beta}$ is the level at which basic material needs are met. While people can survive at levels below this, they focus their expenditure on meeting basic material needs until this level.
7. The preference function is insensitive to changes in y_k when $y_k > \beta_k$ for all material satisfiers k; while consumers may actually consume more of the

material satisfier, above the basic-needs level that consumption is because they are using material satisfiers to satisfy non-material needs.

8. For each material satisfier k there is a base price π_k that sets a floor on prices of goods that supply the material satisfier. Prices of goods can therefore be written $p_i = \sum_{k=1}^{n} \pi_k b_{ki} + q_i$, where the q_i, which capture the market value of meeting non-material needs, are positive.

To these definitions and assumptions we add the standard assumption that individuals consume their most preferred bundle of goods consistent with their income.[3]

3.1. Decision rules for poor and non-poor consumers

We first split the population of consumers into the "poor" and the "non-poor". Poor consumers are those who cannot afford the minimal bundle of material satisfiers $\boldsymbol{\beta}$. Below that level consumers meet only their material needs through the market, and have identical preference rankings for bundles of material needs satisfiers.

We denote by $\boldsymbol{\beta}(0)$ that bundle that will meet physiological needs at a basic level of survival and $\boldsymbol{\beta}(1) = \boldsymbol{\beta}$ as that bundle that satisfies basic material needs at a neutral level of satisfaction. Between those two limits is a sequence of bundles of basic needs satisfiers $\boldsymbol{\beta}(s)$, where $s \in [0, 1]$ that maximize the (common) preference function and that is ordered such that $\varphi(\boldsymbol{\beta}(s), \cdot) > \varphi(\boldsymbol{\beta}(s'), \cdot)$ whenever $s > s'$. In this regime consumers' preferences are insensitive to changes in satisfiers of non-material needs z, so these have been replaced by a dot. Each bundle can be met through goods that provide the material satisfier at the base price π_k, and so, to each bundle $\boldsymbol{\beta}(s)$, there is a corresponding income level $I_p(s) = \sum_{k=1}^{n} \pi_k \beta_k(s)$. The poor are those whose income I_r is less than the poverty line, $I_p(1)$. They solve the following optimization problem:

$$\text{Maximize } s \in [0, 1] \text{ such that } I_r = I_p(s). \tag{1}$$

In this expression maximization of the preference function has been replaced by maximization of s because, by assumption, preference for the bundles $\boldsymbol{\beta}(s)$ is strictly increasing in s.

Note that this does not uniquely specify the bundle of goods, since many goods might supply the material satisfier at the same price per unit of service. Individual circumstances—access, preference, skill—determine the detailed way in which households attempt to satisfy their basic material needs. What we

[3]While this assumption is standard, it is questionable whether households can or do actually do this. Cognitive limitations encourage people to use heuristics and habits when choosing bundles of goods (Simon, 1984). Those habits and heuristics may work very well in normal circumstances, but in times of change households may need to engage in a lengthy search for a new set of rules (Loasby, 2001). Also, if people compare goods based on their characteristics, as seems likely (Lancaster, 1966), and they rank characteristics ordinally, but not cardinally, then it is easy to generate situations in which there is a cycle of preference rankings for goods (Kapeller et al., 2012), so that consumers must invoke additional decision rules.

claim is that if there is more than one way for the poor to meet their basic needs, then the prices of the different options will be approximately the same per unit of service. This redundancy does not, therefore, mean that "anything goes", especially in terms of prices. In reality the choice of goods to satisfy basic needs is fairly consistent across poor consumers at the same level of consumption. Pachauri and Spreng's results for energy consumption in India (Pachauri and Spreng, 2004), and the well-established concept of the energy ladder (Hosier and Cleveland, 2004) both suggest that, for energy at least, poor consumers select a reasonably predictable basket of energy sources at different levels of total energy consumption. Moreover, the decision rule for poor consumers gives us a predictable association between income I_r and the satisfaction of material needs: it is the vector $\boldsymbol{\beta}(s)$ at that level of s that satisfies the decision rule given by Equation 1 for a given set of base prices for material needs $\boldsymbol{\pi}$. We therefore propose that at each level of income $I_r \leq I_p(1)$, there is a specific bundle of material satisfiers $\boldsymbol{y}_p(I_r, \boldsymbol{\pi})$ and reasonably predictable bundle of goods $\boldsymbol{x}_p(I_r, \boldsymbol{\pi})$.

In contrast to poor consumers, the material needs of non-poor consumers are fully satisfied—while they may increase their material consumption beyond that level, it is in the service of non-material needs. We define, for non-poor consumers, an effective preference function

$$\psi_r(\boldsymbol{x}) \equiv \varphi(\boldsymbol{\beta}, z_r(\boldsymbol{x})). \tag{2}$$

Non-poor consumers seek their most preferred bundle of goods $\boldsymbol{x}$ subject to two constraints: their budget constraint and the constraint that they meet minimal material needs. They therefore solve the following optimization problem.

$$\text{Maximize } \psi_r(\boldsymbol{x}) \text{ such that} \tag{3a}$$

$$I_r = \sum_{i=1}^{\ell} p_i x_i, \tag{3b}$$

$$\sum_{i=1}^{\ell} b_{ki} x_i \geq \beta_k. \tag{3c}$$

Following standard practice we convert the inequality 3c into an equality by introducing a new decision vector $\boldsymbol{a}$ with dimensionality n (that is, one value for each material need), and write

$$\sum_{i=1}^{\ell} b_{ki} x_i = \beta_k + a_k^2. \tag{4}$$

We can now express the optimization problem using Lagrange multipliers λ and μ_k, and maximize the objective function

$$S(\boldsymbol{x}, \boldsymbol{a}, \lambda, \boldsymbol{\mu}) = \psi_r(\boldsymbol{x}) + \lambda \left(I_r - \sum_{i=1}^{\ell} p_i x_i \right) + \sum_{k=1}^{n} \mu_k \left(\beta_k - \sum_{i=1}^{\ell} b_{ki} x_i + a_k^2 \right). \tag{5}$$

This objective function yields the following first-order conditions.

$$\frac{\partial \psi_r}{\partial x_i} = \lambda p_i + \sum_{k=1}^{n} \mu_k b_{ki}, \tag{6a}$$

$$2a_k \mu_k = 0, \tag{6b}$$

$$I_r = \sum_{i=1}^{\ell} p_i x_i, \tag{6c}$$

$$\sum_{i=1}^{\ell} b_{ki} x_i = \beta_k + a_k^2. \tag{6d}$$

Combining Equations 6c and 6d, and recalling that $p_i = \sum_{k=1}^{n} \pi_k b_{ki} + q_i$, we can rewrite Equation 6c in a way that will be useful later,

$$I_r = \sum_{k=1}^{n} \pi_k \left(\beta_k + a_k^2\right) + \sum_{i=1}^{\ell} q_i x_i. \tag{7}$$

Equation 6b is typical of an inequality constraint. It says that either $a_k = 0$ or $\mu_k = 0$ for each material need k. If $a_k = 0$ then, from Equation 6d, the material need is exactly satisfied, so Equation 6b separates satiable basic material needs from non-satiable needs.

3.2. Satiable and non-satiable material needs

We consider two subsets of material satisfiers: the set of satiable material satisfiers, for which $a_k = 0$ and $\mu_k \neq 0$, and the set of non-satiable material satisfiers, for which $a_k \neq 0$ and $\mu_k = 0$. Suppose first that a good x_i does not provide any satiable material satisfiers, so that b_{ki} is zero for any k that represents a satiable satisfier. In that case, from Equation 6a,

$$\frac{\partial \psi_r}{\partial x_i} = \lambda p_i. \tag{8}$$

This is the same result as in the standard theory of individual demand: the marginal change in the preference function with respect to a change in consumption of good i is proportional to the price of i.

In the general case, good i could provide a mix of satiable and non-satiable material satisfiers, or no material satisfiers at all. To understand the implications of the general case we express p_i as $\sum_{k=1}^{n} \pi_k b_{ki} + q_i$. Out of the set of material satisfiers $k \in [1, n]$ we denote by S the subset of satiable satisfiers, so that the complement of S, $\bar{S}$ contains the non-satiable satisfiers. We then have

$$\frac{\partial \psi_r}{\partial x_i} = \lambda \left(q_i + \sum_{k \in S \cup \bar{S}} \pi_k b_{ki} \right) + \sum_{k \in S} \mu_k b_{ki}, \tag{9}$$

where the sum over the union $S \cup \bar{S}$ is equivalent to a sum over all the k from 1 to n. This equation has a rather challenging right-hand side, with unknown Lagrange multipliers λ and μ_k. While we do not know the values of these multipliers, we now show that the terms multiplied by the μ_k cancel against some of the terms multiplied by λ, so that in fact we are concerned with only a single Lagrange multiplier, λ.

To show this we use a result from standard optimization theory. If $\psi_r^*(I_r, \boldsymbol{\beta})$ is the solution to the optimization problem, then

$$\frac{\partial \psi_r^*}{\partial I_r} = \lambda, \tag{10a}$$

$$\frac{\partial \psi_r^*}{\partial \beta_k} = \mu_k. \tag{10b}$$

(This can be understood informally by studying the objective function, Equation 5.) From these equations, we have that

$$\lambda + \frac{\mu_k}{\pi_k} = \frac{\partial \psi_r^*}{\partial I_r} + \frac{1}{\pi_k}\frac{\partial \psi_r^*}{\partial \beta_k}. \tag{11}$$

However, because of the budget constraint (Equation 7), an increase in income I_r is exactly offset by an increase in the cost of meeting the minimum level of satisfaction of material need k, $\pi_k \beta_k$; that is, an *increase* in income has the same effect on expenditure for non-material needs as a *reduction* in the cost of meeting material needs. The right-hand side of this equation is therefore zero, and we have

$$\lambda + \frac{\mu_k}{\pi_k} = 0. \tag{12}$$

We now re-arrange the terms in Equation 9, and write it as

$$\frac{\partial \psi_r}{\partial x_i} = \lambda \left(q_i + \sum_{k \in \bar{S}} \pi_k b_{ki} \right) + \sum_{k \in S} \left(\lambda + \frac{\mu_k}{\pi_k} \right) \pi_k b_{ki}. \tag{13}$$

The final term we see, from Equation 12, to be zero, so we have

$$\frac{\partial \psi_r}{\partial x_i} = \lambda \left(q_i + \sum_{k \in \bar{S}} \pi_k b_{ki} \right) \tag{14a}$$

$$\equiv \lambda \bar{p}_i. \tag{14b}$$

We have now eliminated all of the terms multiplied by the μ_k. The resulting expression involves only prices, known coefficients, and the single Lagrange multiplier λ. The expression in parentheses in Equation 14a is a price, which we write in Equation 14b as $\bar{p}_i$. This "effective price" lies between the q_i and the p_i,

$$q_i \leq \bar{p}_i \leq p_i. \tag{15}$$

It is equal to p_i in the case that good i supplies no satiable goods, as we saw above; it equals q_i in the case that good i supplies only satiable goods; otherwise it lies between the two values.

Relating this to the standard individual consumption theory, we see from Equation 14b that the marginal rate of substitution between goods is, as usual, a ratio of prices, but here the relevant price is the effective price $\bar{p}_i$, rather than the market price p_i. Also as in the standard theory, non-poor consumers seek their preferred bundle of goods subject to a budget constraint. However, the relevant portion of their budget is their disposable income after taking into account expenditure for basic material needs; that is, $I_r - \sum_{k=1}^n \pi_k \beta_k$.

Although goods can satisfy a mix of satiable and insatiable needs, it is instructive to consider a "satiable good" that only satisfies satiable material needs and possibly some non-material needs, but no insatiable material needs. The effective price is then equal to q_i, which is the gap between the market price for the good p_i and the base price $\sum_{k=1}^n \pi_k b_{ki}$ of providing for material needs. In the case that such a good provides only satiable material needs, and no non-material needs, the market price is the base price, and $q_i = 0$. Consumers will switch away from such goods, if they have sufficient income, to goods which also satisfy non-material needs.

3.3. Aggregate demand

As noted above, the decision rule for poor consumers does not uniquely determine the choice of goods, but we showed that at each level of income $I_r \leq I_p(1)$, there is a specific bundle of material satisfiers $\boldsymbol{y}_p(I_r, \boldsymbol{\pi})$ and argued that there is likely to be a reasonably predictable bundle of goods $\boldsymbol{x}_p(I_r, \boldsymbol{\pi})$ that supplies those material satisfiers. For non-poor consumers, and for satiable goods, consumption saturates near the satisfaction level $\boldsymbol{\beta}$; for non-satiable goods consumption is determined by the individual effective preference functions of non-poor consumers $\psi_r(\boldsymbol{x})$.

For a satiable material need k we can construct an excess demand function that does not refer to specific goods at all. Denoting by m_p the number of poor consumers out of a total of m consumers, we can write the excess demand function for satiable material satisfier k, $\hat{\eta}_k(\boldsymbol{\pi})$, as

$$\hat{\eta}_k(\boldsymbol{\pi}) = \sum_{r=1}^{m_p} \left(y_{pk}(I_r, \boldsymbol{\pi}) - \tilde{\omega}_{rk}\right) + \sum_{r=m_p+1}^{m} \left(\beta_k - \tilde{\omega}_{rk}\right). \tag{16}$$

In this equation, $\tilde{\boldsymbol{\omega}}_r$ is consumer r's endowment in terms of material needs satisfiers rather than in terms of goods. Differentiating with respect to the base price π_j of material need j (and assuming the change is not so large that it moves people from the non-poor to the poor category or vice versa), we have, for fixed levels of endowments,

$$\frac{\partial \hat{\eta}_k}{\partial \pi_j} = \sum_{r=1}^{m_p} \left(\frac{\partial y_{pk}}{\partial I_r} \frac{\partial I_r}{\partial \pi_j} + \frac{\partial y_{pk}}{\partial \pi_j} \right). \tag{17}$$

The change in income with a change in price of a good (or material needs satisfier) is equal to the endowment in that good: $\partial I_r/\partial\pi_j = \tilde{\omega}_{rj}$, so we can write the equation above as

$$\frac{\partial\hat{\eta}_k}{\partial\pi_j} = \sum_{r=1}^{m_p}\left(\frac{\partial y_{pk}}{\partial I_r}\tilde{\omega}_{rj} + \frac{\partial y_{pk}}{\partial\pi_j}\right). \tag{18}$$

We expect the second term in the parenthesis to always be negative: other things being equal, an increase in the price of any material needs satisfier reduces consumption of all material needs satisfiers amongst the poor, while among the non-poor, consumption of satiable material needs satisfiers is insensitive to a change in price.

The first term in parenthesis in Equation 18 might be positive or negative, depending on whether the poor are endowed with enough of the material needs satisfier that the addition to their income offsets the rise in price. The result for an individual consumer is indeterminate and, indeed, this illustrates a classic problem in development economics—does a rise in price of basic foodstuffs increase or decrease poverty, when poor farmers make their living in part by selling the food? In one recent survey, Ivanic and Martin (2008) find that both increases and decreases in poverty occur after a rise in food prices, but that poverty increases are more common. At an aggregate level the net result for the own-price response (that is, when $j = k$) must be negative; if it were not, then poor consumers could become rich by selling each other an identical type of good. Cross-price effects remain indeterminate, as an increase in, say, food prices may allow a majority of poor households to increase their energy consumptio;, but overall we expect that the sector encompassing satiable basic material needs to have relatively stable prices.

For a good i that supplies non-satiable material needs or non-material needs, consumption by the poor is equal to $x_{pi}(I_r, \tilde{\boldsymbol{\omega}}_r)$. For non-poor consumers, the consumption decision is, as we have shown above, exactly the same as in standard consumption theory, but with reduced income $I'_r \equiv I_r - \sum_{k=1}^{n}\pi_k\beta_k$ and effective prices $\bar{\boldsymbol{p}}$. Thus, from the SMD-KK theorem, aggregate demand for non-poor consumers can be almost any function $\hat{\boldsymbol{h}}_{\mathrm{NP}}(\bar{\boldsymbol{p}}, I'_r)$. We therefore write

$$\hat{h}_i(\boldsymbol{p}) = \sum_{r=1}^{m_p}\left(x_{pi}(I_r, \boldsymbol{\omega}_r) - \omega_{ri}\right) + \hat{h}_{\mathrm{NP,i}}(\bar{\boldsymbol{p}}, I'_r). \tag{19}$$

For these goods, as the SMD-KK theorem applies to consumption by the non-poor, the stability of prices depends on how many poor consumers there are compared to the total population and the disposable income of non-poor consumers.

While we remind the reader that Jackson and Marks (1999) found that even in the UK consumption to meet material needs appears to command a large fraction of household budgets, we consider as a hypothetical case the limit of very high levels of income such that the number of poor is small, the purchasing power of the non-poor is large, and $\hat{h}_i(\boldsymbol{p}) \approx \hat{h}_{\mathrm{NP,i}}(\boldsymbol{p}, I'_r)$. In this regime the

SMD-KK theorem holds true for most consumption, and the micro-level theory places few constraints on aggregate consumption. At lower levels of income, the number of poor is large and the purchasing power of the non-poor is constrained by their need to meet basic material needs. In that limit we can expect some variability in price, since the SMD-KK theorem applies to the excess demand of the non-poor, $\hat{\boldsymbol{h}}_{\mathrm{NP}}(\boldsymbol{p}, I'_r)$, but much of household budgets is directed toward satisfying material needs.

4. Stability

While our main purpose was to concretely demonstrate that a needs-based theory at individual level leads to a different outcome than the SMD-KK theorem predicts, we further argued that some prices are likely to be relatively stable. Specifically, there is a stable set of base prices for the satisfiers of satiable material needs and, if material needs make up much of household budgets, there is little additional purchasing power in the less stable sector that supplies non-material needs. We suggest that this economy is roughly characterized by a "base" set of goods with reasonably stable prices surmounted by a "froth" of goods meeting diverse and possibly changing individual non-material needs.

It might be objected that this picture is inconsistent with the empirical facts of instability in food, housing, and energy prices. Indeed, in a study of the thirty-six components of the US consumer price index (CPI) from 1967 to 1997, Clark (2001) provides a table in which the least volatile third of CPI components includes such non-basic consumer categories as personal care services; food away from home; and entertainment services and commodities. More basic needs categories, such as men's and boys' apparel and medical care also appear, but they make up a small portion of the whole. In contrast, the most volatile third contains such items as fuel oil; meats, poultry, fish, and eggs; fruits and vegetables; infants' and toddlers' apparel; and "other food" at home. However, the implications of the theory are more nuanced than this, and require some discussion.

In the theory presented in this paper only the base prices π_k for each material need are expected to be relatively stable, and they are stable only with respect to prices of goods that satisfy the same material need. A given sector (e.g., food, energy, and housing) might be more or less volatile on the whole, a dynamic that we did not include in our analysis. To understand why this is so, note that we have adopted the standard approach to constructing excess demand functions, which treats the entire economy as an exchange economy in which consumers hold "endowments" that they can sell. While this clearly oversimplifies most aspects of a modern economy, it is a reasonable representation of household farm production. Annual (or seasonal) endowments from farms consist in the foods they produce as a flow from their stocks of land, and that flow is both highly variable and correlated across many households. As a consequence, from year to year there will be differences in the aggregate endowments and hence in the price; but we did not consider this inter-annual fluctuation in supply in our discussion of price stability. The cost of "shelter" (the CPI category) is influenced both by the demand for shelter in itself (corresponding to a flow of benefits) and also the demand for real estate as a household investment (the stock that generates the benefits); normally the prices are linked, but the real estate market is subject to booms and busts (Shiller, 2007). Energy price volatility is affected by multiple factors, including expectations of future supply (Pindyck, 2004) and prices of commodities are more volatile than those of manufactures (Jacks et al., 2010). The simple exchange economy model that is standard when studying aggregate demand does not easily accommodate these dynamics, which involve stocks, futures markets, and industrial production.

We therefore turn to less aggregate CPI commodity groupings, as studied by Clem (1985). He calculated a volatility index for different commodities in the US CPI as the standard deviation of monthly price changes from 1975 to 1984. As expected, food prices are more volatile than other prices, with a volatility index of 3.5, compared to an average of 1.7 for all finished goods. However, of the 15 commodity groups within the category "finished consumer foods", the least volatile third included, from least to most volatile: bakery products (0.6); dairy products (0.8); processed fruits and vegetables (0.9); other cereals (1.0); and soft drinks (1.0). The most volatile third included: pork (4.4); processed poultry (4.8); fresh fruits (6.3); eggs (7.0); and fresh and dried vegetables (9.1). Price indices for other meats are only slightly less volatile than that of pork. Thus the least volatile foods are, for the most part, the most basic, and their prices are considerably less volatile than those of more readily substituted foods such as meats, eggs, and fresh fruits and vegetables. Considering energy, prices of natural gas, fuel oil, and gasoline were relatively volatile, with indices ranging from 2.6-3.7. While energy price volatility is not unusual for commodities, it is high for consumer goods, and so it stands out (Regnier, 2007). Excluding both energy and food from the category of finished consumer goods, Clem's list contains 21 commodity groups. The least volatile third includes: apparel (0.4); household appliances (0.4); household furniture (0.4); alcoholic beverages (0.5); over-the-counter drugs (0.5); prescription drugs (0.5); and sporting and athletic goods (0.6). The most volatile third includes: sanitary papers, etc. (0.8); home electronic equipment (0.9); tires and tubes (1.1); cosmetics, etc. (1.3); small arms and ammunition (1.4); tobacco products (2.1); and platinum and karat gold jewelry (5.7). While mixed, there is a clear tendency for more basic and necessary goods to have more stable prices.

Tentatively accepting our proposed division between a "base" and a "froth" in the economy, we note that there are other possible sources of universal and reasonably determinate structures for demands that could expand the base. For example, households must engage in activities to either build up or maintain their capitals—social, human, physical, natural, and financial—and those activities fall into stable patterns—group memberships and social outings; education and apprenticeships; buying a house, motorbike, or car; planting and building up soil; and saving. Also, some "premium" payments over basic needs—captured by the vector $\boldsymbol{q}$ in the model—may be quite constrained, as when a relatively affluent family buys a house in a safe neighborhood with access to good schools for which their monthly payments consumes much of their budget. Consumption patterns are also stabilized through habit (Nelson and Consoli, 2010; Loasby, 2001), and could also be stabilized through heterogeneous networks of interacting agents (Kirman, 1992).

5. Conclusion

Starting from a micro-level needs-based theory of individual demand, we showed that the aggregate excess demand function is not arbitrary. We have therefore shown that there exists a micro-level theory that does not yield the results predicted by the SMD-KK theorem. This was anticipated by Chipman (2006), who pointed out that consumer demand theory constrains the forms of individual demand functions and suggested that if individual preference functions were not arbitrary then the SMD-KK might not hold. We avoided the implications of the SMD-KK theorem by positing that some consumer preferences—those derived from basic needs—are universal and reasonably determinate. We also posited that some of them are satiable. The micro-level theory in this paper therefore differs from the standard theory that underlies the SMD-KK result and the theory of general equilibrium (Ginsburgh and Keyzer, 2002), but is similar to other needs-based theories of individual consumption (e.g., Seeley, 1992; Stigler and Becker, 1977).

Whether basic needs are or are not necessary in the individual-level theory of demand, we argue that they are necessary to understand aggregate demand. The aggregation problem arises because the micro-level theory, through successive waves of abstraction, has produced a lean theory but without the population-wide commonalities that make aggregation possible. There is a long history of economic thought on hierarchical patterns of consumption (Drakopoulos and Karayiannis, 2004), and continuing interest in other fields, that can be brought to bear. Alfred Marshall helped to remove basic needs from mathematical consumption theory, but also developed a reasonably coherent hierarchical picture of needs that is not very different from contemporary models (Haines, 1982). Perhaps it is time to reunite Marshall's efforts, and bring human needs back into the theory of consumption.

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