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A REVEALED PREFERENCE APPROACH TO MEASURING HUNGER AND UNDERNUTRITION

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ABSTRACT

Caloric intake and minimum calorie thresholds are widely used in developing countries to assess hunger and nutrition, and to construct poverty lines. However, it is generally recognized that the sufficiency of an individual's caloric intake cannot be determined, due to: a lack of consensus on the true thresholds; the fact that any such thresholds are individual-varying and unobservable; imperfect nutrient absorption; and the weak and non-monotonic empirical relationship between calories and wealth. We propose a revealed preference approach to measuring hunger and undernutrition that overcomes these challenges. Low caloric intake is associated with a large utility penalty (e.g., physical discomfort). The corresponding high marginal utility of calories causes a utility-maximizing consumer to primarily consume the cheapest available source of calories (a staple). Once they have surpassed subsistence, the marginal utility of calories declines significantly and they substitute towards foods with higher levels of non-nutritional attributes (e.g., taste). Thus, though any individual's requirements are unobserved, their choice to switch away from the staple reveals they are above that requirement. Accordingly, the percent of calories obtained from the staple can be used to indicate nutritional sufficiency. We also provide an application for China that shows the desirable empirical properties of this approach.

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I. INTRODUCTION

Caloric intake and minimum calorie thresholds are widely used in assessing well-being, hunger and undernutrition in developing countries. For example, many governments and international organizations directly track the fraction of a population meeting recommended calorie thresholds. Similarly, the United Nation's first Millennium Development Goal includes halving hunger, defined as the proportion of individuals falling below a calorie threshold. Additionally, most developing countries explicitly define their poverty lines as the level of income or expenditure at which households on average achieve a minimum calorie threshold (see Ravallion 1992a, 1994 and Deaton 1997, 2006). Overall, a considerable amount of attention, effort and resources are devoted to assessing and addressing the problem of low caloric intake. This is a natural priority in countries where deprivation is great and where there may even be relatively recent histories of famine.

While energy intake is certainly an important component of nutrition, there are several significant problems in using it to assess hunger or undernourishment. First, despite considerable research effort, there is no consensus at all on what the correct minimum or subsistence calorie threshold is, how it should be computed, or even whether such a threshold exists (see Dasgupta 1995 and Svedberg 2000 for summaries). Second, any required or recommended threshold would vary considerably across individuals (and for the same individual over time), and depend on a range of characteristics such as age, sex, height, weight, health status, level of physical activity, lean and muscle body mass, fitness level, stress levels and basal metabolic rate. The fact that many of these characteristics are unobservable or too difficult to measure in practice adds to the challenge in creating and applying such thresholds.[1] As Svedberg (2000, p. 24) writes, "It is universally agreed that standardized calorie norms cannot be used to identify undernutrition in the individual person … ."

A third problem for assessing nutrition via caloric intake is that not all nutrients consumed are absorbed before leaving the body. This problem is particularly pronounced in poor countries where health is poor and there is a high incidence of diseases such as diarrhea that can impair nutrient absorption. And even in the absence of disease, the efficiency of absorption will vary considerably across individuals based on both observable and

[1] Ravallion (1992b) attempts to deal with the problem of unobserved, varying requirements by using statistical dominance tests of distributions. However, this does not solve the problem of setting a threshold.

unobservable characteristics. This makes it even more difficult to assess whether an individual has attained their minimum threshold; they might appear to be consuming far more than their "true" need, but absorbing only a fraction of that amount.[2]

Overall, given that energy need and absorption vary considerably across individuals and for a given individual over time, including in unobservable ways, and given the lack of consensus over whether threshold needs exist or can be measured, it is extremely difficult to assess sufficiency by means of comparing caloric intake to a required threshold.[3]

A final challenge to calorie-based indicators of well-being is raised by the large literature estimating the income elasticity of demand for calories (Strauss and Thomas 1995, Deaton 1997). As incomes rise, households often choose to substitute towards foods with higher non-nutritional attributes (e.g., taste), rather than emphasizing additional calories, even at low levels of wealth or nutritional status (though elasticity estimates vary considerably across studies). Such behavior reveals that consumers' desire to increase calories is often weaker than their desire to improve other aspects of their meals. Further, our previous work shows that highly impoverished households in China responded to price subsidies on staple foods such as rice and wheat by substituting *away* from these cheap sources of calories (Jensen and Miller 2011). Thus, even with a policy where the substitution effect should have further encouraged greater caloric intake, we found no evidence that calories increased, and may have actually declined. This is all the more striking given that individuals were originally consuming on average 20−40 percent fewer calories than the recommended level. Finally, recent evidence from both China and India indicates that despite decades of significant economic growth, average caloric intake has actually decreased and the fraction officially undernourished has increased (Deaton and Drèze 2008, Zhai et al. 2007, Meng et al. 2008). These results further call into question whether the recommended calorie thresholds are relevant and whether calories can provide the basis for a meaningful indicator of nutrition or welfare.

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[2] This also adds to the problem of establishing minimum nutritional thresholds, since it will not be possible to relate true nutrient absorption to any outcome appropriate for setting such thresholds (such as health).

[3] While one might then suggest that a threshold is not needed and that gains in nutrition simply be measured through net or average changes in caloric intake (either for individuals or at the aggregate level), cut-offs are needed to actually define and measure undernutrition or hunger, and to construct poverty lines. Net gains in calories for an individual or average gains for a population tell us nothing about changes at the bottom of the distribution, or whether someone has moved beyond their minimum needs. Further, without a threshold, it is not possible to assess undernourishment at the individual level, which is needed for example to examine patterns or covariates of hunger or undernutrition. Finally, thresholds are widely used in practice for communicating levels and trends of nutritional status and for evaluating programs.

In this paper, we propose a new measure of nutritional sufficiency or hunger based on consumer behavior and revealed preferences, without the need for minimum calorie thresholds. The core of our approach derives from the fact that when a person is below their calorie or subsistence threshold (or subsistence range, since there may be no true, single threshold), this imposes a significant disutility, including the familiar physical sensations of hunger, headaches, pain, dizziness, loss of energy, inability to concentrate, etc., that goes away after the threshold is met. These adverse sensations have a physiological and biochemical basis that are directly determined by the level of nutrients in the body.[4] Because the marginal utility of additional calories is so high when calorie-deprived, a utility-maximizing consumer who cannot afford to meet their caloric needs will largely choose foods that are the cheapest available source of calories, typically a staple like cassava, rice or wheat, in order to minimize the disutility of hunger. However, if their income increases to the point where they are able to relieve their hunger, the marginal utility of calories declines significantly and they will begin to substitute towards foods that are more expensive sources of calories but that have higher levels of non-nutritional attributes such as taste or variety. Thus, while the subsistence threshold or range is individual-varying and unobservable, the consumer's choice to switch away from the cheapest source of calories reveals that their marginal utility of calories is low, and that they have surpassed subsistence.[5] In this setting, the percent of calories consumed from the staple food source, or the staple calorie share (SCS), can be used as an indicator for nutritional sufficiency.

SCS offers several advantages over calories in assessing nutritional sufficiency. First, as noted, it avoids the problem of individual-specific and unobserved subsistence thresholds, since a consumer's food choice will reveal when they have attained sufficiency. Second, it accounts for imperfect absorption, since the biochemical basis and physical sensation of hunger is regulated by available nutrient levels, which is determined by absorption, not consumption. Thus, a person consuming more calories than needed but absorbing fewer than needed will still act (in terms of food consumption patterns) as though they are calorie deprived. SCS also has the appeal of being consistent with revealed consumer preferences and behavior and therefore has intuitive public policy appeal. Caring about increasing caloric intake only to the extent that consumers do (or to the extent that the marginal utility of calories is high) is arguably all a

[4] In particular, the liver and the lateral hypothalmus are responsible for the sensation of hunger and satiation.
[5] In fact, a high marginal utility of calories might be the most appropriate definition of hunger.

policy-maker should do, and potentially all they can do (since the literature shows that consumers with a low marginal utility of calories may not increase caloric intake even when encouraged to do so via price subsidies). This also switches the emphasis from calories, which consumers do not maximize, to utility, which presumably they do. This is not only arguably a better public policy goal in general, but even more appropriate given the difficulty in assessing how many calories people really need. Relying on a consumer's behavior provides a better indicator of how highly they value additional calories.

In addition to its basis in consumer behavior, we also show that in practice, for a given set of food choices and prices, it is possible to compute an SCS "threshold" that identifies when an individual has moved beyond their region of high marginal utility of calories. The approach uses a version of the minimum cost diet problem that closely approximates actual consumption behavior among the poor, and that also takes into consideration protein needs that are as relevant for health and the sensation of hunger as calories (Svedberg 2000). And significantly, the threshold is very stable with respect to the factors that affect the level of caloric need (age, height, weight, activity level, etc.), i.e., it is relatively "need neutral" compared to calories. In essence, though a person who is younger, taller, heavier, more active, etc., may need twice as much calories and protein as someone who is older, smaller, lighter and sedentary, calorie and protein needs grow nearly proportionately. So the combination of foods that will achieve those needs at minimum cost is largely invariant to scale. Thus, a very tight range of SCS values can serve to identify hunger across all individuals, regardless of their attributes.

Finally, we explore SCS patterns using household-level data from China. The data reveal a clear, sharp threshold for SCS in wealth as predicted by our model. This threshold also corresponds closely to that predicted by our diet minimization problem. Using this threshold yields an estimate of undernourishment or hunger that is half of that estimated by the traditional method using a minimum calorie threshold. The clear SCS threshold can also be used to construct a poverty line for China, just as is currently done using calories. We also show that SCS provides a better nutrition-based indicator of recent welfare improvements in China than calories; SCS shows clear improvements over a 10 year period of high economic growth, while the level of calories declined and the percent below the recommended threshold increased.

Although it has numerous advantages, SCS will suffer from some of the same problems that plague other nutrition-based indicators such as calories, such as ignoring other nutrients, or whether the body adjusts to long term deprivation. Two other limitations of SCS are that it is less sensitive to the depth of deprivation than calorie-based indicators, and that it relies on the assumption that households follow minimum cost diets when they are at very low levels of wealth. Despite these concerns, SCS provides numerous advantages and can serve as a useful, complementary indicator of hunger and/or well-being alongside calories.

The remainder of this paper proceeds as follows. In section II, we provide a simple model of consumption that motivates the use of SCS as a measure of nutritional sufficiency, and discuss strengths and weaknesses of SCS. Section III provides an application of SCS using data from China, and Section IV concludes.

II. THEORETICAL BACKGROUND

II.A. Model

In this section, we briefly develop a theoretical model of how SCS might be expected to vary with wealth, especially as the consumer's wealth decreases to a point where it is difficult to maintain subsistence consumption. This model helps motivate how SCS can help detect the subsistence threshold or range.

One approach to this problem would be to model consumers as facing both a budget constraint and a subsistence constraint, i.e., requiring the caloric content of the bundle of goods the consumer chooses to be above a certain threshold. However, subsistence requirements are not physical constraints. Consumers can, and indeed do, choose consumption bundles that do not meet their subsistence needs. The reason why consumers do not choose such points when bundles that meet their needs are affordable is because of the adverse consequences of choosing a bundle that does not meet subsistence needs. Because of this, we adopt the approach of modeling consumers as if they face a utility penalty for letting caloric intake[6] drop below subsistence, where the size of the penalty increases as caloric intake drops.

Specifically, we consider a consumer with a utility function over goods x_1 and x_2 of the following form:

$$v(x_1, x_2) = u(x_1, x_2) - f(c_1 x_1 + c_2 x_2 - s),$$

[6] When computing SCS thresholds later, we add protein intake as an additional factor affecting utility, consistent with the emphasis in the nutrition literature on both calories and protein as the two most important nutrients.

where x_1 and x_2 represent quantities of two goods, c_1 and c_2 represent the caloric content of a unit of x_1 or x_2, respectively, and s is a constant that captures subsistence calories. The utility function $u(x_1,x_2)$ is an ordinary utility function. To facilitate the analysis, we will assume that $u(\cdot)$ is homothetic. Among other things, this implies that the marginal rate of substitution between goods x_1 and x_2 depends only on their ratio, x_1/x_2. In other words, we assume that, to the extent that the consumer varies the proportion of the two goods as his wealth changes, this is driven entirely by subsistence concerns.

Function $f(\cdot)$ represents a penalty function. We assume that $f(\cdot)$ is decreasing and convex. Letting $z = c_1x_1 + c_2x_2 - s$, we further assume that $f'(z)$ increases to zero as z increases above zero and decreases to negative infinity as z decreases below zero. Thus, for example, $f(\cdot)$ could be a shifted hyperbolic curve. Figure 1 sketches a typical curve, $f(\cdot)$.

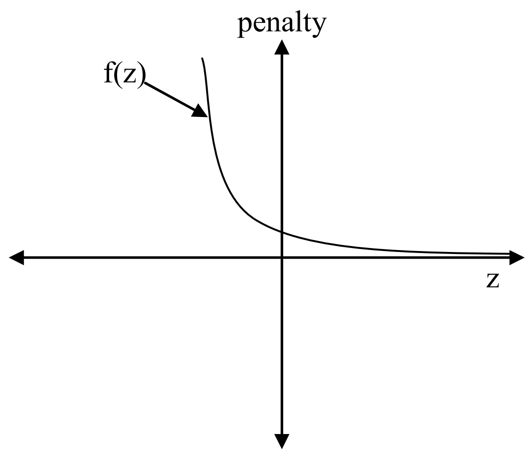

FIGURE 1. THE PENALTY FUNCTION

When the consumer is sufficiently wealthy, $f'(z)$ will approach zero, and so the consumer behaves approximately as if he maximizes $u(x)$ subject to the budget constraint. However, when wealth is so low that the consumer cannot easily afford a bundle with $z > 0$, the penalty function becomes important. A sufficiently impoverished consumer will behave approximately as if he maximizes calories subject to the budget constraint. For intermediate wealth levels, the consumer will blend these two polar cases.

Let good 1 be the staple good. The defining characteristic of the staple is that it is the cheaper source of calories available to the consumer. Hence we assume:

(A1) Good 1 is the staple, $c_1/p_1 > c_2/p_2$.

where p_1 and p_2 are the prices of the two goods. Denoting the consumer's exogenous wealth as w, formally the consumer chooses x_1 and x_2 to solve:

$$\max_{x_1,x_2\geq 0} u(x_1,x_2) - f(c\cdot x - s)$$
$$s.t.\ p\cdot x \leq w$$

Assuming an interior solution, the first-order conditions for the problem are given by:

$$u_i(x_1^*,x_2^*) - c_i f'(c\cdot x^* - s) - \lambda^* p_1 = 0,$$

where λ is the Lagrange multiplier on the budget constraint, $u_i(x)$ denotes the partial derivative with respect to x_i, and asterisks denote optimized values of the variables. Combining the first-order conditions for goods 1 and 2 gives:

$$\frac{u_1(x^*) - c_1 f'(c\cdot x^* - s)}{u_2(x^*) - c_2 f'(c\cdot x^* - s)} = \frac{p_1}{p_2}, \tag{1}$$

the standard condition equating the marginal rate of substitution between the goods with the ratio of their prices.[7] Further rearranging this equation gives:

$$\frac{u_1(x^*)}{u_2(x^*)} = \frac{p_1}{p_2} - \left[\frac{c_2}{p_2} - \frac{c_1}{p_1}\right] f'(c\cdot x^* - s). \tag{2}$$

In the standard problem (without subsistence concerns represented by $f(\cdot)$), the consumer's optimal bundle solves:

$$\frac{u_1(x^{NS})}{u_2(x^{NS})} = \frac{p_1}{p_2}, \tag{3}$$

where "NS" denotes that these values are optimal when there are no subsistence concerns. Hence the additional term on the right-hand side of (2) captures the impact of subsistence concerns. When caloric intake is below s, $f'(cx^* - s)$ is large and negative. Since $(c_2/p_2 - c_1/p_1) < 0$, equation (2) implies that:

$$\frac{u_1(x^*)}{u_2(x^*)} < \frac{p_1}{p_2}$$

[7] Note that as caloric intake declines, the left-hand side of (1) approaches c_1/c_2, which is greater than p_1/p_2 by assumption (A1). Thus, a sufficiently impoverished consumer will be driven toward the corner solution where $x_1 > 0$ and $x_2 = 0$. The remainder of the analysis extends this basic point.

The assumption of homotheticity implies that $u_1(x)$ / $u_2(x)$ is constant along rays from the origin, and $u_1(x)$ / $u_2(x)$ declines as x_1/x_2 decreases. Hence if

$$\frac{u_1\left(x^*\right)}{u_2\left(x^*\right)} < \frac{p_1}{p_2} = \frac{u_1\left(x^{NS}\right)}{u_2\left(x^{NS}\right)}, \tag{4}$$

then $x_1^*/ x_2^* > x_1^{NS}/ x_2^{NS}$. And, when there are only two goods, the share of calories from good 1 increases as x_1/ x_2 increases. Hence, subsistence concerns increase the staple calorie share**.**

Equation (4) establishes that the presence of subsistence concerns increase the staple calorie share. In the absence of subsistence concerns, the consumer's optimal bundle solves (3), which, slightly rearranged, gives

$$\frac{u_1\left(x^{NS}\right)}{p_1} = \frac{u_2\left(x^{NS}\right)}{p_2}.$$

The consumer sets the marginal utility of spending another dollar equal across the goods. In the presence of subsistence concerns, this becomes:

$$\frac{u_1\left(x^*\right) - c_1 f'\left(c \cdot x^* - s\right)}{p_1} = \frac{u_2\left(x^*\right) - c_2 f'\left(c \cdot x^* - s\right)}{p_2}$$

Now, the effect on total utility of spending another dollar on good i consists of the usual marginal utility, $u_i(x)$ /p_i, and the marginal reduction in the penalty per dollar, $- c_i f'(cx^* - s) / p_i$. Since $c_1/p_1 > c_2/p_2$, increasing expenditure on good 1 reduces the penalty more than increasing expenditure on good 2. Hence, introducing subsistence concerns causes the consumer to increase expenditure on good 1 relative to good 2, which, in turn, increases the staple calorie share.

The preceding analysis shows that the consumer's staple calorie share is greater when there are subsistence concerns than when there are not. This result can be extended to show that the SCS of the consumer's optimal bundle increases as his wealth decreases. The intuition is that the poorer the consumer gets, the more pressing the subsistence concerns become. And, as subsistence concerns become more salient, the consumer rebalances his optimal bundle to contain relatively more of the staple good. Letting SCS(w) = $c_1x_1(w)$ / $cx(w)$, where $x(w)$ = ($x_1(w)$, $x_2(w)$) denote the solution to the consumer's problem when wealth is w, the following proposition formalizes this intuition:

Proposition**:** *SCS(w) decreases in w.*

Proof: Since $u(x)$ is homogenous, let $r(w) = x_1(w)/x_2(w)$, and $g(r) = u_1(x(w))/u_2(x(w))$. Homogeneity of $u(x)$ implies that $g(r)$ is decreasing in r. That is, as x_1/x_2 increases, u_1/u_2 decreases. The consumer's budget constraint is:

$$p_1 x_1 + p_2 x_2 = w,$$

which, in terms of $r = x_1/x_2$ and x_1 is:

$$x_1 = \frac{w}{p_1 + p_2 r}.$$

In terms of r and x_1, (2) becomes:

$$g(r) = \frac{p_1}{p_2} - \left[\frac{c_2}{p_2} - \frac{c_1}{p_1}\right] f'\left(x_1\left(c_1 + c_2 r\right) - s\right),$$

and eliminating x_1 yields:

$$g(r) = \frac{p_1}{p_2} - \left[\frac{c_2}{p_2} - \frac{c_1}{p_1}\right] f'\left(\frac{w\left(c_1 + c_2 r\right)}{p_1 + p_2 r} - s\right).$$

Noting that r is a function of w, differentiating with respect to w and solving for $r'(w)$ yields:

$$r'(w) = \frac{-\left(\frac{c_2}{p_2} - \frac{c_1}{p_1}\right)\left(\frac{c_1 + c_2 r}{p_1 + p_2 r}\right) f''\left(\frac{w\left(c_1 + c_2 r\right)}{p_1 + p_2 r} - s\right)}{g'(r) + \left(\frac{c_2}{p_2} - \frac{c_1}{p_1}\right)\left(\frac{w}{p_1 + p_2 r}\right)\left(\frac{c_1}{r}\right) f''\left(\frac{w\left(c_1 + c_2 r\right)}{p_1 + p_2 r} - s\right)} < 0. \quad (5)$$

That $r'(w)$ is negative follows from the numerator of (5) being positive and the denominator being negative.

Since $r'(w) < 0$, the ratio of x_1 to x_2 increases as wealth decreases. Staple calorie share is

$$SCS = \frac{c_1 x_1}{c_1 x_1 + c_2 x_2} = \frac{1}{1 + \frac{c_2}{c_1}\left(\frac{1}{r}\right)},$$

and the latter expression clearly decreases in r. Hence SCS is decreasing in wealth. ■

Thus, when consumers face subsistence concerns, the share of calories they receive from the staple good increases as their poverty increases (i.e., w decreases). Figure 2 depicts a typical Engel curve for this consumer. When wealth is high, the ratio of the consumer's demand for the two goods, x_1^*/x_2^*, approaches x_1^{NS}/x_2^{NS}, the ratio of the goods the consumer would choose if he did not face subsistence concerns. As wealth decreases and the consumer's budget constraint shrinks toward the subsistence-calorie level, x_1^*/x_2^* decreases even further. As subsistence concerns become extremely important, the consumer shifts his demand almost entirely to the staple good, x_1.

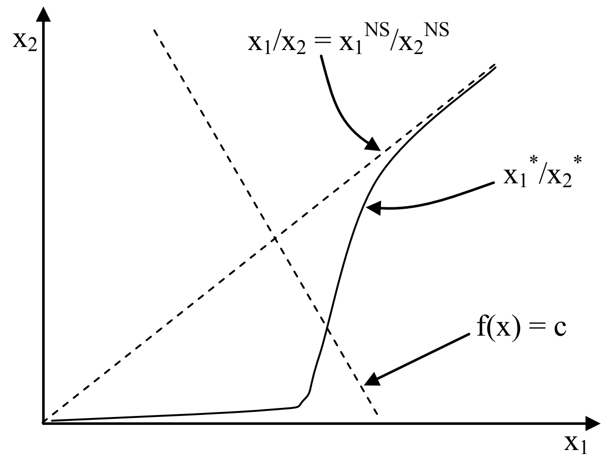

FIGURE 2: CONSUMPTION CHOICE AS A FUNCTION OF WEALTH

Figure 3 plots the staple calorie share (SCS) associated with preferences such as have been discussed. Again, at high levels of wealth, SCS is relatively stable. As wealth decreases toward the point where it is just possible to attain subsistence calories (labeled *w**), SCS increases rapidly. When wealth is well below *w**, SCS is once again stable, only at a high level. This level may be quite close to one, if consumers try to maximize caloric intake even though they cannot obtain subsistence. However, it may continue to be less than one due to, for example, cooking technology (e.g., even if the household eats only bread, bread requires a small amount of oil or other fat in addition to wheat), or, as we argue below, the need for complete proteins.

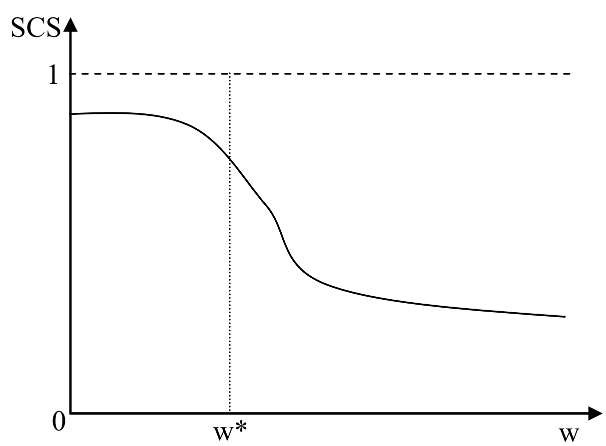

FIGURE 3: STAPLE CALORIE SHARE AND WEALTH

Thus, we view getting a higher percentage of calories from the staple than the SCS threshold as indicating a household is still in the region of rapidly increasing marginal utility of calories, i.e., a likely indication they are below subsistence. Below, we will provide an application to China with two methods for determining the SCS threshold.

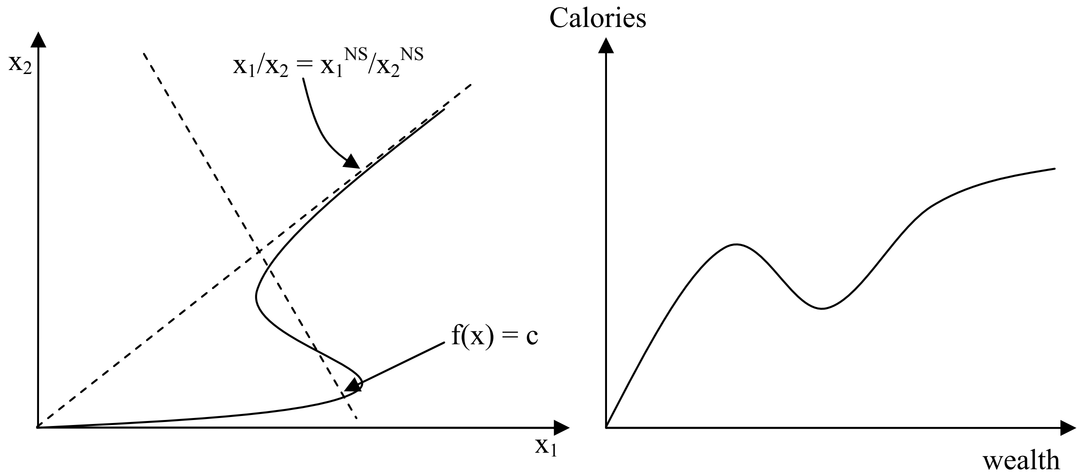

FIGURE 4: CALORIES NEED NOT VARY MONOTOICALLY WITH WEALTH

Figure 3 illustrates that SCS varies monotonically with wealth. While, as illustrated, calories would also vary monotonically with wealth, this need not be the case. Figure 4 illustrates a case consistent with data from our study of nutritional intake among poor consumers in China (Jensen and Miller 2011). In the study, we found that as consumers passed from nutritionally deprived to nutritionally stable, there was a range of prices over which they actually decreased caloric intake, as their increased purchasing power allowed them to substitute from rice toward more expensive, taste-preferred foods like meat. This pattern, driven by the fact that rice was an inferior good and meat a normal one, implies an Engel curve such as the one in the left panel of Figure 4. The implied relationship between calories and wealth is depicted in the right panel. Notice that caloric intake falls as consumers pass from consuming fewer than *c* calories to more. Further, although calories consumed decreases over this range, SCS, given by the slope of the ray from the origin to the Engel curve, increases monotonically over the entire range.

II.B. Additional Points About SCS

We note that the household staple budget share (SBS) offers a potential alternative to SCS. The primary advantage of SBS is the ease of data collection, requiring only expenditure data, commonly collected as part of most household surveys, rather than a food intake diary, as is required for SCS. However, SCS offers several advantages. First, food purchased will not be the amount of food consumed if meals are provided by an employer (as is common for workers in poor countries) or eaten away from home (e.g., visiting friends or relatives, eating at a restaurant or food stall) or if purchased food is provided to others (e.g., meals provided to visitors or relatives). Measuring food eaten would then require significantly more detailed data than is commonly measured in expenditure surveys. SBS would also require detailed price data in order to value those foods eaten but not purchased as above, as well as food they have grown themselves, which is likely to be substantial in rural areas. Finally, while SBS can provide an assessment of household welfare, SCS can be assessed at the individual level. Well-being may not be equally distributed across household members, and the intrahousehold allocation of resources is of considerable academic and policy interest (see Strauss and Thomas 1995).

We also note that while our method in essence focuses on when the consumer begins to substitute away from the cheapest available source of calories, we would not just want to look at when they begin to eat (or purchase) a particular food such as meat. First, using SCS means that we don't need to define the food that consumers substitute toward. This is an advantage because such foods are likely to vary across individuals due to tastes, dietary restrictions (e.g., vegetarianism) or prices. In addition, focusing on SCS allows for the possibility that there are multiple potential foods an individual may substitute toward. Second, as noted above, some non-staple good consumption is needed even for the very poorest households, because it may be required as part of cooking technology or to get protein, which will also cause clear disutility if not consumed (protein and calories are the two most important nutrients (Svedberg 2000); while other nutrients are important for aspects of long-term health, they do not create the clear utility penalties of calories and protein). Therefore, the SCS threshold will not be at going from zero to positive consumption of the other good. Finally, SCS in effect normalizes by need; once we recognize that some alternative food is needed even for those below subsistence calories, the fact that different people have different requirements means we run into the same problems establishing what meets minimum need. While, say, 40 grams of cooking oil may be needed to prepare enough bread to provide enough calories for a young, active man, an older, sedentary woman might only need 10 grams of oil. Using the calorie share, rather than an absolute amount, will normalize for individual variation in total need (see Section III.A below).

II.C. Potential Challenges to Using SCS to Measure Subsistence

There are a number of concerns with the use of SCS as a measure of subsistence or hunger, some of which apply equally to calories. For example, SCS ignores other key nutrients such as vitamins and minerals.[8] And computing SCS requires food intake diaries, which is typically not collected as part of standard income and expenditure surveys.[9]

An additional concern is whether the body "adapts" to low nutrition levels. The Adjustment and Adaptation Paradigm (AAP) argues that individuals can reduce energy needs through physiological mechanisms such as increasing metabolic efficiency and reducing thermogenesis, without impairing function (Sukhatme and Margen 1982, Svedberg 2000). For example, if a person's calorie requirement is 2,000 calories, a prolonged period of consuming only 1,800 calories may cause adjustments such that they now only require 1,800. If so, they may start to substitute away from the staple at 1,800 calories, even though they are still malnourished relative to their "true" calorie requirement. However, there are four important points to be made. First, the literature is very unsettled on whether such adjustment takes place (see Dasgupta 1995 and Svedberg 2000). Second, what is key from our perspective is whether such adjustments affect at what point the marginal utility of calories exhibits a large decline. There is little empirical evidence that the physical discomfort associated with hunger dissipates with adaptation.[10] Third, although adaptation may slow the rate at which individuals substitute toward the staple good in order to increase calories, when deprivation becomes severe enough that the individual can no longer maintain function without changing his diet, they will have no choice but to increase intake of the staple, increasing SCS. Thus, while adaptation may change the rate at which SCS increases, it will still be the case that individuals with an unusually high SCS will be those who are most calorie deprived, and that significant movements in SCS will mark the transition from nutritional sufficiency (net of the effects of adaptation) to deprivation.

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[8] However, the literature emphasizes calories and protein are the most important. See, for example, Svedberg (2000, p. 106): "On economic as well as common-sense grounds, one would think that the energy-protein content of food is the most basic of all economically constrained needs people have." As illustrated below, to the extent that these other needs are important and not met by the staple, they will influence the maximum SCS consistent with a healthy diet. Thus, even very poor consumers need not consume only the staple.

[9] One concern with food intake diaries is whether individuals can accurately recall all the foods they have eaten over some reference period. However, when food intake is so low, consumers are likely to be acutely aware of how much they have eaten. And a validation study by Zhai et al. (1996) finds that the food intake diary approach is very accurate, yielding similar data than what is obtained from the more intensive "household inventory" approach that uses enumerators to weigh individual ingredients before cooking and waste following each meal.

[10] Though certainly it could, if adjustment is via reduced energy expenditures by the body.

Fourth, we note that if the AAP is correct and individuals suffer no consequences in adjusting to lower caloric intake, then perhaps we should not consider the higher threshold to be the relevant one for assessing undernutrition, and that in fact using the 2,000 calorie threshold overestimates true undernutrition. Alternatively, we also note that under the AAP, a common method for deriving minimum calorie thresholds, namely examining the health and functioning of poorly nourished people, would yield estimates of the threshold that are too low, just as with SCS; if the body adjusts to deprivation so that someone can be productive and healthy at the adjusted intake as suggested by the AAP, then we will find the 2,000 calorie person functioning well at 1,800 calories, and believe that is the true threshold. Thus, we would underestimate true undernutrition with calories just as we would with SCS.

The concerns discussed so far would apply to calories as much as to SCS.[11] However, there are a few concerns that may apply more to SCS. One is whether people systematically substitute away from the staple even before their true calorie threshold is met. This concern is often raised in the context of whether the poor or malnourished eat junk food. Such a person would be classified as nutritionally adequate from our SCS measure, but a calorie threshold may capture that they are not.[12] However, empirically, there is little evidence that this happens systematically.[13] Our assumption, based on the literature on the body's physiological and biochemical reactions to calorie deprivation, is that individuals suffer a strong penalty if they do not get enough calories, which causes them to favor calories over other food attributes. While an individual may deviate from this for a very short period of time (either by choice or because other food is not available), they will not do so for an extended period.[14] Additionally, even if some individuals substitute before their calorie threshold, their behavior reveals they are not interested in calories, so any policy efforts to improve caloric intake may have little impact anyway. And again, policy should perhaps by definition only care about calories for those who themselves are concerned with calories, and such behavior reveals they are not.

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[11] While in light of these difficulties one might say we should abandon nutrition-based indicators, they remain widely used, and they have the appeal of assessing as best as possible a minimum basic need. Further, unlike income or expenditure, nutrition-based measures can be assessed at the individual level, which is important given the literature indicating the unequal provision of resources within households (see Strauss and Thomas 1995).

[12] Though some junk food is very high in calories, and the person may appear calorie nourished.

[13] Though it is observed that poor people do consume junk food, testing whether those who are malnourished do so is not possible, given the significant problems noted above in identifying whether someone is malnourished.

[14] However, we must rule out (as do calorie based measures) extreme irrational behaviors, due for example to drug addiction or severe mental impairment.

A second and related concern is whether there is variation in the taste for the non-nutritional attributes of foods. Some people may not care about the non-nutritional attributes as much, so they may continue primarily eating the staple even after they have met their required caloric intake.[15] SCS would assign as undernourished those who are attaining enough calories but prefer not to switch away from the staple. Alternatively, some people may care a great deal more about the non-nutritional attributes of food, so they are willing to suffer a penalty to get these other attributes. Our assumption is that people value the non-nutritional attributes of foods, and will not continue to heavily consume the staple if they can afford to substitute. And we note that deviating from the staple might not mean substituting towards a particular food like meat, but just any food that is favored in some way but not as cheap per calorie as the staple. Substitution towards some form of protein (such as meat or pulses) is in fact widespread as wealth grows. Or, substitution may simply be not for the attributes of a specific food, but for the sake of dietary diversity. Finally, since our approach is aimed at finding when a person has attained their subsistence level, what matters most is that all individuals assign some non-zero utility to the non-nutritional attributes of foods. Though some individuals may value those attributes more than others, that will affect the rate at which they substitute once they have passed the subsistence threshold--but the point at which they begin to substitute, which identifies the subsistence region of interest, depends only on whether they value those attributes more than additional calories, and will start to substitute away from the bare minimum of those attributes associated with the calorie maximizing food choices.

An additional limitation that applies to our method is the need for consumption to be dominated by a low cost staple for the poor. While this fits the consumption pattern of most poor countries, it may not be appropriate for wealthier countries. However, in these countries, where true undernutrition is extremely low, calorie measures are likely to be inappropriate as well, or at least uninformative. A final disadvantage with SCS is that it cannot assess the depth of deficiency, since it remains constant until subsistence has been passed. For example, a person who is below subsistence and consuming only the staple would be recorded as having the same SCS regardless of whether they were consuming 1,000 calories or 1,200 calories. SCS would indicate both are below subsistence, but would not distinguish the depth of deficiency.

[15] For example, perhaps the elderly don't like meat as much as young people, either because they were born at a time when incomes were much lower and meat was rarely eaten so they never developed a taste for it, or because they preferred it less as they aged (e.g., loss of taste, dental problems, etc.).

Overall, then, there is a tradeoff, with advantages to SCS and advantages to calories as indicators of nutritional sufficiency. Assigning a fixed, specific calorie threshold against which to measure nutritional status, despite the difficulty in measuring, determining and assessing that threshold, at least ensures households have enough nutrition to meet some minimum defined standard. The SCS threshold provides an indicator that reflects how consumers behave and eliminates the need to figure out the unobservable and highly varying thresholds (or whether they even exist), but allows them to make decisions that may appear irrational from a nutrition perspective, since it identifies as undernourished, by definition, those who do not value marginal calories. Thus, the two measures may perhaps best be used in conjunction.

A final issue to consider is whether anthropometric measures such as Body Mass Index (BMI) might perform better than either calories or SCS. However, we note that BMI suffers from many of the same problems as calories as an indicator of hunger or undernutrition. First, there is no agreement on what the minimum, subsistence healthy BMI threshold is, or indeed whether one even exists (and as with calories, average or net changes in BMI cannot be used instead of a threshold to assess hunger or undernourishment).[16] Second, any such threshold would also vary considerably across individuals (and within individuals over time, such as due to age, pregnancy, menstruation, etc.), due to differences in skeletal system and body shape (e.g., wide frames vs. narrow), muscle and bone density, etc. Finally, we noted above that calories may change only slowly, and even non-monotonically, with increases in wealth; since calories determine weight, any changes in BMI would therefore follow those same patterns and suffer from the same problems.

III. EXAMPLE APPLICATION FOR CHINA

III. A. Calculating the SCS threshold

To gain insight into the practical application of SCS as a measure of subsistence, we solve a version of the "diet problem" (Stigler 1945, Dorfman, Samuelson and Solow 1958,

[16] Again, a threshold is needed to measure undernutrition or hunger and to define a poverty line. And net, average gains in BMI tell us nothing about changes at the bottom of the distribution, which is what we care about. Further, without a BMI threshold we can't identify undernourishment at the individual level, which is needed for example to examine patterns or covariates of undernutrition.

Dantzig 1963).[17] Since application of this problem requires the input of food items and prices to yield a specific solution, we consider an application using diets and prices for China.

The goal of the diet problem is to determine the minimum-cost diet that fulfills a person's nutritional needs. If we were to focus only on energy intake, the solution to this problem would be simple: consume only the food that is the cheapest source of calories. However, while calories are important, they are by no means a person's only nutritional requirement. Additional nutritional requirements, as well as cooking technology, will result in a minimum-cost diet that features high, but not 100 percent, SCS. Thus, if we observe individuals with SCS significantly above the SCS of the minimum-cost diet, that suggests that they are likely to be malnourished, while those with SCS significantly below that of the minimum-cost diet are likely to be meeting their nutritional needs. Thus, the solution to the diet problem provides a natural benchmark against which to compare SCS and evaluate subsistence.

Although there are questions about the real-world relevance of minimum cost diets, households in many poor countries do closely approximate such diets (we consider China below), subject to one caveat: there may be cheaper sources of calories that are almost never consumed (e.g., millet). However, in the case we consider, the most widely consumed staple, rice, is in fact the cheapest source of calories. Further, foods such as millet are not even available in most markets (though of course this is endogenous), since it is not part of the traditional diet, so many people aren't familiar with it and don't know how to cook it. Aside from the specific case of China, however, the fact that impoverished households rarely consume the very cheapest staples available remains a puzzle (Deaton 1997). But conditional on widely available foods that are actually consumed, the poorest households in China do appear to approximate a low-cost diet (see Jensen and Miller 2008). Households get a significant portion of their calories from the staple good, and then substitute towards a food that is favored for taste, meat or bean curd, when they can afford it. And the patterns of substitution are clear, as demonstrated below.

In principle, the solution to the diet problem should take into account all of a person's nutritional requirements, including energy, protein, vitamins, minerals, etc. However, for our purposes it is enough to focus on a simplified version of this problem. As Svedberg (2000, p.

[17] This analysis draws on material in the unpublished working paper version and online appendix from our previous study (Jensen and Miller 2008).

106) notes, “the energy-protein content of food is the most basic of all economically constrained needs people have.” Hence, a natural starting point for the analysis would be to consider both energy and protein requirements. While calories is an adequate measure of the energy intake of food, protein requirements are somewhat more complex, as different protein sources will contain more or less of the various amino acids that form the “building blocks” of protein. In particular, when considering the nutrition of people consuming traditional diets consisting primarily of cereal grains, the amino acid most likely to be in short supply is Lysine. Lysine is an essential amino acid, meaning that it cannot be produced by the body and must be ingested in food. Further, it is in relatively short supply in cereal grains such as rice or wheat but plentiful in pulses, legumes and animal proteins, which explains why the traditional diets consumed by poor people throughout the world generally consist of a cereal grain and a pulse (e.g., rice and beans, wheat noodles and tofu, etc.).

To capture the importance of amino acids in nutrition, using information from the National Research Council we imposed intake requirements for calories and the 11 “indispensible” amino acids for adults (NRC 2005, IOM 2006). We construct SCS thresholds for a diet typical of much of southern China, where rice is the staple food. Rice is the cheapest source of calories, but is relatively deficient in the essential amino acid Lysine. To account for the fact that complementing rice with legumes such as bean curd is typically the cheapest way to ensure that a person receives all essential amino acids, we construct diets consisting of rice plus bean curd. Typically, only small amounts of bean curd are needed to complete the protein. We do not directly include cooking oil as a choice variable in our model as oil is used primarily as an input for the cooking process rather than consumed as an end food in itself. Rather, consistent with our data from China, we instead assume that households receive 13 percent of their calories from cooking oil (about one tablespoon per day).

The data on the foods’ nutritional content come from the USDA National Nutrient Database for Standard Reference. The individual nutrient requirements come from the Estimated Energy Requirement equations from the Institute of Medicine (Gerrior et. al 2006), which take into account the individual’s gender, age, weight and activity level.

In our analysis of the simplified minimum-cost diet problem, we considered a number of different representative “people” with a range of different height, weight and activity level profiles. For each person, we solve for the diet that minimizes the cost of satisfying the individual's required daily intake of energy and protein/amino acids. Prices come from the data gathered as part of a survey we conducted in 2006 in Hunan province (see Jensen and Miller 2008 for more detail on the survey). Although we consider all eleven required amino acids in our analysis, in each case the binding constraint is for Lysine. Hence to conserve space, we do not report the other amino acid requirements.

Table 1 presents the recommended daily requirements of energy and lysine for the various profiles, as well as the diet consisting of rice, bean curd and cooking oil that satisfies these requirements at the minimum cost. We also report the cost of the diet as well as the SCS of the minimum-cost diet.

Scenario A computes the minimum cost diet for an active man 67 inches tall and weighing 121 pounds, which is average for China. A person with these characteristics requires 2,554 calories per day. His minimum-cost diet consists of 586 grams of rice, 134 grams of bean curd and 11.4 grams of cooking oil, and results in an SCS of 0.84, i.e., 84 percent of calories come from rice. The remaining columns of the table vary these attributes. Columns B – D vary the activity level from active (A) to very active (V), less active (L), and sedentary (S). Moving from sedentary (S) to very active (V) increases the individual's calorie requirement by approximately 42 percent (from 2,112 to 2,996). However, the SCS associated with the minimum-cost diet is much less variable, changing only from 0.86 to 0.81. Columns E and F return to the attributes of the typical man in column A but vary his weight from 110 to 200 lbs. Calorie requirement under these scenarios range from 2,464 to 3,202, a difference of about 30 percent. Yet despite this large change in weight and the corresponding calorie requirement, SCS is again fairly stable, varying only between 0.85 and 0.80. Columns G and H vary the individual's height from 61 to 77 inches, while columns I and J vary the age from 30 to 67. Again, the SCS associated with the minimum-cost diet remains much more stable than caloric intake requirements.

The stability of SCS can be seen even more strikingly under more extreme comparisons. Column L represents an 85 year old, sedentary woman who is 62" and weighs 110 pounds, while column K represents a 25 year old, very active man who is 74" and weighs 220 pounds. The woman needs 1,1351 calories and 1,550mg of lysine, which under the minimum cost diet can be purchased at a cost of 1.21 *yuan*, while the man needs 4,264 calories and 3,100mg of lysine, costing 2.91 *yuan*. While the man's calorie needs are more than triple those of the woman's and the cost of the bundle is almost 2.5 times greater, the SCS threshold for the man is only 6 percentage points greater (0.85 and 0.79), and both are very close to the less extreme cases in columns A through J. Now instead of the elderly woman in column L, consider a woman aged 40 of the same height but weighing 121 pounds and who is active rather than sedentary, and who would therefore need 2,174 calories and 1,698mg of lysine, which can be purchased for 1.54 *yuan* (Column M). The man in column K's calorie and lysine needs, and the cost of the food bundle, are all nearly twice as great, yet the calorie share thresholds at which the two attain their needs are nearly identical (0.85 vs. 0.84). Thus, overall, the SCS of the minimum-cost diet is much less sensitive to variation in attributes, i.e., it is more need neutral, than calorie requirement. Finally, we note that the SCS thresholds are nearly identical if we instead use a wheat-based diet typical of northern China (bottom panel). Using wheat rather than rice, even with a completely different set of prices (drawn from our data for Gansu province), the scenarios in Table 1 still yield SCS thresholds that vary only from 0.78 to 0.85. For example, the cases of the tall, heavy, active man in column K and the lighter woman in column J with only half the calorie needs yield SCS thresholds of 0.84 and 0.83, respectively. This suggests SCS thresholds are likely to be applicable across individuals even when the staple foods (and prices) vary.

While the staple calorie share associated with the least-cost diet typically ranges between approximately 0.80 to 0.85 in the scenarios we consider, we are interested in identifying those who can satisfy their nutritional needs while eating something other than the least-cost diet. These people will exhibit SCS lower than the SCS of the minimum-cost diet we found above. Given our results, the minimum-cost diet problem suggests a cut-off of around 0.8. People who consume 80 percent or more of their calories from the staple are likely to be undernourished, while those who receive less than 80 percent from the staple reveal through their behavior that they have passed subsistence.

III.B. Empirical Distribution of SCS

The model and discussion above argued that SCS could be used to identify when the marginal utility of calories has declined significantly, as SCS will remain constant until the threshold has been met, and then begin to change. We now consider whether it is possible to empirically identify such a threshold with consumption data. For this exercise, we use data from the China Health and Nutrition Survey (CHNS), a panel survey gathered by the Carolina Population Center at the University of North Carolina at Chapel Hill, the Institute of Nutrition and Food Hygiene and the Chinese Academy of Preventative Medicine. The sample consists of approximately 16,000 individuals in 3,800 households per round, drawn using a multi-stage, random cluster strategy for 9 provinces. For our analysis, we use data from the 2000 survey, the latest round for which we can compute calorie shares from food intake data.[18] A key part of the CHNS was a 24-hour food diary completed by each household member for three days. Respondents were asked to report everything they ate and drank the previous day, whether inside or outside the home, by specifically listing the components of all foods eaten. These foods were recorded in detail in order to match with the 636 detailed food items listed in the 1991 Food Composition Tables constructed by the Institute of Nutrition and Food Hygiene at the Chinese Academy of Preventative Medicine, which can be used to convert food consumption into calorie intake.

Figure 5 uses a locally-weighted regression smoother (LOWESS, Cleveland 1979) to explore the bivariate relationship between SCS and log per capita income.[19] While income is likely to be a noisy measure of the ability to move beyond the calorie or SCS threshold, these figures are presented just to provide a rough sense of the correlation. The graph provides clear evidence consistent with the model. In particular, SCS among the poorest households is very high, at almost 80 percent. This is very close to the range that arose from the minimum cost diet problem in the previous subsection. We also note that for the very poorest households, SCS does not change with additional income, consistent with their consuming mostly staple foods and little else, and using additional income to just buy more of the cheapest source of calories. However, once a threshold level of wealth is reached, SCS begins to decline rapidly. Overall, there is clear evidence of an SCS Engel curve, i.e., as income increases, the share of the calories consumed from the staple good decreases, with a clear threshold effect.

Figure 6 shows the share of calories consumed from other major food categories. The pattern here is consistent with the model of consumer substitution outlined above. After the consumer has moved beyond the point of high marginal utility of calories, the substitution away from cereals begins, with meat taking on a larger share of calories. The patterns are

[18] Rounds were also conducted in 2004 and 2006, but the food composition tables required for converting the food diaries into nutrients have not been released (and the food codes used in the survey changed from earlier rounds).
[19] While it might be better to use expenditure data, the CHNS unfortunately did not gather these data.

nearly symmetric. Similar time-series changes in consumption patterns, away from cereals and towards meat, have been noted for China (Du et. al 2002, Zhai et. al 2007). Other contributions to calories, such as fruits and vegetables, are fairly stable (and very low overall).

We note that Figure 5 also shows the potential value of SCS in constructing a poverty line, using the same approach currently used for calories. In our data, the income cut-off at which households appear on average to move beyond subsistence is about 225 yuan per person. Of course, while using SCS rather than calories to construct poverty lines is valuable for the reasons outlined above, it does not solve many of the other problems in constructing poverty lines, such as the need to adjust for adult equivalents or economies of scale, or consideration of any non-economic aspects of well-being.

We can also show that, as predicted by the model, using SCS to monitor changes in nutrition and welfare over time in China offers advantages over calories. In particular, many authors have noted that despite large increases in wealth, caloric intake in China appears to be declining, even as malnourishment persists (Zhai et. al 2007 and Meng et. al 2008; Deaton and Drèze 2008 document similar patterns for India).[20] Figure 7A shows non-parametric, kernel density estimates of the distribution of daily household per capita calorie consumption for CHNS rounds collected in 1991, 1993, 1997 and 2000. These densities show that caloric intake has systematically declined over this decade, with each density to the left of the previous round. Using a threshold of 2,100 calories per person per day (the calorie threshold used by the government of China to set poverty lines) we find that the fraction of calorie-undernourished households increased steadily from 53 to 67 percent over this decade (statistically significant at the 0.01 level), which on its own would be taken as evidence of a sharp decline in nutritional status. As the distributions show, at almost any calorie intake threshold, a greater fraction of households are undernourished in the later years.

Figure 7B shows the distributions of household-level SCS along with our preferred 80 percent subsistence threshold.[21] The figure shows that the distribution of SCS has steadily shifted to the left, indicating that there has been an improvement in nutritional status (since we

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[20] Though Deaton and Dréze (2008) argue that there may be some reduced need for calories (rather than households just choosing to consume fewer calories) due to changes in the level of physical activity associated with the mechanization of home production and formal production, and increased access to transportation. And Meng et. al (2008) suggest price changes play a role in the nutrition decline in China.

[21] SCS is computed by summing calories from various sources across all household members and all diet diary days, not the average of SCS for each member or for the whole household for each of the three days.

argued both theoretically and empirically that SCS declines as wealth grows). The fraction of households consuming more than 80 percent of their calories from the staple declines steadily from 49 percent in 1991 to 32 percent in 2000 (statistically significant at the 0.01 level). This same conclusion would also be seen for a wider range of choices of SCS (0.85, 0.75, etc.). Thus, calories and SCS yield strikingly opposing conclusions about changes in nutritional status during this period of substantial economic growth in China, with SCS better reflecting that growth caused utility gains in food consumption via substitution away from the cheapest sources of calories.

Finally, it is also worthwhile to compare the levels of hunger or undernutrition from the two approaches for a particular point in time. In the 2000 survey round, 67 percent of households are hungry according to calories[22] but only 32 percent are hungry according to SCS. SCS in general provides an estimate of nutritional inadequacy that is much lower than that using calories. The two measures are of course capturing different things, so we would not claim that the calorie measure overstates malnutrition or hunger by a factor of two. The calorie threshold measure is the fraction who meet a fixed, pre-defined threshold deemed a minimum acceptable standard. Our measure indicates the fraction that behave as though their dietary choices are guided by a priority of maximizing calories.

IV. CONCLUSION

We argue that the staple calorie share is a valuable tool for assessing whether households have attained a subsistence level of nutrition. Under the assumption that the marginal utility of calories is very high at low levels of intake and then declines, a person can be inferred to have attained sufficient caloric intake when they are observed to substitute away from the cheapest source of calories available to them. While the SCS threshold may not capture whether a specifically defined calorie or nutrient threshold has been met (though as noted, there is considerable debate over whether such thresholds exist and how accurate current estimates of those thresholds actually are), it represents the point at which the consumer does not place as much value on calories. Policy makers should perhaps not care about whether someone meets a calorie threshold, which can't be determined precisely anyway, but instead

[22] The fact that this number is so high is perhaps in itself another indication that recommended caloric intakes may not be meaningful.

getting the consumer to the point where the marginal utility of additional calories is revealed to be low, suggesting they are not a priority for the consumer, and thus should not be for the policy maker (and since policies promoting increased caloric will not be very effective at that point anyway). And the best way to determine when that unobservable, individual-varying point has been met is when they begin to substitute towards other foods.

We provide an application with data from China that shows that the threshold predicted by theory is evident in the data, and that this empirical threshold closely matches what would be estimated from a minimum cost diet calculation. Among nutrition-based indicators, which are widely used, SCS offers several clear advantages, such as avoiding the problem of individual-varying and unobservable thresholds, imperfect absorption, and a consistency with revealed preferences. We believe SCS can play an important role alongside other nutrition-based indicators. Future research should explore the properties of SCS in more detail, and consider whether the patterns observed for China are found elsewhere.

Subsequent research could also explore other uses for SCS. For example, because both theoretically and empirically SCS is monotonic in wealth, it could be used in the same way as the food budget share in Engel curves, such as to estimate economies of scale or adult equivalents in consumption (see Deaton 1997). SCS could be used as a simple indicator of consumption patterns for developing countries. SCS gives a sense of whether consumers have begun the "dietary transition," away from a traditional diet dependent on a staple good, and towards a more diversified or modern diet focusing on non-nutritional attributes of food. Of course, SCS does not capture the full complexity of diets, but for a single, simple indicator that can be compared over time and across countries (and without the need to define or measure what they substitute towards (meat, processed foods, etc.), which will vary within countries, across countries and over time), SCS may be valuable.

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TABLE 1.STAPLE CALORIE SHARE OF MINIMUM COST DIET

Scenario	A	B	C	D	E	F	G	H	I	J	K	L	M
Sex	M	M	M	M	M	M	M	M	M	M	M	F	F
Age	40	40	40	40	40	40	40	40	30	75	25	85	40
Height (inches)	67	67	67	67	67	67	61	77	67	67	74	62	62
Activity	A	V	L	S	A	A	A	A	A	A	V	S	A
Weight (lbs.)	121	121	121	121	110	200	121	121	121	121	220	110	121
Nutrient Requirements													
Calories	2554	2996	2309	2112	2464	3202	2457	2716	2651	2214	4264	1351	2174
Lysine (mg)	275	275	275	275	250	455	275	275	275	275	3100	1550	1698
							Southern-Style Diet						
Least-Cost Diet													
Rice (g)	586	703	521	469	571	699	561	629	612	496	996	291	503
Bean Curd (g)	134	64	173	204	99	383	149	108	118	188	123	185	93
Cooking Oil (g)	11.4	13.4	10.3	9.5	11.0	14.4	11.0	12.2	11.9	9.9	19.1	6.1	9.7
Cost (yuan)	1.86	2.00	1.79	1.72	1.74	2.76	1.83	1.91	1.89	1.76	2.91	1.21	1.54
Staple Calorie Share	0.84	0.86	0.82	0.81	0.85	0.80	0.83	0.85	0.84	0.82	0.85	0.79	0.84
							Northern-Style Diet						
Least-Cost Diet (Gansu)													
Wheat (g)	581	697	516	465	565	692	555	623	606	491	986	288	498
Bean Curd (g)	178	116	212	239	142	435	191	155	164	225	198	207	131
Cooking Oil (g)	11.4	13.4	10.3	9.5	11.0	14.4	11.0	12.2	11.9	9.9	19.1	6.1	9.7
Cost (yuan)	1.73	1.84	1.67	1.62	1.61	2.60	1.71	1.77	1.76	1.65	2.69	1.15	1.43
Staple Calorie Share	0.83	0.85	0.81	0.80	0.83	0.79	0.82	0.84	0.83	0.81	0.84	0.78	0.83

1 cup uncooked rice = 185 grams. 1 cup uncooked flour = 125 grams. 1 tablespoon cooking oil = 13.6 grams.

FIGURE 5. SCS AND LOG INCOME PER CAPITA

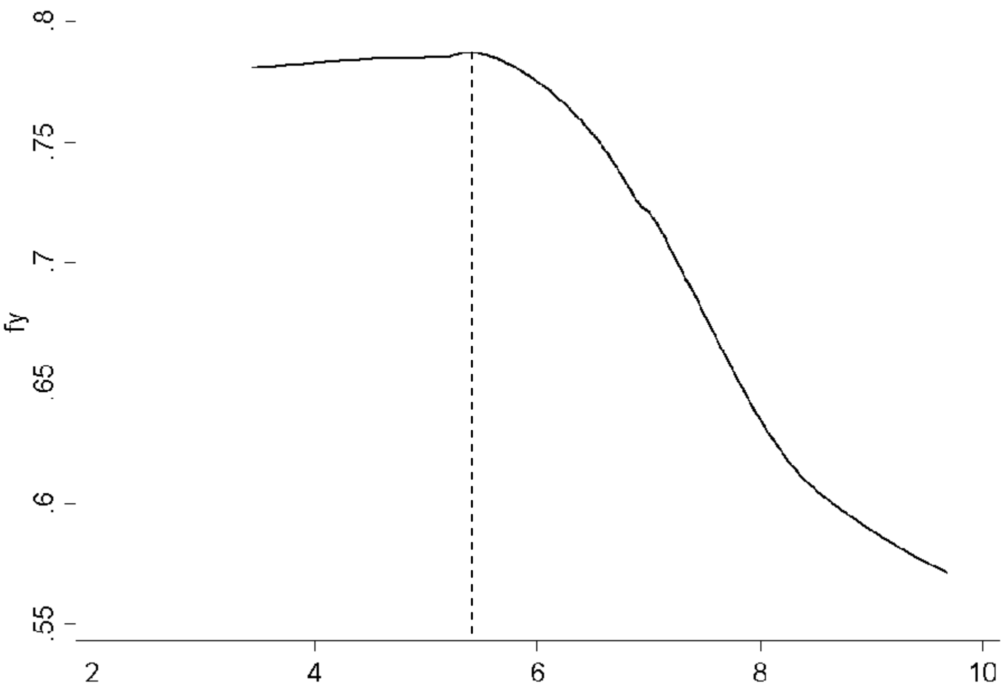

FIGURE 6. CALORIE SHARES VS. LOG INCOME PER CAPITA

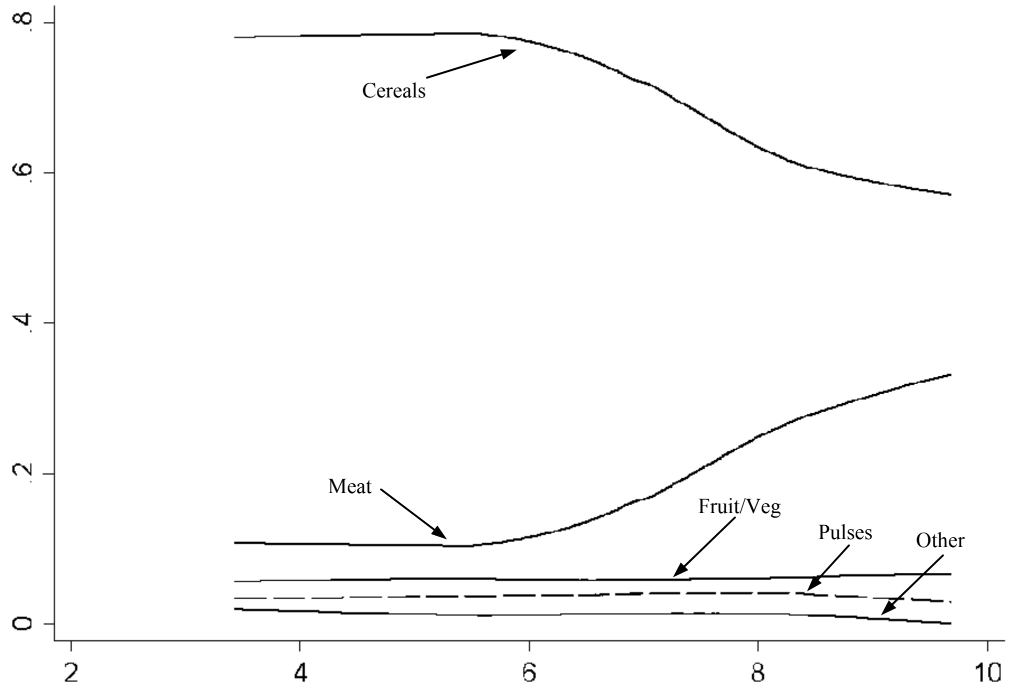

FIGURE 7A. DENSITIES OF HOUSEHOLD CALORIES PER CAPITA BY YEAR

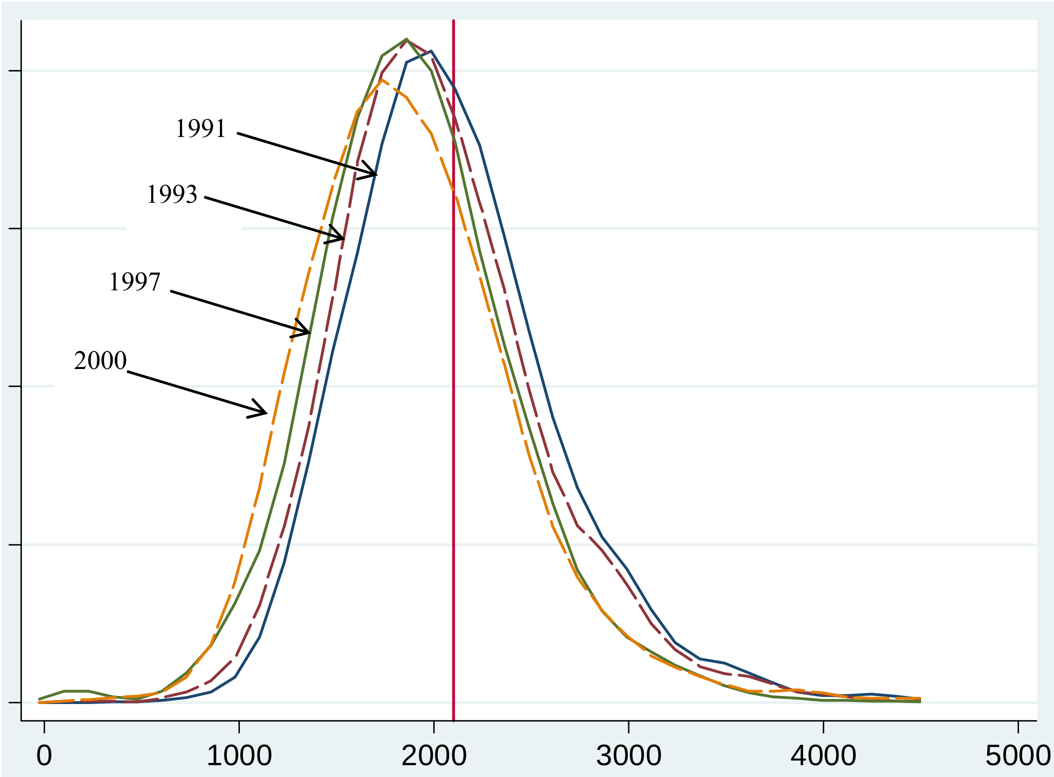

FIGURE 7B. DENSITIES OF SCS BY YEAR