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Measures of Food Insecurity at the Household Level

Indranil Dutta,[1] Craig Gundersen,[2] and Prasanta K. Pattanaik[3]

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Abstract

Food insecurity and hunger have traditionally been measured by aggregate food supplies or by variables correlated with food insecurity. Because these measures often poorly reflect individuals' true deprivation, economists have turned to surveys with direct questions about food insecurity. Using these surveys, households have then been classified into broad categories, a classification system which ignores the richness of the multiple questions. In this paper, we propose food insecurity measures, along the lines of the well established poverty measures, which incorporates this richness and allow us to reflect the depth and severity, in addition to the incidence, of food insecurity. Using these indices, we calculate the extent of food insecurity and hunger in the United States. Along with giving a richer picture of food insecurity in the US, these food insecurity measures demonstrates that the ordering of various demographic categories differs depends on the choice of measure.

Keywords: deprivation, food insecurity, hunger, poverty measures

JEL classification: D63, I31, I38

[1] UNU-WIDER, Helsinki, Finland, and Department of Economics, University of Sheffield, UK. [2] Department of Human Development and Family Studies, Iowa State University, USA. [3] Department of Economics, University of California, Riverside, USA.

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The Tables appear at the end of the paper.

UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

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1 Introduction

The extent of hunger and food insecurity in a country is an important indicator of standard of living (Anand and Harris, 1990). The Food and Agriculture Organization of the United Nations (FAO 2003) estimates around 800 million people worldwide to be food insecure. Using a different definition of food insecurity, the U.S. Department of Agriculture (USDA) has found that approximately one-in-eight persons in the United States are food insecure (Nord et al., 2004). These aggregate measures just counts the number of people who are food insecure. It is now well established that the simple head count aggregation rules, as followed by USDA and FAO, though easy to calculate, can be seriously misleading. In the spirit of well established poverty measures such as Sen (1976) and Foster, Greer and Thorbecke (1984), we propose here aggregation rules to measure food insecurity that go beyond simple head count ratios.

Food insecurity has traditionally been measured by aggregate food supplies, availability, accessibility, and adequacy (Busch and Lacy, 1984; FAO 2003). Studies have clearly shown the inadequacy of the supply side approach to food insecurity (Reutlinger 1989; Dreze and Sen, 1989). The emphasis now is to understand food insecurity at the individual/household level rather than the national level. Several approaches have been put forward including measuring variables (e.g. household income, height to weight ratios) generally thought to be correlated with food insecurity (see Reutlinger 1985; Maxwell and Frankenberger, 1992; FAO 2003). Recently, however, dissatisfaction with these measures has led to the use of direct measures of food insecurity (e.g. Maxwell, 1995; Maxwell et al., 1999; Wolfe and Frongillo, 2001) such as household food consumption data (based on recalls) and qualitative measures based on subjective household survey questionnaires.

A household is food insecure if it does not have sufficient food to maintain an active and healthy life for all its members. The exercise of measuring food insecurity then becomes closely related to measuring food deprivation. Typically any measure of deprivation would have two parts, identification and aggregation (Sen 1981). Here we implicitly assume that using some indicator[1] we are properly able to identify households that suffer from food insecurity. Our primary concern here is with the step after the identification of the food insecure individuals/household, that is the aggregation issue. The total food insecurity of the society should be based on these food insecure households. Exactly how we should combine the amount of food insecurity suffered by each household to form the society's food insecurity is the object of this paper.

It has been argued strongly that aggregate measures of food deprivation should take in to account aspects of inequality within food insecure households (Sen 1981; Foster and Leathers, 1999). We would like our aggregate measure of food insecurity to be able to distinguish households who have barely enough from households who do not have adequate food to the extent that they suffer from severe hunger pangs. This distinction is important since we surely do not want to treat both the households at a similar level in terms of policy intervention. The aggregation rules we propose gives a higher weight to the more food deprived household and provides a single food insecurity index. Obviously we will have different food insecurity indices depending upon the different weighting procedure used. This type of aggregation rules have been used in similar contexts by Vecchi and Coppolla (2003), Fujii(2004) and Jha(2004). Vecchi and Coppola (2003) and Jha (2004) had used the aggregation rule proposed by Foster et al. (1984)

[1]This indicator may be direct consumption of food by households or anthropometirc measures or subjective measure (as has been used by USDA).

to measure severity of undernutrition in terms of calorie deficiency while Fujii (2004) uses the same aggregation rule to measure malnutrition using standardized heights and weights. Compared to these papers, here we have proposed broader set of rules that take includes rank based aggregation measures (Sen (1976)) along with the Foster et al. (1984) measures to calculate food insecurity in the US. We also discuss the theoretical issues associated with these measures especially in the context of its application to subjective measures of food insecurity as is the case with the US food insecurity data that we have. Taking a step further, using these aggregation rules, we test whether food insecurity is statistically significant for different demographic categories.

In this paper we begin by a brief description of the qualitative approach and designing a theoretical framework that allows us to incorporate more information from food insecurity instruments with multiple questions. We then consider an empirical application of this framework. With the indices established in the theoretical framework, we calculate the extent of food insecurity and the extent of food insecurity with hunger in the U.S. in 1998. To do so, we use the 18-item Core Food Security Module (CFSM) which is on numerous surveys including the Current Population Survey (CPS). In addition to comparing results for all households, we further consider how the indices differ by various demographic categories.

2 Basic framework

2.1 A qualitative approach

In US, where the extent of hunger and food insecurity is much less severe than in the developing world, insufficient demand for food rather than the supply

of food is the reason for food insecurity. As a consequence, aggregate food supplies in a particular region are not used as a measure of food insecurity. The income-based (indirect) measure of food insecurity at the household level is also not effective because some poor households do not suffer from food insecurity and, conversely, many households above the poverty line do suffer from food insecurity.

In a qualitative approach to food insecurity, developed in US, food insecurity is treated as a latent variable (such as IQ) and hence subjective questionnaire related to the food intake of the household are used to elicit that information. Depending on their response to the set of questions, each houshold in then given a food insecurity index that is calculated using multivariate analysis (see Hamilton et al. 1997). More affirmative responses to food inadequacy questions represent higher degrees of food insecurity. The household food insecurity index varies between [0, 10] with the higher number indicating greater food insecurity. Once each household is given a food insecurity index, the next step is to formulate an aggregate measure of food insecurity.

Instead of a single food insecurity index, in the official statistics, the households are classified as food secure, food insecure without hunger, or food insecure with hunger (Andrews et al., 2001). Just plain distinguishing the households in terms of severity of food insecurity, however, is not very helpful since it simply partitions the set of food insecure households in to coarse sets and does not provide a unified index of food insecurity. While this kind of partitioning may be helpful for policy targeting purposes, in the sense that one knows exactly which group within the food insecure should be given first priority, one can still argue for a unified index that takes the severity of food insecurity in to account within the coarse sets, to better

understand the impact of policy. By classifying households into just a few categories, much of the information contained in the multiple questions is not utilized. Hence, a household is classified as food insecure without hunger if it responds affirmatively to more than 3 and less than 7 (out of 18) questions and a household is classified as food insecure with hunger if they respond affirmatively to 8 or more questions. Through this classification system, the possible richness of the measure is not fully utilized. Consider two households, one responding affirmatively to 8 questions and one responding affirmatively to 18 questions. Both are treated as food insecure with hunger yet, as Sen (1976) has eloquently argued in the context of poverty measurement, such differences in the degree of deprivation are important and should be reflected in the indices we construct.

2.2 Notation and concepts

Let $N = \{1, \ldots, n\}$ denote the set of all households under consideration, n being the total number of households in the set. For all $i \in N$, let s_i denote the *food indicator* (FI) for household i where a higher value of s_i indicates a more unfavorable food situation for household i. We assume that, for every $i \in N$, s_i lies in the interval $[0, z]$, where the value 0 denotes the complete absence of any unfavorable circumstance relating to food and z denotes the most unfavorable situation with respect to food. What one would consider the most unfavorable or least unfavorable food situation may, however, depend on the specific context and the judgement of the assessor. In a study in Ghana, Maxwell et al. (1999) defines the least unfavorable response as a response of "once a week" to "Because food is not enough, or money to buy food is not enough, in the past month, how often have you had to rely on less preferred and less expensive foods". The most unfavorable

response is a response of "every day" to "Because food is not enough, or money to buy food is not enough, in the past month, how often have you had to skip whole days without eating". In the US, Nord et al. (2004) has an affirmative response to "Our family worried food would run out before we got more money to buy more because we were running out of money for food" as the least unfavorable food situation and an affirmative response to "The children did not eat for a whole day because there wasn't enough money for food" as the most unfavorable food situation.

Let e $(1 > e \geq 0)$ be the benchmark such that a household i is considered food insecure if and only if $s_i > e$. Note that it is possible to set $e = 0$. However, this will constitute a very stringent criterion for a household to be considered food secure (as we will see later, a benchmark, that is widely used in the US, for judging whether a household is food insecure does not set e at 0). We can now define the notions of a *food insecurity index* and a *normalized food insecurity index* for a household. For every household i, the *food insecurity index* (FII) for i is defined to be 0 if $s_i \leq e$ and it is defined to be $(s_i - e)$ if $s_i > e$. The FII of a household provides us with a measure of the extent to which the household is food insecure; it is clearly analogous to the notion of an individual's "shortfall" from the poverty line, used in the literature on poverty measurement. We get the *normalized food insecurity index* (NFII) for a household when we normalize the FII by dividing it by $(z - e)$. Thus, the normalized food insecurity index for household i, to be denoted by d_i, is given by

$$d_i = \begin{cases} \frac{s_i - e}{z - e} \text{ if } s_i > e \\ 0 \text{ if } s_i \leq e \end{cases} . \tag{1}$$

Let d denote the degree of food insecurity suffered by the group, N, of

all households. We assume that d is a (real valued) function of $d_1, \ldots, d_n$. We shall call such a function a rule for aggregating household food insecurity levels, or, simply an aggregation rule. Thus, an *aggregation rule* is a function $D : [0,1]^n \longrightarrow R^n$. We write

$$d = D(d_1, \ldots, d_n). \tag{2}$$

2.3 The form of the aggregation rule D

What form should one assume for the function D that aggregates the food insecurity levels, $d_1, \ldots, d_n$, of the households to arrive at the index, d, of social food insecurity? The properties of similar rules for aggregating deprivation levels have been discussed extensively in the literature on income poverty. Some of the familiar properties that one may wish to impose on D are:

Normalization: For all $(d_1, \ldots, d_n) \in [0,1]^n$, [if $d_i = 0$ for all $i \in N$, then $d = 0$] and [if $d_i = 1$ for all $i \in N$, then $d = 1$].

Anonymity: For all $(d_1, \ldots, d_n)$, $(d'_1, \ldots, d'_n) \in [0,1]^n$, and, for all i, $j \in N$, if $[d_i = d'_j]$, $[d_j = d'_i]$ and [for all $t \in N - \{i, j\}$, $d_t = d'_t$], then $d = d'$.

Monotonicity: For all $(d_1, \ldots, d_n)$, $(d'_1, \ldots, d'_n) \in [0,1]^n$, if [$d_i \geq d'_i$ for all $i \in N$] and [$d_i > d_i$ for some $i \in N$], then $d > d'$, where $d = D(d_1, \ldots, d_n)$ and $d' = D(d'_1, \ldots, d'_n)$.

Transfer: For all $(d_1, \ldots, d_n)$, $(d'_1, \ldots, d'_n) \in [0,1]^n$, and all distinct $i, j \in N$, if [(for all $p \in N - \{i, j\}$, $d_p = d'_p$) and ($d_i > d_j > 0$ and, for some $\delta > 0$, $d'_i = d_i + \delta$ and $d'_j = d_j - \delta > 0$) and (for all $p, q \in N$, $d_p \geq d_q$ if and only if $d'_p \geq d'_q$)], then $d' > d$.

Normalization, which requires that d be 0 when the *NFII* is 0 for all households and d should be 1 when the *NFII* is 1 for all households, is an innocuous property. Its justification lies in the convenience it ensures. Anonymity requires that, other things remaining the same, if the *NFII* of two households are interchanged, then the food insecurity index for the society remains unaffected. Thus, anonymity demands that the households be treated by the aggregation rule in a symmetric fashion. In a framework based on the aggregation of individual deprivation levels, symmetric treatment of individuals is a compelling property. However, in our framework, where D aggregates the *NFII*'s of households to arrive at the measure of overall food insecurity for N, the symmetric treatment of the households is a much less compelling property, given the possibility that the households may differ in their sizes. Monotonicity requires that, other things remaining the same, an increase in the *NFII* of a household leads to a rise in the value of the food insecurity index of the society as a whole. The transfer property is the counterpart of a similar property in the literature on poverty measurement (see, for example, Sen, 1976). Suppose, to start with, two households i and j suffer from food insecurity but the food insecurity of i is greater than the food insecurity of j. Now suppose the *NFII* of i increases by δ, and, simultaneously, the *NFII* of j decreases by δ, while the *NFII* of every other household, the set of food-insecure households, and the ranking of the food-insecure households all remain unchanged. Then the transfer property stipulates that the food insecurity of the set, N, of all households must increase.

In this paper we use four different aggregation rules for the function D. Let N' denote the set of all food insecure households (i.e. the set of all households such that $s_i > e$) and let $\#N'$ be denoted by n'. Name the

households in N' as $r(1), \ldots, r(n')$ such that $d_{r(1)} \leq d_{r(2)} \leq ... \leq d_{r(n')}$. The rank $l(i)$ of each household, i, in N' is defined to be v, where $i = r(v)$.[2] The four food insecurity measures we use are: (i) the head count, denoted by d^H; (ii) the food insecurity gap, denoted by d^G; (iii) the squared food insecurity gap, denoted by d^{SG}; and the (iv) "Sen" food insecurity measure, denoted by d^{SN}. The four measures are given by:

$$d^H = \frac{n'}{n}, \tag{3}$$

$$d^G = \frac{\sum_{i=1}^{n} d_i}{n}, \tag{4}$$

$$d^{SG} = \frac{\sum_{i=1}^{n} (d_i)^2}{n} \tag{5}$$

and

$$d^{SN} = \frac{\sum_{i=1}^{n'} l(i) d_i}{n(n'+1)}. \tag{6}$$

The first three indices are members of a class of measures discussed by Foster et al. (1984) and defined by (7) below:

$$d^{\alpha} = \frac{\sum_{i=1}^{n} (d_i)^{\alpha}}{n}, \tag{7}$$

[2]Later empirically analyze the extent of food insecurity with hunger in the United States using various measures. In that context, we shall consider different groups of households, such as the set of all households without children and the set of all households with children, and so on. It is clear that, N, N', n, n', and the rank number of a household have to be interpreted with reference to the specific set of households under consideration.

where α is a given positive number. When $\alpha = 0$, d^α defines the head count measure; when $\alpha = 1$, d^α defines the food insecurity gap; and when $\alpha = 2$, d^α defines the squared food insecurity gap.

The Sen food insecurity measure ranks the households in an ascending order, starting with rank 1 for the household with the lowest food insecurity. These rank numbers are then used as weights to aggregate the household insecurity levels into an overall index. Thus, the household with the highest food insecurity gets the highest weight in the aggregate index. One of the problems with the Sen food insecurity measure is that, if the food insecurity of a household increases, with the rank of the household remaining unchanged, the Sen index would still attribute the same weight to the household. In the squared food insecurity index, the weight of a household in the aggregate increases as the food insecurity of the household increases. Both these indices take into account the inequality in terms of food deprivation within the food insecure households.[3] If the inequality gets worse, this measures will also register an increase in food insecurity. The current measures of aggregate food insecurity do not follow this property.

The table below shows which of the four properties, normalization, anonymity, monotonicity, and transfer sensitivity, are satisfied by each of the measures mentioned above. ✓ in the appropriate place indicates that the measure satisfies the relevant property, while the absence of ✓ indicates that the measure

[3]More specifically, the Sen index measures the gini coefficient of inequality in terms of food deprivation within the food insecure households, whereas the squared food insecurity gap measures the coefficient of variation.

does not satisfy the relevant property.

	Normalization	Anonymity	Monotonicity	Transfer
d^H	✓	✓		
d^G	✓	✓	✓	
d^{SG}	✓	✓	✓	✓
d^{SN}	✓	✓	✓	✓

3 An Application of the Theoretical Framework

We now apply our theoretical framework to the measurement of food insecurity in the United States. We first discuss in a little more detail how food insecurity is measured in the US followed by a discussion of the data used for our analysis.

3.1 The Core Food Security Module

The Core Food Security Module (CFSM) contains 18 questions that provide detailed information about the experiences of household members as it pertains to a household's inability to meet basic food needs due to financial constraints. A household's responses to these questions are used to categorize the household as (a) food secure, (b) food insecure without hunger, or (c) food insecure with hunger. The CFSM has been included in numerous national surveys, including the Current Population Survey (CPS), the Survey of Program Dynamics, the Panel Study of Income Dynamics, the National Food Stamp Program Survey, and in surveys at a sub-national level. The results from the CPS are used to derive the official measure of food insecurity

and hunger in the U.S. The CFSM built on previous research into various food security measurement issues (e.g., Briefel and Woteki, 1992; Radimer et al., 1990) and was established by the US Department of Agriculture and the US Department of Health and Human Services.

The 18 questions used in the CFSM are listed in Table 1. Each question is designed to capture some aspect of food insecurity and, for some questions, the frequency with which that particular aspect of food insecurity manifests itself. The questions in Table 1 are listed in ascending order of food inadequacy. Examples of questions include "I worried whether our food would run out before we got money to buy more", (the least severe question); "Did you or the other adults in your household ever cut the size of your meals or skip meals because there wasn't enough money for food?"; "Were you ever hungry but did not eat because you couldn't afford enough food"; and "Did a child in the household ever not eat for a full day because you couldn't afford enough food?" (the most severe question).

[Table 1 about here]

For many of the questions, the response can be of more than two types. Consider, for example, the following question in Table 1: "How often did [the adults in this household not eat for a whole day]—almost every month, some months but not every month, in only one or two months, or never?" There are four different responses to this question. However, for every question, irrespective of whether it admits two or more than two possible responses, the responses are converted into a binary format (1 or 0) by following certain rules. (For a discussion of these rules, see Hamilton et al. 1997). A value of 1 indicates that the aspect of food deprivation that the question seeks to capture is present in the household (i.e. an "affirmative response") and

0 indicates the absence of that aspect of food insecurity (i.e. a "negative response").

Based on households' responses to the 18 questions, an FI is assigned to each household. This assignment is done as follows. The affirmative and negative responses to the 18-item questionnaire are converted into a single indicator by the Rasch scoring method. The underlying assumption of the Rasch method is that the probability that a household will answer a question affirmatively relative to answering it negatively (that is the odds ratio) depends on the degree of the food insecurity of the household and the extent of the severity of food insecurity captured by the question. In other words, the Rasch score assumes that the probability of a household answering a question positively or negatively, follows a logistic distribution, the parameters of which depend on the households food insecurity level and the level of severity of the question. Using a maximum likelihood estimation based on the overall response pattern of households to all the questions, one can then derive each households level of insecurity (or Rasch score) which is shown to depend on the number of questions the household answers affirmatively. The FI for a household can be expressed as a one to one mapping to its Rasch score. Note that by this rule, the FI for a household depends on the particular sample under consideration; the FI is not assigned exogenously.

Using the 1998 CPS (discussed below), the FI ranges from 0 (no affirmative responses) to 13.026 (18 affirmative responses) for households with children and from 0 to 11.052 (10 affirmative responses) for households without children.[4] Along with a list of the questions in ascending order of severity, Table 1 displays the FI associated with the number of a household's affirmative responses (m). While we do not list the item severities in Ta-

[4]Eight of the 18 questions in the CFSM refer to the food insecurity status of children and these questions are therefore not asked of households without children.

ble 1, there is a connection between the questions and the FI for the modal household. In terms of Table 1, the modal household responding affirmatively to m items will have responded affirmatively to the mth question but negatively to the $(m+1)$th question and each subsequent question. Thus, for the modal household, the most severe affirmative response corresponds with the question listed in the final column.

In the 1998 CPS, a household is defined as food insecure if they respond affirmatively to three or more questions. For households with children, this means that any household with an FI of more than 2.56 is food insecure and any household without children with an FSI of more than 3.10 is food insecure. In other words, $e = 2.56$ for households with children and $e = 3.10$ for households without children. A household with children is defined as food insecure with hunger if they answer affirmatively to 8 or more questions (i.e. $e = 6.61$) and a household without children is defined as food insecure with hunger if they answer affirmatively to 6 or more questions (i.e. $e = 7.07$).

At this time we return to a discussion of the property of anonymity as it pertains to the method of measuring food insecurity at the household rather than individual level. All four of the food insecurity indices we use in this paper satisfy anonymity. With the CFSM, we do not have information regarding individual levels of food insecurity rather we only observe household level. This is problematic as the following example illustrates. Consider a society of 100 households, where households 1 through 50 have 20 members each and households 51 through 100 have 2 members each. To start with, assume that each of the first fifty households has a normalized FII of, say, 0.2 and each of the other households has a normalized FII of 0.8. Suppose D yields a social food insecurity index of 0.6 in this situation. Then symmetry will require that, in another situation, where each of the first 50 households

has a food insecurity index of 0.8 and each of the other households has a food insecurity index of 0.2, the social food insecurity index must be 0.6. Yet, this would seem unreasonable, since, intuitively, it would seem that in the second situation a much larger fraction of the total number of individuals suffer from food insecurity.

One solution to this problem can be to assume that: (i) aggregate food insecurity is a function of the food insecurity levels of all the individuals in the society (rather than being a function of the food insecurity levels of the households); and (ii) every individual in a household suffers from a degree of food insecurity which is the same as the degree of food insecurity of the household as a whole. Assumption (ii) however, does not seem to be a reasonable assumption if we use the FII for the households. This is because, in the construction of the FII for the different households, there is no presumption that all individuals in a given household suffer from the same degree of food insecurity. This important intra-household difference will be neglected if one assumes that all individuals within a household suffer from the degree of food insecurity specified by the FII for the household as a whole.

It may seem that the ideal procedure would be to measure the degree of food insecurity of each individual in each household and then to aggregate the food insecurity indices of all the individuals to arrive at the overall social food insecurity level. We do not have such data for individuals, but, even if such data were available, the appropriateness of this procedure will depend on what we are seeking to measure through the food insecurity index for the society. The food insecurity index, constructed in this fashion, will reflect the deprivation that the individuals suffer themselves. However, it will not reflect the "external diseconomy" that the children of a household may

suffer by watching their parents suffer from hunger, although the children themselves may not be hungry. Nor would it be able to distinguish between the deprivations of two mothers both of whom have to go hungry but only one of whom has to see the hunger of her children as well.

In any case, the CFSM does not give us information about individuals. Thus, one has two options. One can aggregate the food insecurity indices for the households, ignoring the size differences between the different households. Alternatively, one can assume that the food insecurity index for any given household measures the extent of food insecurity of each individual belonging to the household; one can then aggregate these individual food insecurity levels to arrive at the social food insecurity. Each of these two procedures involves conceptual problems. In the case of the second option, the construction of the food insecurity measure is designed to portray household rather than individual food insecurity.[5] Thus, to assign the household-level food insecurity measure to each individual would be ascribing information to the measure that it was not designed to portray. Hence, we have chosen to use the first option and aggregate the food insecurity indices for the households. In the process, we are ignoring household size. (We are breaking the analyses down by whether or not children are present so household size is controlled for to some extent.) While household size is one determinant of food insecurity, its effect in multivariate settings is generally either insignificant or small in magnitude in comparison to other factors. (See, e.g., Dunifon and Kowaleski-Jones, 2003; Gundersen et al., 2003; Ribar and Hamrick, 2003.)

[5] The only exception is households with one individual. There, ofcourse, the household and the individual are the same.

3.2 Data

We use data from the CFSM in the Food Security Supplement that has been fielded with the CPS each year since 1995. The CPS is administered to a sample of approximately 50,000 households each month. The Food Security Supplement used in this paper was collected in August 1998 and refer to the 12 months previous to the survey. We apply weights in our analysis such that the CPS is representative of the nation as a whole.

4 Empirical analysis

In this section we discuss the empirical findings of our paper. Tables 2 and 3 contain the food insecurity rates under the four measures discussed above (the headcount, the food insecurity gap, the squared food insecurity gap, and the Sen food insecurity measure). In Table 2, the results are for households with children and, in Table 3, the results are for households without children. Tables 4 and 5 contain the rates of food insecurity with hunger for households with children and households without children respectively. One important reason for separating out households with children and without children is that the scale of FI is different in each of these categories. In each table, we list food insecurity under the different measures for all households and we also break these into various demographic characteristics of note. We find that food insecurity is statistically significant for all the demographic categories in these tables.[6] For expositional reason, we multiply all our food insecurity measures by 100 in what follows.

[6] To calculate the standard errors, which are required to test for significance, we have used the methods provided in Kakwani (1993) for the Foster et al. (1984) class of measures; for the Sen (1976) class of measures we have used the bootstrap methods (see Osberg and Xu, 2001).

4.1 Food insecurity for households with children

As seen in Table 2, for households with children, the head count measure of food insecurity is 14.19, the food insecurity gap is 3.73, the squared food insecurity gap is 1.39, and the Sen food insecurity measure is 5.03. The results for the various demographic categories are generally as expected. Households with characteristics associated with higher poverty rates also have higher food insecurity under all the measures. For example, the head count is 28.95 and the squared food insecurity gap is 3.09 for households headed by someone with less than a high school education while the figures are 9.04 and 0.92 for households headed by someone with at least some college education. The only surprise is for the breakdown of households by poverty status. Under the head count measure, food insecurity rates are actually higher among households with incomes between 100 and 200 percent of the poverty line than among households with incomes below the poverty line. For the better-off households, the head count is 22.10 and for households below the poverty line it is 19.21. This finding, though, is reversed when we use the squared food insecurity gap where the figures are 1.98 and 2.24.[7] One conclusion from this is that while the incidence of food insecurity may be higher in these slightly better-off households, the depth of food insecurity is worse in the poor households. The finding of higher food insecurity rates for households above the poverty line is also consistent with studies showing that current income is not always a good predictor of food insecurity (e.g., Gundersen and Gruber, 2001). With the exception of income, the ordering of categories is robust to choice of food insecurity measure. For example, homeowners have lower food insecurity levels than renters across all four measures — 8.62 versus

[7] In this and all succeeding discussions of differences, unless otherwise noted, we only consider differences significant at the 95 percent confidence level.

26.25 for the head count, 2.07 versus 7.30 for the food insecurity gap, 0.72 versus 2.84 for the squared food insecurity gap, and 2.81 versus 9.80 for the Sen food insecurity measure.

[Table 2 about here]

Our wider array of food insecurity measures enables us to comment on previous work on how parents protect their children, especially the youngest children, from food insecurity (Nord and Bickel, 2001). We find that food insecurity rates are higher for families with children under the age of 6 — 14.92 versus 14.19. However, we find that the squared food insecurity gap for households with children under 6 are lower than for all households with children, 1.24 versus 1.39. Thus, it may be that households with small children are more likely to prevent their children from suffering from more severe food insecurity but not from more mild levels of food insecurity.

4.2 Food insecurity for households without children

In Table 3 we present the results for households without children. The head count measure for all households in this category is 6.95, the food insecurity gap is 2.79, the squared food insecurity gap is 1.57, and the Sen food insecurity measure is 3.76. The breakdown of results by categories, presents further evidence as to the insights that can be drawn when we move beyond the simple head count of food insecure households. For all common demographic categories, the percentage of food insecure households is substantially higher for households with children in comparison to households without children. As an example, in non-Hispanic white households with children, the head count measure is 10.47 and in non-Hispanic white households without children, it is 5.38. This ordering often changes when

we look at our other measures, especially the squared food insecurity gap which gives more weight to those suffering from higher levels of food insecurity. Considering again, households headed by a non-Hispanic white person with children, the squared food insecurity gap is 1.03 whereas it is 1.20 for households without children. Or, for example, renters with children have a head count of 26.25 and renters without children have a head count of 13.71 but for the squared food insecurity gap, the figures are 2.84 and 3.40.

[Table 3 about here]

4.3 Food insecurity and hunger

In Tables 4 and 5, we present our results for food insecurity with hunger. As in Tables 2 and 3, these are broken down by whether households have children and broken down further by various demographic categories. By definition, the rates of food insecurity with hunger will be lower than the rates of food insecurity because all households suffering from food insecurity with hunger also suffer from food insecurity but the converse is not true. In Table 4, the extent of food insecurity with hunger is presented for households with children. The head count measure for all households in this category is 2.55, the food insecurity gap is 0.69, the squared food insecurity gap is 0.28, and the Sen food insecurity measure is 0.95. Across all categories, the ordering is the same for all food insecurity measures. For example, high school graduates have higher levels of food insecurity than households headed by someone with at least some college education. In two instances, however, the differences are statistically significant for the head count, food insecurity gap, and the Sen food insecurity measure but not for the squared food insecurity gap. This happens in comparisons of high school graduates with households headed by someone with at least some college education and in comparisons

of non-Hispanic blacks with Hispanics. In the latter comparison, the head count measure for households headed by a non-Hispanic black person is 5.10 and it is 3.74 for families headed by a black person. But for the squared food insecurity gap the figures are 0.57 and 0.52 and this difference is not statistically significant.

[Table 4 about here]

In Table 5, we present the food insecurity with hunger measures for households without children. The head count measure for all households in this category is 1.74, the food insecurity gap is 0.93, the squared food insecurity gap is 0.66, and the Sen food insecurity measure is 1.22. As occurred to a lesser extent in the food insecurity measure, the food insecurity with hunger measures are lower for households without children in comparison to households with children when one examines the head count measure but are higher when one examines many of the more sensitive measures. As an example, in households with children the food insecurity with hunger head count measure is 1.97 in households headed by a non-Hispanic white person and is 1.31 in households without children and headed by a non-Hispanic white person. For the food insecurity gap, however, the order is reversed, with figures of 0.54 and 0.70.

[Table 5 about here]

5 Conclusions

We moved beyond the simple head count measure of food insecurity in this paper and proposed three measures of food insecurity, along the lines of new poverty measures (Zheng ,1991) and explained the desirable properties these

measures have that the head count measure does not possess. We then applied these food insecurity measures to the official statistics used to derive the extent of food insecurity in the United States. We found that conclusions about certain aspects of food insecurity in the U.S. do differ depending on whether one uses just the head count measure of food insecurity or if one uses the measures we develop that reflect the depth and severity, in addition to the incidence, of food insecurity.

Building on the work of this paper, there are many directions for future research. First, in the U.S., other data sets could be used besides the CPS to examine what new insights are possible when multiple food insecurity measures are used. Second, these food insecurity measures could be applied to household-based food security measures in developing countries. Given the greater depth of food insecurity in comparison to the U.S., food insecurity measures that incorporate the depth and severity along with the prevalence of food insecurity would seem to be especially important. Third, in this paper we have created food insecurity measures based on two sets of income poverty measures — the Foster, Greer, and Thorbecke and the Sen measures. More generally, there are numerous other income poverty measures that may be justifiable as food insecurity measures. Finally, we have examined the aggregate food insecurity measure by aggregating the standard food insecurity index (which is based on the Rasch score) for each household. It would be interesting to see how the results change when we use different measures of household food insecurity.

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Table 1: The 1998 Household Food Insecurity Scale by the Number of Affirmative Responses in the Core Food Security Module of the Current Population Survey

Households with children		Households without children		Food Security Question Associated with the Modal Number of Affirmative Responses
Number of affirmative responses	Food Indicator (FI)	Number of affirmative responses	Food Indicator (FI)	
1	1.30	1	1.72	Worried food would run out
2	2.56	2	3.10	Food bought did not last
3	3.41	3	4.23	Respondent not eat balanced meals
4	4.14			Child fed few, low-cost foods
5	4.81	4	5.24	Adult cut/skip meals
6	5.43			Child not fed balanced meals
7	6.02	5	6.16	Respondent eat less than should
8	6.61	6	7.07	Adult skip meals, 3+ months
9	7.18			Child not eating enough
10	7.74	7	8.00	Respondent hungry but did not eat
11	8.28	8	8.98	Respondent lost weight
12	8.79			Child meal size cut
13	9.31	9	10.15	Adult not eat for whole day
14	9.84			Child hungry
15	10.42	10	11.05	Adult not eat for whole day, 3+ months
16	11.13			Child skipped meal
17	12.16			Child skipped meal, 3+ months
18	13.03			Child not eat for whole day

Table 2: The Extent of Food Insecurity For Households with Children in 1998

	Head Count	Food Insecurity Gap	Squared Food Insecurity Gap	Sen Food Insecurity Measure
All households	14.19(0.27)	3.73(0.09)	1.39(0.05)	5.03(0.12)
Income of household, percent of poverty line				
≤ 100	19.21(0.54)	5.54(0.19)	2.24(0.11)	7.44(0.25)
> 100 and ≤ 200	22.10(0.69)	5.57(0.21)	1.98(0.11)	7.48(0.30)
> 200	7.07(0.32)	1.57(0.09)	0.52(0.04)	2.13(0.12)
Education of household head				
Less than high school education	28.95(0.91)	7.99(0.32)	3.09(0.18)	10.70(0.42)
High school graduate	15.91(0.49)	3.95(0.15)	1.40(0.08)	5.32(0.20)
At least some college education	9.04(0.30)	2.41(0.10)	0.92(0.05)	3.26(0.13)
Homeownership status:				
Homeowners	8.62(0.26)	2.07(0.08)	0.72(0.04)	2.81(0.11)
Renters	26.25(0.60)	7.30(0.21)	2.84(0.12)	9.80(0.29)
Race-ethnicity of household head				
Non-Hispanic White	10.47(0.28)	2.72(0.08)	1.03(0.05)	3.70(0.12)
Non-Hispanic Black	25.91(0.96)	7.00(0.32)	2.68(0.18)	9.44(0.44)
Hispanic	24.39(0.98)	6.52(0.32)	2.40(0.18)	8.62(0.41)
Non-Hispanic Other	15.50(1.25)	3.70(0.35)	1.17(0.015)	4.85(0.45)
Household composition				
Wife and husband	9.04(0.26)	2.13(0.07)	0.70(0.03)	2.85(0.10)
Single person	26.27(0.62)	7.46(0.22)	3.00(0.13)	10.08(0.30)
Households with child(ren) under age 6	14.92(0.41)	3.68(0.12)	1.24(0.06)	4.88(0.16)

Notes: The standard errors are in parentheses. The standard errors for the Headcount, the Food Insecurity Gap and the Squared Food Insecurity Gap have been calculated using the methods in Kakwani (1993). The standard errors for the Sen Food Insecurity Measure have been calculated using the bootstrap method.

Table 3: The Extent of Food Insecurity For Households without Children in 1998

	Head Count	Food Insecurity Gap	Squared Food Insecurity Gap	Sen Food Insecurity Measure
All households	6.95(0.15)	2.79(0.07)	1.57(0.61)	3.76(0.93)
Income of household, percent of poverty line				
≤ 100	13.62(0.46)	5.96(0.25)	3.64(0.19)	8.04(0.32)
> 100 and ≤ 200	10.80(0.42)	4.12(0.19)	2.21(0.14)	5.54(0.25)
> 200	4.17(0.16)	1.58(0.07)	0.83(0.05)	2.11(0.10)
Education of household head				
Less than high school education	12.72(0.45)	4.90(0.22)	2.78(0.17)	6.71(0.28)
High school graduate	6.92(0.26)	2.78(0.12)	1.54(0.09)	3.72(0.16)
At least some college education	4.87(0.18)	2.03(0.09)	1.16(0.06)	2.71(0.12)
Homeownership status				
Homeowners	3.82(0.13)	1.39(0.06)	0.73(0.04)	1.88(0.08)
Renters	13.71(0.35)	5.82(0.18)	3.40(0.14)	7.80(0.24)
Race-ethnicity of household head				
Non-Hispanic White	5.38(0.14)	2.14(0.07)	1.20(0.05)	2.88(0.09)
Non-Hispanic Black	15.53(0.69)	6.67(0.36)	3.97(0.28)	8.96(0.47)
Hispanic	15.05(0.92)	5.69(0.43)	3.08(0.31)	7.71(0.58)
Non-Hispanic Other	9.86(0.92)	3.70(0.42)	2.02(0.31)	5.03(0.57)
Household composition				
Wife and husband	3.07(0.15)	1.04(0.06)	0.52(0.04)	1.41(0.09)
Single person	9.94(0.23)	4.14(0.11)	2.39(0.09)	5.55(0.15)
Households with elderly persons				
Households with elderly persons	4.60(0.20)	1.57(0.08)	0.78(0.06)	2.13(0.11)
Households without elderly persons	8.26(0.20)	3.47(0.10)	2.02(0.07)	4.65(0.13)

Notes: The standard errors are in parentheses. The standard errors for the Headcount, the Food Insecurity Gap and the Squared Food Insecurity Gap have been calculated using the methods in Kakwani (1993). The standard errors for the Sen Food Insecurity Measure have been calculated using the bootstrap method.

Table 4: The Extent of Food Insecurity with Hunger For Households with Children in 1998

Variable	Head Count	Food Insecurity Gap	Squared Food Insecurity Gap	Sen Food Insecurity Measure
All households	2.55(0.12)	0.69(0.04)	0.28(0.03)	0.95(0.06)
Income of household, percent of poverty line				
≤ 100	4.41(0.28)	1.24(0.10)	0.54(0.07)	1.71(0.14)
> 100 and ≤ 200	3.44(0.30)	0.88(0.09)	0.33(0.05)	1.20(0.13)
> 200	0.79(0.11)	0.23(0.04)	0.09(0.02)	0.31(0.05)
Education of household head				
Less than high school education	5.61(0.46)	1.56(0.16)	0.69(0.11)	2.17(0.23)
High school graduate	2.51(0.21)	0.63(0.07)	0.24(0.04)	0.86(0.09)
At least some college education	1.73(0.14)	0.48(0.05)	0.20(0.03)	0.65(0.06)
Homeownership status				
Homeowners	1.20(0.10)	0.32(0.03)	0.13(0.02)	0.44(0.05)
Renters	5.46(0.31)	1.49(0.11)	0.63(0.07)	2.05(0.15)
Race-ethnicity of household head				
Non-Hispanic White	1.97(0.13)	0.54(0.04)	0.21(0.02)	0.73(0.06)
Non-Hispanic Black	5.10(0.48)	1.39(0.16)	0.57(0.10)	1.88(0.23)
Hispanic	3.74(0.43)	1.06(0.16)	0.52(0.12)	1.50(0.23)
Non-Hispanic Other	1.89(0.47)	0.34(0.10)	0.09(0.03)	0.44(0.13)
Household composition				
Wife and husband	1.09(0.10)	0.27(0.03)	0.09(0.01)	0.36(0.04)
Single person	5.97(0.33)	1.68(0.12)	0.73(0.08)	2.32(0.17)
Households with child(ren) under age 6	2.04(0.16)	0.48(0.05)	0.18(0.03)	0.66(0.07)

Notes: The standard errors are in parentheses. The standard errors for the Headcount, the Food Insecurity Gap and the Squared Food Insecurity Gap have been calculated using the methods in Kakwani (1993). The standard errors for the Sen Food Insecurity Measure have been calculated using the bootstrap method.

Table 5: The Extent of Food Insecurity with Hunger For Households without Children in the United States in 1998

Variable	Head Count	Food Insecurity Gap	Squared Food Insecurity Gap	Sen Food Insecurity Measure
All households	1.74(0.08)	0.93(0.05)	0.66(0.04)	1.22(0.06)
Income of household, percent of poverty line				
≤ 100	4.14(0.27)	2.42(0.18)	1.81(0.16)	3.11(0.22)
> 100 and ≤ 200	2.71(0.25)	1.52(0.16)	1.09(0.14)	1.95(0.20)
> 200	0.91(0.77)	0.44(0.04)	0.29(0.04)	0.58(0.06)
Education of household head				
Less than high school education	3.10(0.23)	1.73(0.15)	1.27(0.13)	2.25(0.18)
High school graduate	1.61(0.13)	0.85(0.08)	0.60(0.07)	1.12(0.10)
At least some college education	1.32(0.09)	0.69(0.06)	0.48(0.05)	0.90(0.07)
Homeownership status				
Homeowners	0.77(0.06)	0.39(0.04)	0.27(0.03)	0.51(0.05)
Renters	3.84(0.20)	2.10(0.12)	0.82(0.11)	2.74(0.16)
Race-ethnicity of household head				
Non-Hispanic White	1.31(0.07)	0.70(0.04)	0.49(0.04)	0.91(0.05)
Non-Hispanic Black	4.32(0.39)	2.49(0.25)	1.84(0.22)	3.21(0.32)
Hispanic	3.61(0.48)	1.75(0.27)	1.15(0.23)	2.28(0.35)
Non-Hispanic Other	2.28(0.46)	1.18(0.28)	0.83(0.25)	1.54(0.37)
Household composition:				
Wife and husband	0.55(0.06)	0.26(0.04)	0.17(0.03)	0.35(0.05)
Single person	2.66(0.12)	1.45(0.08)	1.03(0.07)	1.89(0.10)
Households with elderly persons:				
Households with elderly persons	0.77(0.08)	0.38(0.05)	0.25(0.04)	0.50(0.06)
Households without elderly persons	2.28(0.11)	1.24(0.07)	0.88(0.06)	1.62(0.08)

Notes: The standard errors are in parentheses. The standard errors for the Headcount, the Food Insecurity Gap and the Squared Food Insecurity Gap have been calculated using the methods in Kakwani (1993). The standard errors for the Sen Food Insecurity Measure have been calculated using the bootstrap method.