Hunger and the Demands for Cheap Dietary Staples of the Extreme Poor

Ramses Y. Armendariz*

July 29, 2021

Abstract

I construct a tractable structural model of a poor household's demand for cheap dietary staples, which characterizes the trade-offs that the household faces between satiating hunger and satisfying other needs when it spends its scarce resources on food. I use this model to extrapolate the equivalent variation, the willingness to pay, and the dead-weight loss of Jensen and Miller's (2008) price subsidy experiment on cheap dietary staples among the extreme poor (figure 1). I also use this model to extrapolate Pareto improving policies relative to their subsidy treatment (figure 5) and to measure the impact of their experimental subsidy on some indicators of access to food (figure 6). Finally, I use this model to extrapolate the demands for dietary staples from Jensen and Miller's price elasticity estimates (figure 4) and the indifference curves of their experiment subjects (figure 3).

Key words: hunger, staples, inferior goods, Giffen behavior, Giffen utility, structural demand

JEL Classification: D12, I31, O12

1 Introduction

Governments and international organizations often manipulate the prices of dietary staples in an attempt to mitigate hunger among the extreme poor. In this paper, I construct a fully specified structural model of a poor household's demand for cheap dietary staples — as defined by Low and Meghir (2017) — that enables us to measure the economic impacts of that kind of policies, and I use it to measure the welfare effects of the experimental price subsidy on dietary staples shown in Jensen and Miller (2008).[1]

*University of Illinois at Urbana-Champaign. email: ramses@illinois.edu. Revised versions of the paper can be found here: https://www.drarmendariz.com/research.

[1] Jensen and Miller (2008) document the effect on quantity consumed caused by their subsidy treatment among extreme poor households. They do not report the welfare effects of their experiment nor provide a model that can be used to account for those effects.

To understand the contribution of this project, it is natural to ask, why do we need a structural model to measure these welfare effects, specially when it is common practice to approximate the welfare effects of price changes using the change in consumer surplus (i.e., measuring the change in area underneath the demand as it is done in Willig (1976))? My answer to this question is that this practice is not appropriate when dealing with changes in price of cheap dietary staples, because the wealth effects of these price changes on consumers are large and non-monotone. Moreover, in the particular case of Jensen and Miller's experiment, it is not viable to measure the change in consumer surplus because Jensen and Miller document strictly positive price elasticities in some instances, but it is not possible to measure the change in consumer surplus using upward-sloping demands. Therefore, in order to measure these welfare effects, it is more adequate to use an alternative technique, like simulating a structural model.

Structural models are used to compute the welfare effects of price changes because they enable us to simulate counterfactuals that compare the changes in price with hypothetical cash transfers, where the size of these cash transfers serve as the unit of measurement for the welfare effects. There are some structural demand models that have been used to estimate welfare effects of price changes in the literature as, for example, Deaton and Muellbauer (1980) and Banks et al. (1997). Those models characterize a generic household that satisfy some empirical restriction as, for example, accounting for non-linear Engel curves. The model I am presenting in this paper, in contrast, not only accounts for some of the empirical particularities observed in the demands for food among the extreme poor as, for example, some of the demands for dietary staples are upward-sloping and calories are an inelastic normal good, it also characterizes a theory that justifies the results of the counterfactuals.

The theory of the demands for cheap dietary staples that I propose in this paper is formalized in the model that I construct in section 2 of this paper. This demand model is the optimal policy of a household that maximizes a Cobb-Douglas utility function between two characteristics that food commodities provide: hunger satiation and flavor. Hunger satiation is the difference between total caloric intake and a level of calories that makes the feeling of hunger become unbearable while flavor is an abstract characteristic that consumers enjoy. To obtain these characteristics, households must go to the markets to buy a dietary staple, which I call bread from now on, and a superior composite food, which I call meat. Bread and meat are perfect substitutes at the provision of caloric intake; meat, however, is the only source of flavor. This utility function, therefore, models a household that faces a trade-off between satiating its feeling of hunger and enjoying flavor, and this trade-off rationalizes indifference curves that follow the so-called "elbow shape", the shape that textbooks use to portray indifference-curves maps when they explain upward-sloping demands.[2]

[2]In section 3, I extrapolate the indifference curves of poor households in each Chinese region. A textbook example of the elbow-shape indifference curves is Figure 1.19 in Jehle and Reny (2011). Jensen and Miller (2008) show examples of these curves in their paper and appendix. Neither Jehle and Reny nor Jensen and Miller show a utility function that

Intuitively, this model argues that lowering income of poor households increases the scarcity of the calories available to consume, and this increment in scarcity strengthens their feeling of hunger. To mitigate this feeling, households are motivated to increase their dependence on the cheapest source of calories, the dietary staple, resulting in Giffen behavior for some of them. Mathematically, the feeling of hunger is modeled as an Inada condition on the amount of calories that makes this feeling become unbearable.[3] This Inada condition makes the marginal utility of calories grow unbounded as caloric intake gets closer to the quantity that makes the feeling of hunger become unbearable. This large growth in the marginal utility of calories makes the household prioritize calories over flavor. Therefore, as caloric intake drops, households increase their dependence on the cheapest source of calories, which is the staple. In summary, this model characterizes a hypothesis of how poor households would react to changes in prices and income when they face the feeling of hunger.

The hypothesis that this model characterizes departs from the standard one. The standard hypothesis in Economics sustains that subsistence constraints shape the demands for dietary staples among the poor. That hypothesis argues that sufficiently poor households would like to starve, but they face a subsistence constraint that denies this possibility (e.g., see van Marrewijk and van Bergeijk (1990) and Gilley and Karels (1991)). The standard hypothesis, therefore, characterizes a questionable micro-foundation, mainly because it goes against survival instincts.[4] Furthermore, while we have not been able to support the existence of subsistence constraints empirically, the standard hypothesis also ignores the role of hunger, which is a primal behavioral aspect that has driven our search for food since we were conceived, in these demands. The model I present in this paper brings attention to the role of hunger in the demands for dietary staples, because it models how suffering from this feeling affects the trade-offs that poor households face when they allocate their scarce resources on food commodities.

The model I am presenting has two mathematical properties that I exploit in the rest of this paper. First, this model is consistent with the standard assumptions of the Neoclassical Consumer Theory. That is, the utility function of the household is strictly increasing, strictly quasi-concave, and continuously differentiable. This property enables me to extrapolate "two well-known measurements of welfare change originating in Hicks (1939), the *Equivalent Variation* (EV) and the *Compensating Variation* (CV)", using the standard techniques shown in textbooks.[5] Second, this model is tractable. The tractability of my model enables me to present all the functions I employ in closed form and facilitates the estimation process and the simulation of the counterfactuals shown in this paper.[6]

rationalizes their indifference curves.

[3]The Inada condition is a consequence of the Cobb-Douglas utility.

[4]Davies (1994) argues that subsistence constraints are not consistent with survival instincts.

[5]Microeconomics textbooks impose these assumptions when deriving EV and CV. In this paper, I follow pp. 80 - 83 in Mas-Colell et al. (1995) to derive these measurements.

[6]This latter property makes this paper suitable to teach different analytical tools of Eco-

In section 3 of this paper, I use Jensen and Miller's price elasticity estimates to calibrate my model. To derive their estimates, Jensen and Miller develop a controlled experiment in which they randomly assign price subsidies on dietary staples to extreme poor households in two Chinese regions, Hunan and Gansu, and they use these exogenous price changes to estimate the price elasticity of the household demand for dietary staples in each region. To calibrate my model, I choose the values of the parameters that enable my model to account for the price elasticities that Jensen and Miller document.

In section 4, I use the calibrated version of my model to extrapolate the household's demand for dietary staples. This extrapolation shows a u-shape relationship between price and quantity demanded, which explains why it is difficult to document Giffen behavior, even with randomized controlled experiments. This difficulty arises because the pre-intervention price can be located in two places: either where the demand is downward-sloping, or where it is upward-sloping. If it is located where the demand is downward-sloping, no subsidy treatment will capture Giffen behavior, even though the demand function becomes Giffen at some point. On the other hand, if the pre-intervention price is located where the demand is Giffen, a large enough subsidy treatment will fail to capture Giffen behavior as well. Therefore, estimating negative price elasticites is not sufficient to rule-out Giffen behavior. Moreover, according to my model, the staple becomes a normal good at very low prices; thus, estimating a positive income elasticity is not sufficient to rule out Giffen behavior either. Instead, Giffen behavior is rather a consequence of the properties and prices that the staple has relative to other food commodities, where the other commodities are perceived as superior because they not only feed calories, but satisfy other wants that the staple does not, like flavor.[7]

Also in section 4, I extrapolate the demand for total caloric intake and calculate the income elasticity of calories in both regions using this demand. In this exercise, I find that the income elasticity of calories is 0.105 in Hunan and 0.347 in Gansu. These predicted values are consistent with the consensus that calories are an inelastic normal good among the extreme poor.[8]

In section 5, I use my model to derive the Hicksian demands, the indirect utility, and the expenditure function; and I use these derivations to construct three measures of welfare: the *Equivalent Variation*, the *Compensating Variation*, and the *dead-weight loss*. The *Equivalent Variation* is the size of the lump-sum transfer of cash that is equivalent in terms of utility gain to a policy that changes the price of the dietary staple. The *Compensating Variation* (or

nomics at a wide range of levels because its results are not challenging to replicate. In my Predictive Analytics course at the University of Illinois, for example, students use this paper to learn how to calibrate non-linear models and use those models to simulate counterfactuals.

[7] Giffen behavior for dietary staples was questioned empirically prior the publication of Jensen and Miller (2008). The main claim was that there is no robust empirical evidence of its existence other than some anecdotal comments. Some examples that questioned its existence are Stigler (1947), Rosen (1999), and Nachbar (1998).

[8] Subramanian and Deaton (1996) estimates an income elasticity between 0.3 and 0.5 in India, while Santeramo and Shabnam (2015) argues that calories are income inelastic using a meta-analysis.

Welfare Effects of Jensen and Miller's (2008) Experiment in China

Region	Price Subsidy (Treatment)	Equivalent Variation	Compensating Variation (Willingness To Pay)	Deadweight Loss
Hunan	08.33 %	02.95 %	03.05 %	0.02 %
	16.66 %	05.78 %	06.14 %	0.10 %
	25.00 %	08.50 %	09.29 %	0.27 %
Gansu	09.61 %	03.33 %	03.36 %	0.08 %
	19.23 %	06.80 %	06.88 %	0.38 %
	28.84 %	10.46 %	10.59 %	1.02 %

- Jensen and Miller's experiment has three treatment levels. Each treatment level is a price subsidy amount. I report them as %.
- The price subsidies are 0.10, 0.20, and 0.30 Yuan/jin, where 1 jin = 500 g. (p. 1559, Jensen and Miller, 2008).
- The average pre-intervention price was 1.20 Yuan/jin in Hunan and 1.04 Yuan/jin in Gansu. (p. 1559, Jensen and Miller, 2008).
- The equivalent variation is the size of the lump-sum transfer of cash that is equivalent to the price subsidy.
- All welfare effects are measured as a % of food expenditure per household pre-intervention.
- Examples of how to read this table:
  - Transferring 8.5% of the household's food expenditure in cash is equivalent to subsidizing the price of the staple by 25% in Hunan.
  - Households in Gansu are willing to pay up to 6.88% of their current food expenditure to see a subsidy of 19.23% on the price of their dietary staple being implemented.
  - Implementing a 16.66% subsidy on the price of the dietary staple in Hunan induces a per household dead-weight loss of 0.1%.

Figure 1: Summary of Main Findings

willingness to pay) is the size of the lump-sum transfer of cash that a household would have to make after the price of its dietary staple has changed to remain indifferent to its original state. Finally, the *dead-weight loss* is the difference between the resources spent at implementing the price subsidy and their Equivalent Variation. The welfare effects of Jensen and Miller's price subsidy treatments are summarized in Figure 1.

In Economics, it is a principle that price subsidies induce dead-weight losses. One implication of this principle is that an alternative policy (as, for example, a lump-sum transfer) can benefit more agents using the same amount of resources, without making any of the original beneficiaries of the price subsidy worse off. Without a model that enables us to compare the real income effects of alternative policies, however, it is not possible to know which alternative policies are Pareto improving relative to the price subsidy. In this paper, I use my model to calculate the number of households that could have been benefited had Jensen and Miller's treatment been a lump-sum transfer using the same amount of resources. I find that up to 93 more households would have been benefited had the experimental resources been spent on lump-sum transfers rather than a price subsidy (without making the original subjects of the experiment worse off). This number represents about 9.5% of the subjects that were treated. A summary of this analysis is located in Figure 5 located in section 5.

There are several studies that document the cost-effectiveness of policies that reduce the prices of dietary staples.[9] One application of those studies is to evaluate the impact on food security that those policies have. To calculate that

[9] Alderman et al. (2017) and Shrinivas et al. (2018) are two examples of that growing literature.

impact, researchers often construct indicators that measure the level of access to food and see how these indicators change as the policy is implemented. The model I propose in this paper provides a framework that enables the construction and interpretation of three indexes that measure the access to food among the extreme poor: the real food expenditure (measured in terms of staple calories), a food price index, and the real price of non-staple calories (measured in terms of the price of staple calories). In Figure 6, I show the impacts that Jensen and Miller's experiment had on the access to food of their subjects. This figure is located in section 5.

My attempt at modeling the demands for dietary staples among the extreme poor is not a novel proposition. In fact, attempts at constructing such a model can be traced back to Marshall (1895), the father of Neoclassical Economics, and the publication of the Slutsky (1915) equation.[10] As part of those attempts, a few models were created that are consistent with the Slutsky equation, but their theoretical connection with the demands for dietary staples of the extreme poor is not tight.[11] In contrast, the model I present in this paper strengthens this connection by arguing that the particularities seen in the demands for dietary staples are a consequence of the efforts of the extreme poor to mitigate their suffering from the evil of hunger.

To conclude this paper, in section 6, I present my final remarks.

2 Hunger as a behavioral micro-foundation

In this section, I use Lancaster (1966) approach to consumer theory to construct a structural model of a poor household's demand for dietary staples. I start this construction by characterizing the preferences of the household for food commodities, which embeds the feeling of hunger as a behavioral micro-foundation and explains how the feeling of hunger affects the elasticity of substitution across food commodities.

The household preferences are characterized by the following utility function:

$$u(b, m) = [\alpha_b b + \alpha_m m - \bar{c}]^{\beta} [\delta m]^{1-\beta} \tag{1}$$

where b is the quantity of bread (the cheap dietary staple) consumed, α_b is the calories that each unit of bread provides, m is the quantity of meat consumed (a composite food commodity that embeds all the others sources of calories), α_m is the calories that each unit of meat provides, $\bar{c}$ is the caloric level that makes the feeling of hunger become unbearable, δ is the amount of flavor that each unit

[10] Stigler (1947) provides a brief history of how the dialectics on the demand for dietary staples started. Hicks and Allen (1934) shows that Neoclassical Consumer Theory can be used to construct such a model using the Slutsky Equation.

[11] Most models of Giffen behavior (i.e., strictly positive demand elasticities) available in the literature have little or no theoretical connection with the demands for dietary staples among the poor. E.g., see Sørensen (2007), Doi et al. (2009) Heijman and von Mouche (2012), and Biederman (2015). Those models mostly focus on showing concrete examples of utility functions that rationalize an upward-sloping demand, a feature that is mathematically challenging to achieve, not on formalizing hypotheses of the demands of dietary staples.

of meat provides, and β is a parameter between zero and one and represents the importance of satiating hunger in the preferences of the household. Thus, $\alpha_b b + \alpha_m m$ is total caloric intake, $\alpha_b b + \alpha_m m - \bar{c}$ is hunger satiation, and δm is flavor.[12]

In the interior of its domain, this utility function is strictly increasing, strictly concave, and continuously differentiable. It satisfies Inada conditions in meat, while the marginal utility of bread is finite when the amount of bread is zero, and it approaches zero as the quantity of bread grows. Therefore, when the household maximizes this utility function subject to its budget constraint, $p_b b + p_m m \leq i$, there are two types of solutions: either the solution is interior or the household spends all its income on meat.[13] The interior solution is characterize by a system of two equations: the budget constraint holding with equality and the ratio of marginal utilities equalized to the ratio of prices. After solving this system of equations, we find the demand for bread in closed-form:

$$b = \frac{i\left[\beta\alpha_b p_m - p_b\alpha_m\right] + p_m p_b\left(1-\beta\right)\bar{c}}{p_b\left(\alpha_b p_m - p_b\alpha_m\right)} \tag{2}$$

where p_b is the price of bread, p_m is the price of meat, and i is income.

3 Calibrating the household demand

In this section, I calibrate the parameters of the structural demand model I construct in section 2 that enable the model to account for the demand elasticities that Jensen and Miller (2008) document with their randomized experiment.

The model I am calibrating is shown in equation 2, where b is the quantity demanded for bread (the cheap dietary staple). Jensen and Miller (2008) measure the quantities consumed of food in calories. Therefore, I calibrate the model so that the units of measurement of bread and meat are calories. That is, I fix $\alpha_m = \alpha_b = 1$. With this change, the model becomes:

$$b = \frac{i\left[\beta p_m - p_b\right] + p_m p_b\left(1-\beta\right)\bar{c}}{p_b\left(p_m - p_b\right)} \tag{3}$$

To substitute for income in this model, first, I use Walras Law, which is a consequence in this model. Thus, I substitute for the income using this equation: $i = p_b b + p_m m$, where b is the calories consumed from the staple while

[12] I choose the names bread and meat for historical reasons. In the Giffen paradox, Marshall (1895) mentions that bread is the cheap food of the poor, and meat is a superior food that the poor stop consuming as the price of bread increases.

[13] When the households specialize their consumption on meat, it does not imply that they stop eating the dietary staple. It could be that they stopped consuming the cheapest version of the staple and upgraded to one that is perceived as better quality. Also, notice that the Problem of the Household is not characterized for the case when $i/p_b < \bar{c}$. This is not a mathematical problem though. The utility function can be extended to include this case as it is done in my PhD thesis (Armendariz, 2016). In this extension, the household's priority shifts to maximize caloric intake when they are sufficiently poor. Thus, there is no trade-off between satiating hunger and satisfying other wants.

Model Calibration Summary

	Calibrated Parameters			Sample Moments			
Region	β	$\bar{c}$	p_m	**calories per capita**	**household average size**	**HSCS**	**Elasticity (ATE)**
Hunan	0.059	4,897.91	3.107	1,805	2.85	0.640	+ 0.235
Gansu	0.173	3,711.77	4.182	1,710	2.75	0.685	− 0.353

- The sample moments are taken from Table 1 and Table 3 in Jensen and Miller (2008).

Figure 2: Calibration Summary

m is the amount of calories consumed from all the other sources. Second, I use table 1 in Jensen and Miller (2008) to find the quantities consumed for b and m before the treatment is implemented. Specifically, table 1 says that total caloric intake per-capita in Hunan is 1,805; the average size of the household is 2.85 members; and the household staple calorie share (HSCS) is 0.64. Thus, the quantities consumed before the treatment is implemented in Hunan are: $b_0 = 1,805\,(2.85)\,(0.64)$ and $m_0 = 1,805\,(2.85)\,(1-0.64)$. Third, I normalize the whole model in terms of the price of calories coming from the staple before the experimental intervention. That is, $p_{b0} = 1$. Hence, the income of the representative household in Hunan becomes $i = 1,805\,(2.85)\,(0.64 + p_m\,(1-0.64))$.

Finally, I calibrate $\beta, \bar{c}$ and p_m that enable the model to account for the demand elasticities that Jensen and Miller (2008) document. That is, the values of the parameters are such that they solve this system of four equations:

$$i = 1,805\,(2.85)\,(0.64 + p_m\,(1-0.64)) \tag{4}$$

$$1,805\,(2.85)\,(0.64) = \frac{i\,[\beta p_m - (1)] + p_m\,(1)\,(1-\beta)\,\bar{c}}{(1)\,(p_m - (1))} \tag{5}$$

$$1,805\,(2.85)\,(0.64)\,(1+0.00235) = \frac{i\,[\beta p_m - (1.01)] + p_m\,(1.01)\,(1-\beta)\,\bar{c}}{(1.01)\,(p_m - (1.01))} \tag{6}$$

$$1,805\,(2.85)\,(0.64)\,(1-0.00235) = \frac{i\,[\beta p_m - (0.99)] + p_m\,(0.99)\,(1-\beta)\,\bar{c}}{(0.99)\,(p_m - (0.99))} \tag{7}$$

The left-hand side of equation (5) is the quantity demanded for b prior the price change according to the data. The left-hand side of equation (6) shows the quantity demanded of b after its price increases 1% according to Jensen and Miller's elasticity estimate, and (7) shows the quantity demanded of b after its price decreases 1%. The right-hand side of equation (5) is the quantity demanded that the model predicts when the price of the staple $p_b = 1$, which is the number inside the parenthesis. Similarly, the right-hand side of equation (6) is the quantity demanded that the model predicts when the price of the staple increases by 1%. That is, when $p_b = 1.01$. And the right-hand side of equation (7) is its equivalent when the price of the staple drops by 1%.

Figure 2 shows the values of the calibrated parameters and the values of the sample statistics in Hunan and Gansu. To obtain the values in Gansu, I followed an analogous process. According to this figure, the calibrated value of the price index p_m is 3.107 in Hunan. Since the price of the dietary staple is normalized to 1, this price index says that the price of calories coming from all other sources is 3.107 times the price of calories coming from the staple. Also, this calibration provides a value for $\bar{c}$, which is a novel feature that this model presents. Previews models of the demand for dietary staples were based on the assumption that poor households face a "subsistence constraint," which is a level of caloric intake that households cannot go under even when they would prefer to do so. In contrast, according to my model, $\bar{c}$ is a caloric level that households are not willing to go under. That is, they prefer to avoid consuming this level of calories, whenever this option is possible. Thus, they adapt their diets to stay as far as possible from this caloric level while preserving nutritional variety.

3.1 Indifference curves of the households

Plugging the values shown in Figure 2 into the utility function of the household (Equation 1), enables me to extrapolate the indifference curves of the households in each Chinese region. This indifference curves are shown in Figure 3, and it shows how the indifference curves follow the so-called elbow shape.

Notice that, at each given quantity of calories consumed from non-staple sources, the indifference curves get closer to each other as the quantity consumed of staple calories drops. This happens because total caloric intake is dropping while the consumption of flavor is not increasing. Therefore, the marginal utility of both commodities (b and m) increases, which graphically means that the indifference curves get closer to each other. Also notice that the indifference curves flatten out and approach a straight line as the indifference curves get closer to each other. That straight line that they approach is $\alpha_b b + \alpha_m m = \bar{c}$, which characterizes the set of bundles that provide the quantity of calories $\bar{c}$ (the quantity that makes the feeling of hunger become unbearable), and this is how this model characterizes the feeling of hunger. As caloric intake gets closer to that line, the marginal utility of consuming food increases, which is motivated by a strengthening in the feeling of hunger.

4 Extrapolating the demands

In this section, I extrapolate the demands for dietary staples and for total caloric intake in both regions.

To extrapolate the demands for dietary staples in both regions, I plug the values found in 2 into the Equation 3, and then I find the quantity demanded for the staple at different prices. The result of this exercise is shown in Figure 4.

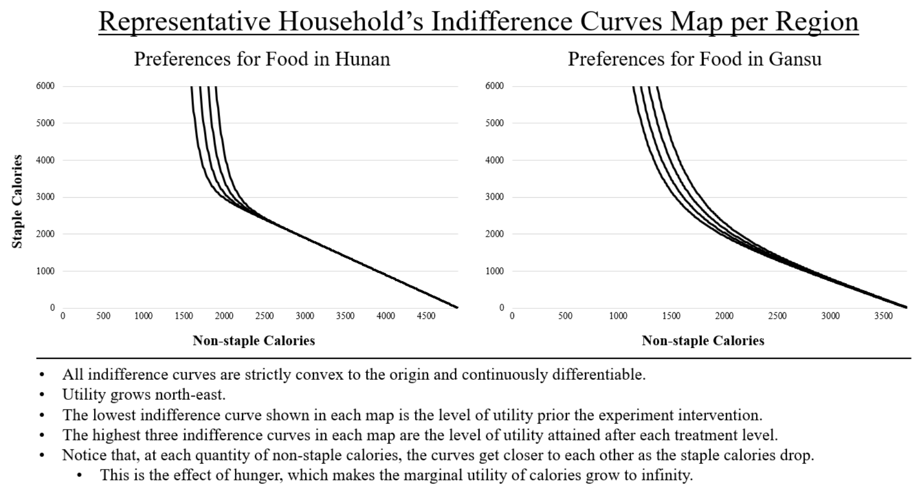

Figure 3: Indifference Curves Maps

This figure shows a u-shape relationship between the price of the staple and its quantity demanded when the price of the staple is mapped on the X-axis, opposed to how it is taught in Principles courses. This implies that, at low prices of X, the Law of Demand holds, while this Law falls apart at high prices. When deriving equation 3 with respect to i, it shows that the staple is a normal good at sufficiently low prices, and it becomes inferior as its price increases.

In this same figure, the price of the staple pre-intervention is normalized to 1. Thus, according to that Figure, the pre-intervention price in Hunan is located in the Giffen zone while in Gansu it is located in the downward-sloping section.

To derive the demands for total caloric intake, first, I derive the demand for meat, the non-staple composite food, using the utility function shown in Equation 1. After I fix $\alpha_m = \alpha_b = 1$ to show that quantities consumed are measured in calories, the demand for meat becomes:

$$m\left(p_m, p_b, i\right) = \left(\frac{i - p_b \bar{c}}{p_m - p_b}\right)(1 - \beta) \tag{8}$$

Second, since total caloric intake is $b + m$, I add Equations 3 and 8 to find the demand for total caloric intake:

$$Cal = \left(\frac{i\beta}{p_b}\right) + \bar{c}\,(1 - \beta) \tag{9}$$

Using the demand for calories, I calculate the income elasticity of calories following this rule:

$$\frac{\frac{\partial Cal}{Cal}}{\frac{\partial i}{i}} = \frac{i\beta}{i\beta + p_b \bar{c}\,(1 - \beta)} \tag{10}$$

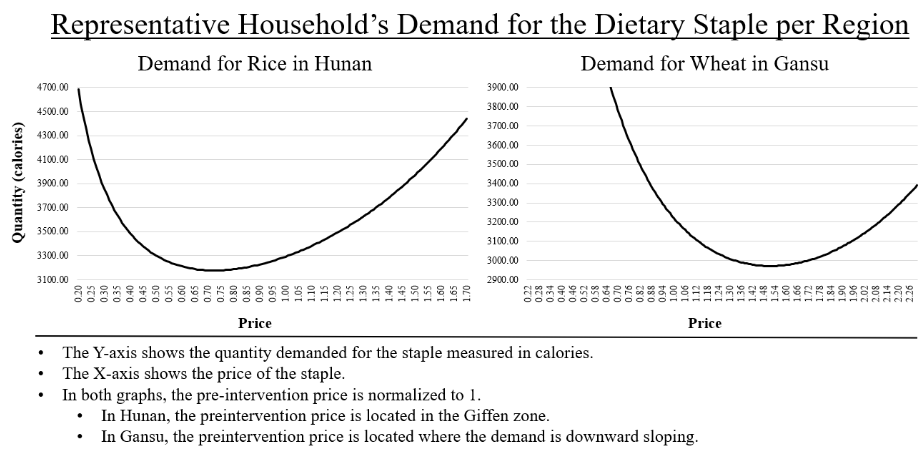

Figure 4: Household's Demand for Dietary Staples in each Chinese Region

After plugging the values from figure 2 into the last equation, my findings for the income elasticities are 0.103 in Hunan and 0.347 in Gansu. These values are consistent with the standard view that calories are an inelastic normal good among the extreme poor who face severe caloric scarcity.

5 Extrapolating the Welfare Effects

In this section, I extrapolate the Equivalent Variation, the Compensating Variation (also known as willingness to pay), and dead-weight loss of Jensen and Miller's price treatments. To achieve this, I follow the standard procedure shown in Mas-Colell et al. (1995), which is done in five steps.

First, I derive the indirect utility function:

$$v\left(p_b, p_m, i\right) = \left(\frac{\beta}{p_b}\right)^{\beta} \left(\frac{1-\beta}{p_m - p_b}\right)^{1-\beta} \left(i - p_b \bar{c}\right) \tag{11}$$

Second, I derive the Hicksian demands:

$$b^H = \bar{u}\left[\frac{\beta - (1-\beta)\,P}{\beta^{\beta}\left(1-\beta\right)^{1-\beta} P^{1-\beta}}\right] + \bar{c} \tag{12}$$

$$m^H = \bar{u}\left(\frac{1-\beta}{\beta}\right)^{\beta} P^{\beta} \tag{13}$$

where $P = \frac{p_b}{p_m - p_b}$ is the price index of food according to this model.

Third, I derive the expenditure function:

$$e\left(P, \bar{u}\right) = p_b \bar{u}\left[\frac{\beta - (1-\beta)\,P}{\beta^{\beta}\left(1-\beta\right)^{1-\beta} P^{1-\beta}}\right] + p_b \bar{c} + p_m \bar{u}\left(\frac{1-\beta}{\beta}\right)^{\beta} P^{\beta} \tag{14}$$

Number of Households Benefited from Each Policy

Region	Treatment Level	Price Subsidy	Lump-Sum Transfer	Lump-Sum Transfer (Maximum Beneficiaries)
Hunan	08.33 %	162	163.22	183
	16.66 %	162	164.91	162
	25.00 %	159	164.11	159
Gansu	09.61 %	162	165.92	234
	19.23 %	162	171.05	162
	28.84 %	162	177.84	162

- The column *treatment level* shows different sizes of price subsidies.
- The column *price subsidy* shows the numbers of households assigned to each treatment level in the experiment.
  - e.g., 159 households in Hunan were treated with a subsidy of 25% on the price of their dietary staple.
- The column *lump-sum transfer* shows the number of households that could have been benefited had the treatment been a lump-sum transfer rather than a price subsidy using the same amount of resources per treatment level.
  - e.g., the amount of resources that were spent to implement a subsidy of 28.85% on the price of the dietary staple in Gansu could have equally benefited 177 households with a lump-sum transfer without making any of the 162 original recipients of the price subsidy any worse off.
- The last column shows a Pareto improving allocation relative to the experimental price subsidy that maximizes the number of beneficiaries assuming that no new household can be worse off than any of the original subjects treated with the low subsidy.

Figure 5: Pareto Improving Policies relative to Experiment Treatment

Fourth, I use the indirect utility function to calculate the level of utility attained before and after the price of the dietary staple has changed. I will use sub-index zero to indicate prior the policy intervention and sub-index one after the intervention.

Fifth, I use the expenditure function to compute the Equivalent Variation (EV), the Compensating Variation (WTP), and dead-weight loss (DWL). The formulas for each are

$$EV\left(P_0, P_1, i\right) = e\left(P_0, \bar{u}_1\right) - i \tag{15}$$

$$WTP\left(P_0, P_1, i\right) = i - e\left(P_1, \bar{u}_0\right) \tag{16}$$

$$DWL\left(P_0, P_1, i\right) = \left(p_{b0} - p_{b1}\right) b\left(p_{b1}, p_m, i\right) - EV\left(P_0, P_1, i\right) \tag{17}$$

The EV extrapolates the size of a hypothetical lump-sum transfer of cash that is equivalent in terms of utility to a policy that changes the price of the staple. This implies that the EV is a measure of the opportunity cost of the resources spent at implementing the price subsidy. This is why it is used to measure the DWL.

The results of these exercises are summarized in figure 1. This figure shows that the WTP is higher than the EV at all treatment levels, and it also shows that the difference between the WTP and EV increases with the treatment size.

5.1 Pareto Improving Policies

The dead-weight loss that Jensen and Miller's price subsidy treatments induce imply that there are alternative uses of those resources that are Pareto improv-

Access to Food Indicators: Impacts of the Experiment on the Access to Food

Region	Treatment	Real Expenditure	Food Price Index	Real Price of Non-staple Calories
Hunan	00.00 %	09,045.90	0.475	3.107
	08.33 %	09,315.88	0.418	3.389
	16.66 %	09,579.05	0.367	3.728
	25.00 %	09,840.78	0.318	4.142
Gansu	00.00 %	09,415.43	0.314	4.182
	09.61 %	09,737.76	0.276	5.324
	19.23 %	10,092.48	0.239	5.957
	28.84 %	10,497.64	0.205	6.761

- The column *Treatment* shows the price subsidy as a percentage, where 00.00% stands for no subsidy (i.e., the pre-intervention state).
- The *real expenditure* uses the prices of food pre-intervention and the quantities demanded after the intervention predicted by the model.
  - Real expenditure is measured in staple calories.
  - e.g., the model accounts that 10,092.48 staple calories is the real expenditure after a 19.23 % price subsidy is implemented in Gansu.
- The *food price index* is derived from the Hicksian demands. See that section to learn how to derive the food price index formula.
  - Notice that the value of this index drops as the price subsidy gets larger in each region.
- The real price of non-staple calories is $\frac{p_m}{p_b}$, where p_m is the calibrated price for non-staple calories, and p_b is the price of staple calories.

Figure 6: Impacts of the Experiment Treatment on the Access To Food

ing. In this section, I use my model to extrapolate two of those Pareto improving allocations. These allocations compute the potential number of households that could have been benefited had the treatment resources been spent on a lump-sum transfer of cash rather than a price subsidy.

Figure 5 shows the results of this exercise. This figure has four columns. The first column shows the size of the treatment from Jensen and Miller's experiment. The second column shows the number of households treated. The third column shows the number of households that could have been treated had the treatment resources been spent on a lump-sum transfer of cash per treatment level. For example, figure 5 shows that 162 households were treated with the largest treatment level in Gansu, while almost 178 households could have been benefited with the same amount of resources. Finally, the fourth column shows a policy that maximizes the largest number of beneficiaries without making any of the original price subsidy treatments worse-off.

5.2 Access To Food Indicators

According to figure 2, the calibrated value of the price index p_m is 3.107 in Hunan. Since the price of the dietary staple is normalized to 1, this price index says that the price of calories coming from all other sources is 3.107 times the price of calories coming from the staple; and, consequently, it enables us to compute the real expenditure in food measured in staple calories. This is done by plugging the value of p_m in equation 4. This computation tells us that the average household in the experiment has a real food expenditure of 9,045.90 calories coming from the staple in Hunan prior the policy intervention.

A price subsidy on the dietary staple induces the household to change its optimal consumption bundle. When the new consumption bundle is evaluated at the original prices (the prices before the subsidy was implemented), we find the real food expenditure of the household. For example, with an 8.33% price subsidy on the dietary staple in Hunan, the real food expenditure of the household becomes 9,315.88 staple calories measure at prices prior the policy intervention.

A price subsidy on the dietary staple also increases the price of the non-staple calories relative to the price of the staple (i.e., the real price of non-staple calories). For example, with an 8.33% price subsidy on the dietary staple in Hunan, the real price of non-staple calories becomes 3.389 staple calories.

Finally, the Hicksian demands derived previously provide functions that compute price indexes of food according to the theory that this model characterizes. Specifically, $P = \frac{p_b}{p_m - p_b}$ is the price index of food according to this model.

Figure 6 shows the impacts on the access to food that Jensen and Miller's (2008) price subsidy experiment induced.

6 Concluding Remarks

This paper shows how to extrapolate the welfare effects that Jensen and Miller (2008) induced with their price subsidy experiment conducted in China. The values of the welfare effects are reported in Figure 1.

To achieve this, this paper constructs a micro-founded structural model of the demand for dietary staples that enables us to simulate counterfactuals. This model also enables us to extrapolate economic indicators like the price index of non-staple calories, which represents the trade-off that poor households face when allocating their scarce resources in food, and the real expenditure in food measured in staple calories.

Finally, the model in this paper formalizes a theory of the trade-offs that poor households face between satiating the feeling of hunger and satisfying other wants. This formalization is consistent with the Neoclassical Consumer Theory, which enables this model to follow standard techniques to measure welfare effects.

References

Alderman, H., Gentilini, U., and Yemtsov, R. (2017). *The 1.5 billion people question: food, vouchers, or cash transfers?* The World Bank.

Armendariz, R. (2016). Essays on giffen behavior and international trade.

Banks, J., Blundell, R., and Lewbel, A. (1997). Quadratic engel curves and consumer demand. *Review of Economics and statistics*, 79(4):527–539.

Biederman, D. K. (2015). A strictly-concave, non-spliced, giffen-compatible utility function. *Economics Letters*, 131:24–28.

Davies, J. E. (1994). Giffen goods, the survival imperative, and the irish potato culture. *Journal of Political Economy*, 102(3):547–565.

Deaton, A. and Muellbauer, J. (1980). An almost ideal demand system. *The American economic review*, 70(3):312–326.

Doi, J., Iwasa, K., and Shimomura, K. (2009). Giffen behavior independent of the wealth level. *Economic Theory*, 41(2):247.

Gilley, O. W. and Karels, G. V. (1991). In search of giffen behavior. *Economic Inquiry*, 29(1):182–189.

Heijman, W. and von Mouche, P. (2012). A child garden of concrete giffen utility functions: A theoretical review. In *New Insights into the Theory of Giffen Goods*, pages 69–88. Springer.

Hicks, J. R. (1939). Value and capital (london: Oxford university press).

Hicks, J. R. and Allen, R. G. (1934). A reconsideration of the theory of value. part ii. a mathematical theory of individual demand functions. *Economica*, 1(2):196–219.

Jehle, G. and Reny, P. (2011). Advanced microeconomic theory (third). *Essex: Pearson Education Limited*.

Jensen, R. T. and Miller, N. H. (2008). Giffen behavior and subsistence consumption. *American Economic Review*, 98(4):1553–77.

Lancaster, K. J. (1966). A new approach to consumer theory. *Journal of Political Economy*, 74(2):132–157.

Low, H. and Meghir, C. (2017). The use of structural models in econometrics. *Journal of Economic Perspectives*, 31(2):33–58.

Marshall, A. (1895). Principles of economics.

Mas-Colell, A., Whinston, M. D., and Green, J. R. (1995). *Microeconomic theory*, volume 1. Oxford university press New York.

Nachbar, J. H. (1998). The last word on giffen goods? *Economic Theory*, 11(2):403–412.

Rosen, S. (1999). Potato paradoxes. *Journal of Political Economy*, 107(S6):S294–S313.

Santeramo, F. G. and Shabnam, N. (2015). The income-elasticity of calories, macro-and micro-nutrients: What is the literature telling us? *Food Research International*, 76:932–937.

Shrinivas, A., Baylis, K., Crost, B., and Pingali, P. (2018). Do staple food subsidies improve nutrition. *Unpublished manuscript. Retrieved from http://barrett. dyson. cornell. edu/NEUDC/paper_520. pdf*.

Slutsky, E. (1915). Sulla teoria del bilancio del consumatore. *Giornale degli economisti e rivista di statistica*, pages 1–26.

Sørensen, P. N. (2007). Simple utility functions with giffen demand. *Economic Theory*, pages 367–370.

Stigler, G. J. (1947). Notes on the history of the giffen paradox. *Journal of Political Economy*, 55(2):152–156.

Subramanian, S. and Deaton, A. (1996). The demand for food and calories. *Journal of political economy*, 104(1):133–162.

van Marrewijk, C. and van Bergeijk, P. A. (1990). Giffen goods and the subsistence level. *History of Political Economy*, 22(1):145–148.

Willig, R. D. (1976). Consumer's surplus without apology. *The American Economic Review*, 66(4):589–597.