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Meeting Dietary Needs of Poor Households Under Stress: An Integrated Commodity/Food Group Household Simulation Model

Sherman Robinson

Kristi Mahrt

Emily Schmidt

Channing Arndt

International Food Policy Research Institute (IFPRI)

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Abstract

This paper uses recent work defining healthy diet measures of poverty lines as the starting point for developing household simulation models that operate with a two-level utility function. At the top level, utility is defined in terms of aggregates of food groups and nonfood. There is a vast theoretical and empirical literature specifying and estimating expenditure functions at this level. At the commodity level, behavior is based on a sparse specification of utility, assuming only that observed data sets reflect preferences. This paper uses the linear expenditure system (LES) at the aggregate level. Changes in commodity demand in reaction to shocks (changes in prices and income) are assumed to follow an entropic adjustment procedure that is based on information theory. The resulting two-level LES/entropy household simulation model is implemented with household data on healthy diet poverty lines for Myanmar and Papua New Guinea (PNG). The household models are then shocked with comparable changes in prices and incomes to measure their ability to maintain nutrition standards under stress. The simulation results indicate that poor households operating near the poverty line in the two countries are potentially resilient to negative shocks (prices or incomes) amounting to 11-17 percent of real expenditure. These results indicate that, for these households, policy makers can prioritize groups outside of the resilient range of negative shocks in order to target assistance to households with unmanageable stress on diets.

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Introduction

There is a large and active literature on defining and measuring minimum levels of income, consumption, and nutrients necessary to meet basic needs. The idea is to describe poverty lines based on the consumption behavior of households operating at or near the boundary. The goal of this paper is to use that description to build a simulation model of poor households and then use the model to describe how such households might behave under stress due to a fall in aggregate expenditure or an increase in prices of commodities necessary to meet basic needs. Such a model can be used to provide information to policy makers about the resilience of households near the poverty line in adapting to shocks while maintaining nutrient levels. If, for example, households are resilient to a negative income shock within a known bound, then income and/or price support policies based solely on the poverty line can be relaxed somewhat when faced with a shock within that bound. A goal of this paper is to provide a model that can describe such resilience bounds empirically.

Two approaches to estimating the cost of nutritious diets are widely used in the literature. The first uses linear programming (LP) models to identify least-cost, nutritionally adequate, diets at the level of commodities. From the perspective of providing the basis for a useful household simulation model, the LP models are deeply flawed. They generate unrealistic results, with optimal solutions that include few commodities and diets that are dramatically different from observed data. In spite of some efforts to constrain the LP models to provide more realistic results, they are still ill-suited to provide the basis for a model of actual household behavior.

The second approach is to use survey data on household consumption patterns to provide information about commodity choices that households view as desirable and that should inform the analysis. The observed data are assumed to reflect (reveal) household preferences and so provide information about utility. At the commodity level, the analysis uses very sparse assumptions about utility functions. The focus on basic needs has led to consideration of both food aggregates as well as commodities. In this approach to defining poverty lines, households achieve a desirable "healthy diet" mix of aggregate food groups that meet nutritional standards and mixes of commodities within food groups that are consistent with basic utility theory. Households are assumed to have a two-level utility function that includes food groups as well as commodities.

Moving from defining healthy diet poverty lines to implementing a household simulation model requires a more elaborated view of consumer behavior consistent with economic theory. At the level of aggregates, demand and utility are described by standard economic models of systems of expenditure equations based on explicit utility functions, drawing on an extensive theoretical and empirical literature. At the commodity level, we retain the sparse utility assumptions of the poverty-line literature and assume that consumers adjust their commodity composition of food groups in a manner consistent with an information-theoretic model of behavior. The result is an integrated household simulation model of both commodity and food group demand.

We start from healthy diet poverty line measures developed for different categories of households in two countries, Myanmar and Papua New Guinea (PNG).[1] The measures describe nine representative households (five in Myanmar and four in PNG) operating at the poverty level and the simulation model is implemented for all of them. The model is then used to explore the

[1] The poverty line measures for these countries are described in Mahrt et al. (2022) and Schmidt et al. (2022).

resilience of these households to shocks, including a fall in their aggregate expenditure and increases in various commodity prices.[2] The results provide empirical information about the bounds of shocks to which households can adjust while maintaining nutrient standards.

Methodology: Two-Level Utility and Demand

Estimating Poverty-Line Households

We start from a procedure for estimating poverty levels that is very sparse in its assumptions about utility functions and commodity demand behavior. The method is called the Poverty Line Estimation Analytical Software (PLEASe).[3] The approach works at the commodity level and uses an estimation procedure based on information theory. The fundamental behavioral assumption is that households choose commodity bundles they prefer (formally, maximizes utility) and so household survey data provide information about those preferences. The information content of observed food bundles is defined by using an entropy measure and the data provide a prior for a Bayesian-like estimation procedure.[4]

The household survey data on consumption and prices are noisy and involve many problems of measurement error. In defining poverty lines, additional information is included in the estimation procedure in the form of constraints. The first is to standardize the households by their demand for calories, which defines an energy-adequate poverty line (PLEASe-energy). The second is to ensure that the different households satisfy minimal constraints on consistency arising from utility theory: the data must satisfy the property of revealed preference. The observed bundle must be preferred to any other bundle that the household could purchase at given prices. Utility consistency is achieved by adding revealed preference constraints in the estimation model.

In PLEASe-energy poverty line estimation, the priors on commodity expenditure shares are adjusted given information in the form of constraints on meeting energy (calorie) standards and utility consistency to provide a posterior distribution of shares that is entropy close to the prior.[5] The method preserves, to the greatest extent possible, the information content of the base data. The estimation procedure is "efficient" in the sense that it uses all the information available (theoretical and observed), while it does not assume any information that is not available.[6]

In a recent paper, Mahrt et al. (2022) extend the PLEASe estimation procedure by including food groups into the analysis to define healthy diets using data for Myanmar. Schmidt et al. (2022) use the same methodology using data for PNG. In the new healthy-diet, poverty-line model, food shares in the objective function are expressed in terms of quantity shares both of commodities within food groups and of food groups in total consumption. Implicitly, consumers are assumed

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[2] Throughout this paper, we assume that aggregate expenditure is exogenous and do not consider how it might be financed (e.g., changes in income, savings, wealth, and/or borrowing).

[3] Early work using this approach is described in Arndt and Simler (2007, 2010). Arndt and Mahrt (2017) and other chapters in Arndt and Tarp (2017) describe the PLEASe methodology in detail. .

[4] The underlying information theory using an entropy measure is based on work by Claude Shannon (1948). Golan, Judge, and Miller (1996) discuss the theory and present applications to estimation in economics. The links to Bayesian estimation are discussed in detail in Jaynes (2003).

[5] The entropy measure is the Kullback-Leibler relative entropy measure, also called informational distance or cross-entropy. See Golan (2018), Chapter 3, for a discussion of the underlying theory. There are theoretical links between the use of minimum cross entropy and empirical likelihood estimation—see Judge (2021), p. 151.

[6] See Zellner (2002) who defines the concept of an efficient information processing rule drawing on both information theory (Shannon entropy) and Bayes Theorem.

to care about food groups as well as commodities in making consumption decisions—a two-level utility function.[7]

In defining poverty lines, the model is constrained to match both calories and recommended food group quantities. In practice, the addition of constraints on food groups to define a healthy diet yields nutrient results that are largely consistent with standard recommendations. It is feasible to include constraints in the model to set bounds on nutrients as well as calories, but generally not necessary when food groups are constrained.

The equations of the healthy-diet PLEASe model are:

$$\min_{q_{i_f r}, s_{ir}^{ent}} \sum_r \sum_f \sum_{i_f} s_{i_f r}^{ent} \, ln\left(\frac{s_{i_f r}^{ent}}{s_{i_f r}^{orig}}\right) \qquad (1)$$

subject to:

$$\sum_f \sum_{i_f} p_{i_f r} * q_{i_f s} \ \geq \ \sum_f \sum_{i_f} p_{i_f r} * q_{i_f r} \qquad \forall\, r, s \quad r \neq s \qquad (1a)$$

$$\sum_{i_f if} q_{i_f r} = g_f \qquad \forall\, i_f, r, f \qquad (1b)$$

$$s_{i_f r}^{ent} \sum_{i_f'} q_{i_f' r} = q_{i_f r} \qquad \forall\, i_f, r, f \qquad (1c)$$

$$\sum_f \sum_{i_f} calpg_{i_f} \, q_{i_f r} = cal \qquad \forall\, r \qquad (1d)$$

$$0 \leq s_{i_f r}^{ent} \leq 1, \, q_{i_f r} \geq 0, \, q_{ir} \geq 0 \qquad \forall\, i_f, r \qquad (1e)$$

Where:

$q_{i_f r}$	variables representing quantities consumed in food group f;
$s_{i_f r}^{ent}$	variables representing quantity shares of the reference bundle in food group f;
$s_{i_f r}^{orig}$	parameters representing initial quantity shares of the reference bundle in food group f;
g_f	parameters representing the average recommended quantities for food group f.
f	index of food groups;
i_f, i_f'	indices of goods in the consumption bundle of food group f; and
r, s	indices of domains across space.

The objective function is the Kullback-Leibler cross entropy measure. Condition 1a ensures that revealed preference conditions are satisfied across regions. Condition 1b defines entropy budget shares of commodities by food group, $s_{i,r}^{ent}$, as a function of the modified quantities, q_{ir}, and imposes the constraint that the food group quantities are fixed at target levels (g_f). Condition 1c defines food group quantity shares. Condition 1d constrains the basket to attain caloric requirements (cal), which are held constant across regions.

In the Myanmar and PNG studies, following the standard approach to estimating the cost of basic needs poverty lines, the priors on quantities are first adjusted by an iterative scaling procedure that generates data that is close to the equality constraints. This procedure yields a new prior for

[7] Note that food markets and cafeterias are always organized by food groups, which indicates that consumers approach commodity choices at two levels.

the cross-entropy estimation procedure that includes those constraints exactly and also imposes utility consistency.[8]

The result of the estimation procedure is a set of standard consumption bundles (defined by region in the case of Myanmar and by household survey sample area in the case of PNG) that have the same calorie consumption and composition of demand by food groups, and also satisfy utility consistency, but have very different commodity consumption bundles and different monetary values of total consumption. These bundles can be viewed as describing nine representative poor households (four in PNG and five in Myanmar) with different commodity bundles but the same level of basic needs (or welfare) in terms of nutrition and food group demand.

Two-Level Household Simulation Model

The next step is to move from defining a collection of poor households at the same poverty level to a model that simulates their behavior. We start with the PLEASe model assumption that households operate with a two-level utility function with preferences over food groups and commodities.[9] The approach we take is to add to the healthy-diet model a set of expenditure functions that specify the demand for food groups as a function of their prices and aggregate expenditure. Operationally, we replace the fixed food group constraints in equation 1b with a system of demand equations based on utility theory. We use the linear expenditure system (LES) that is derived from the Stone-Geary utility function.[10] The expenditure system is:

$$P_c Q_c = P_c \gamma_c + \beta_c \left(Y - \sum_c P_c \gamma_c \right)$$

P and Q are prices and quantities, the first term on the right is committed expenditure (the γ parameters are sometimes called “subsistence minima”) and the second term in parentheses is discretionary or supernumerary income (income above committed expenditure). The β parameters are marginal expenditure shares out of discretionary income. While there are many demand systems in use in empirical studies, the LES has a number of features that make it attractive for this household simulation model:

- The LES system is relatively easy to parameterize and calibrate. The parameters can be estimated by a variety of approaches that take advantage of available data, statistical methods, and prior information about parameters.
- The specification of committed expenditure is closely linked to poverty line estimates. The specification that some income is committed for fixed expenditures is consistent with the behavior of poor households operating near the poverty line.

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[8] The iterative scaling procedure is closely related to the RAS method for balancing input-output coefficient matrices. Mathematically, the iterative scaling procedure in the RAS method can be shown to be an entropy-theoretic estimation procedure. The iterative scaling procedure used in the PLEASe model is analogous and should also be an entropy-based estimator. See Bacharach (1970.

[9] We also implicitly assume that the healthy diet food groups are seen as desirable. In fact, many households with similar incomes choose unhealthy diets. We are assuming that these representative households pay attention to the advice of nutritionists.

[10] See Varian (1992) and Stone (1954) for a discussion of the LES system. Lluch, Powell, and Williams (1977) is a seminal work applying the LES system in developing countries.

- A natural extension of the LES model is to assume that consumers might wish to adjust their use of discretionary income (beta parameters) in order to meet nutrient needs when under stress.
- The LES system is widely used in economic simulation models, particularly computable general equilibrium (CGE) models. It would be feasible to link the household demand model with CGE models that endogenize prices and incomes.

The integrated healthy diet household simulation model consists of the equations of the PLEASe healthy-diet model and the LES expenditure functions that determine the demand for aggregates. There are a few other changes:

- An additional aggregate commodity, nonfood, is added to the model so that the expenditure system is complete in that it includes all household demand. The nonfood item is estimated as the value of nonfood expenditure from surveys of household near the poverty line, and so has an exogenous price equal to 1 in the model. There is no need for a corresponding disaggregated commodity.
- The "real" variables—quantities and shares—are defined as in standard economic models by valuing solution quantities in base prices. This approach does not require defining standard quantities for food groups, as is done in the PLEASe healthy-diet model.[11]
- The objective function includes real expenditure shares at the commodity level within food groups where real quantities are defined in base prices.
- The model drops the revealed preference constraints, which were satisfied as part of the poverty line estimation procedure for the base data. Utility consistency and the utility basis for the combined model are now specified by the LES demand system, which assumes utility maximization.
- The model allows the option of specifying the marginal budget shares (β) as choice variables for the consumer. In this case, the marginal budget shares are included in the objective function to minimize their entropy deviation from the initial shares as priors and/or can be constrained by lower and upper bounds.

The integrated model specifies the prices of commodities (and of the nonfood aggregate) as exogenous. The prices of food group aggregates are endogenous and will change as the commodity composition of the food groups changes. These aggregate prices are the prices used in the LES demand system. Consumer behavior operates at both the commodity and aggregate levels. At the commodity level, the household is assumed to seek to maintain its initial consumption shares, which are viewed as desirable. Adaptive behavior by the household is to deviate as little as possible from the initial position, using the cross-entropy measure.[12] At the commodity level, there is no need to specify an explicit utility function, only that consumers chose their initial bundles and wish to maintain them under stress. At the level of aggregates

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[11] In the PLEASe-healthy-diet model applied to Myanmar and PNG, household expenditure and food consumption quantities are expressed in per-adult-woman equivalents per day, with different ages in the two countries.

[12] There is a growing literature on the use of the entropy concept as descriptive of adaptive processes in many fields, including economics. For a discussion of its use in economics, see Judge (2021). For examples from other fields, see various chapters in Chen et al. (2021): e.g., chapters 5 and 6, John Harte on ecology and Ariel Caticha on physics.

(food groups and nonfood), consumers are assumed to maximize a particular utility function resulting in the LES expenditure system.

The integrated LES/entropy model includes commodities and aggregates in a unified two-level utility function. Adaptive behavior operates at both levels simultaneously and consistently. An advantage of this approach is that there is no need to make a strong separability assumption about behavior or utility at the two levels.

The integrated model is coded in the GAMS (General Algebraic Modeling System) software.[13] The code is flexible in that a variety of constraints can be implemented.[14] In the cases where the model sets bounds on quantities (e.g., nutrient constraints), we specify scaled multiplier variables that are bounded between 0 and 1, with a prior that specifies the value of the target in the base data. The variables are included in the objective function, so the model will seek to remain entropy-close to the base priors.

LES/entropy Model Application: Household Response to Shocks

We apply the integrated LES/entropy model to nine poverty-line households defined in Mahrt et al. (2022) and Schmidt et al. (2022) for different regions in Myanmar and household groups in PNG. We parameterize the LES expenditure functions and calibrate the model so that the initial data on food group consumption and prices, plus nonfood consumption, are a solution to the LES model. We then subject the nine households to two kinds of negative shocks: (1) 50 percent increases in prices in Myanmar of commodities in the food groups DGLV (dark green leafy vegetables), other vegetables, and fruits; and in PNG of commodities in the food groups fruits and vegetable, and (2) 15 percent loss of aggregate expenditure in both countries. In the first set, nominal household expenditures remain constant and in the second prices are unchanged.

We consider two adaptation strategies that seek to maintain initial dietary standards, achieving calorie targets and satisfying lower bound constraints for other nutrients. In the first strategy, the LES demand system with fixed parameters determines expenditure on food groups, given the income or price shocks. All further adjustment is at the commodity level, seeking to remain entropy-close to the initial real commodity shares of food groups.

In the second strategy, we assume that, under stress, consumers can choose to vary their marginal expenditure shares of food groups out of discretionary income. In this case, they are moving away from LES utility maximization in a limited way (behavior at the margin) in response to shocks. The changes in marginal expenditure shares are included in the objective function, so they are assumed to desire to stay entropy-close to the original shares in the LES system. In this case, more adjustment at the food-group level allows less adjustment at the commodity composition level.

Which, or what mix, of the two strategies is more realistic depends on views about how households near the poverty line actually behave under stress. In the second strategy, the assumption is that the initial consumption data and the LES system both provide information about demand behavior, and that both might adjust under stress. The adjustment of marginal

[13] An appendix describing the GAMS equations is available on request.
[14] The two PLEASe models are special cases in the code.

expenditure shares in the LES system is similar to the adjustment of commodity real expenditure shares.[15]

The maintenance of the committed expenditure shares in the LES system in both strategies presumes that households are unwilling to adjust these expenditures. The implication is that adaptation that maintains dietary standards in the model is only relevant for modest shocks that would not force households to resort to more extreme changes in demand behavior. Under shocks that lower aggregate expenditure, the model will move in the direction of least-cost diet models while seeking to maintain the starting food group and commodity shares. Empirically, the outer boundaries of the domain of applicability of this empirical simulation model are revealed when it fails—if a shock is too large, the model is infeasible and no possible adjustment maintains dietary standards.

Nine Poverty-Line Households

Commodities, Food Groups, and Nutrients

By construction, the nine households start with the same energy levels (calories) and structure of real demand by food groups. Commodity prices and quantities differ across households. Food group shares and food and nonfood expenditure in base prices are shown in Tables MYN-1 and PNG-1 (five in Myanmar and four in PNG). Nonfood shares differ significantly across households; they are median values from household survey data. Total food expenditures also vary since each household is assumed to achieve the same calorie level but facing different prices.

Tables MYN-2 and PNG-2 provide data on nutrient values for the food groups. There are nutrient coefficients by commodity available for 24 nutrients in both countries. The distribution of nutrients across food groups is generally diversified—many nutrients appear significantly in many food groups. There are some exceptions. Fats and oils in Myanmar and oil in PNG (predominantly derived from coconut milk and byproduct), for example, have few nutrients, but a major share of the supply of lipids and vitamin E. Fruits and vegetables are major sources of micronutrients, while staples are major sources of many nutrients, especially calories and carbohydrates.

When we impose nutrient constraints, we use EAR (Estimated Average Requirement) standards, which are available for 16 of the nutrients (plus calories), and we require that solution consumption bundles meet these EARs. For a few EAR nutrients, some households did not meet the standards in the base data (Tables MYN-8 and PNG-8). In those cases, we lowered the standards to be the observed values, so that the constraints are interpreted as requiring solution diets with no worse nutrient intake than the initial value.[16]

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[15] For an interesting piece, see the story in the Guardian newspaper on how poor customers are adjusting their consumption behavior in a UK grocery store. They appear to be using a mix of the two strategies. https://www.theguardian.com/business/2022/may/23/people-are-under-pressure-the-shop-staff-paying-for-strangers-groceries-or-turning-a-blind-eye-to-theft?CMP=share_btn_link

[16] Since the surveys did not cover food outside the home, it is possible that the missing nutrients were acquired from non-observed foods ("dark" food). The implicit assumption is that, with shocks, households are able to achieve the same level of missing nutrients as in the base data.

The survey data, and the model, includes 124 commodities for Myanmar and 44 for PNG (Tables MYN-3 and PNG-3). The numbers of commodities consumed in each food group for each household are shown in the two tables. The full commodity consumption data includes many zero observations, with households consuming only 33 to 42 different items in Myanmar and 17 to 27 in PNG. There are many examples of foods that are region specific, only consumed by one of the households. In the simulation model, if a consumer does not consume a particular commodity in the base data, it will not do so in any of the simulations.[17]

Linear Expenditure System

Since the nine households are constructed to be essentially identical in being at the poverty line in terms of calories, with the same recommended shares and quantities of food groups, it makes sense to assume that they have very similar utility functions and expenditure functions, even though they face different commodity prices and have different shares of nonfood expenditure. We calibrated nine versions of the linear expenditure system assuming (data presented are available from backup tables):

- They have identical average budget shares by food groups. Nonfood shares vary.
- Total food expenditure varies across the groups since food commodity prices vary and they have the same target calorie levels.
- They have similar shares of committed expenditures (gamma parameters in the LES system) to total expenditures.[18] The share of committed expenditure is around 75% for food groups and 50% for nonfood in Myanmar and 41-45% in PNG. These differ from average budget shares shown in tables MYN-1 and PNG-1.
- They have similar income elasticities of demand for aggregates. Their income elasticities of demand are around 0.7 for food groups and 1.5-1.7 for nonfood.
- They have similar own-price elasticities of demand across households in both countries (around -0.3 for food groups and -0.7 for nonfood).

The LES systems specified for these poverty-line households reflect the high shares of committed expenditures for food and low own-price elasticities that one would expect for poor households. The shares of discretionary expenditure are also small (around 25% in both countries), indicating a limited ability to adjust marginal shares, except for nonfood (where discretionary expenditure is around 55% in both countries).[19]

Adaptation to Price and Income Shocks

We specified four simulations:

(1) PShk: 50% increase in prices of all commodities in the food groups (Myanmar: DGLV (Dark Green Leafy Vegetables), Other Vegetables, and Fruit; PNG: fruits and vegetables). Beta shares are fixed—no adjustment of marginal expenditure shares out of discretionary income.
(2) PShk-Beta: Same as (1) but beta shares are free to adjust.
(3) YShk: 15% cut in total expenditure for all households; beta fixed.

[17] This is a constraint that can be loosened, but requires adjusting the priors in the analysis.
[18] That is, the same Frisch parameter in the LES system.
[19] Note that low own-price elasticities and high shares of committed expenditure make these poor households excellent targets for exploitation by sellers that can achieve a degree of monopoly power.

(4) YShk-Beta: Same as (3) but beta shares are free to adjust.

Table MYN-4 and PNG-4 present simulation results for real aggregates (valued in base year prices). The impact of price increases on total real expenditure for the price-shock simulations (PShk and PShk-beta) ranges from −11 to −13 percent for Myanmar and −11 to −17 percent for PNG. For the income shocks (YShk and YShk-beta) the impact, by construction, is −15 percent for everyone. The price shock hits about 45 percent of total food expenditure for both Myanmar and PNG (Tables MYN-1 and PNG-1), which is serious. The percentage cuts in demand by food groups are all smaller than the cuts in aggregate expenditure in both countries. There is a shift in consumption away from nonfood toward foods in order to maintain nutrient constraints given the shocks.

Adjustment at the level of food commodities is summarized on Tables MYN-5 and PNG-5, which shows the average absolute change in food commodity shares within food groups needed to maintain nutrient standards. For the PShk and YShk simulations, which maintain fixed expenditure shares in discretionary expenditure in the LES system, the adjustments are large and vary widely across food groups and households. While feasible in the sense that the model solves, they do imply major changes in food commodity demands by the households.

When we include the possibility that households can adjust their spending shares out of discretionary income in simulations PShk-beta and YShk-beta, the picture changes dramatically. The average adjustments in food commodity shares are much smaller. Allowing adjustment at the level of the utility-based expenditure functions for aggregates shifts much of the adjustment burden away from food commodities and toward food group and nonfood aggregates.

Tables MYN-6 and PNG-6 show the percentage point changes in expenditure shares by food groups and nonfood. Under the income and price shocks, there is a significant switch away from nonfood to food groups. The values for the “beta” simulations are larger than for the simulations with fixed marginal budget shares.

The decline in nonfood shares generates increases in food group shares. For the price shock, the differences between share changes for staples change sign in Myanmar, with increases for PShk-Beta and decreases for PShk. The shares for the food groups with price increases (DGLV, Other-veg, and Fruit in Myanmar and Vegetables and Fruits in PNG) decrease with beta changes, which allow households to shift more expenditure away from these more expensive food groups and increase their demand for staples.

Tables MYN-7 and PNG-7 show the marginal expenditure shares in the base (which do not change in the PShk and YShk simulations) and the two simulations with beta changes. The nonfood shares fall and the share for staples rises significantly. In the case of the reduced income simulation, the “beta” simulation leads to a much larger shift in demand toward staples (close to two percentage points). The changes for the other food groups are smaller, with a mix of increases and decreases. Overall, the changes in marginal expenditure shares are reasonable and within reach of poor households. The shocks are spread over the food groups in a way that is less disruptive of commodity demand patterns.

Conclusion

The paper describes an integrated commodity/food group household simulation model using a linear expenditure system (LES) at the level of aggregates and an entropy model at the level of commodities. The resulting two-level LES/entropy model is applied to nine households in two countries that operate at the healthy diet poverty level. Adjustments of the magnitudes the model generates in response to serious shocks seem plausible and similar across poor households in both countries. Poor households operating near the poverty line in the two countries are potentially resilient to negative shocks (prices or incomes) amounting to 11-17 percent of real expenditure. As shocks increase, the integrated household model will generate optimal diets that will move in the direction of a least cost diet. It makes much more sense to have a model of household behavior that will, under stress, move in the lease-cost diet direction rather than start from a completely unrealistic least cost solution diet.

One criticism of the definition of a poverty line based on achieving a healthy diet is that the estimated cost is higher than an estimate based on a least-cost diet. Policy makers then face the difficult problem of allocating scarce resources to deal with a larger poverty population (Mahrt et al., 2022). The results from the household simulation model indicate that, for these households, policy makers can prioritize groups outside of the resilient range of negative shocks (around 15%) in order to target households with unmanageable stress on diets.

Successful adaption behavior in these households depends on being able to divert expenditure from nonfood to food. The LES model that determines food group and nonfood demand allows specification of degrees of constraints on committed expenditures, and so provides a good framework for exploring the impact of specifying more detail in nonfood expenditures. In the applications, we specified only one nonfood group. If nonfood is very hard to change (high fixed costs of items like housing, clothing, transportation, medical, education), it is straightforward to tighten the constraints on diverting nonfood expenditure and to expand the number of nonfood groups in the model, given data, to provide a more refined analysis. The result will be that these poor households are less resilient.

In this application, the LES system was calibrated for nine poverty-level households in two countries with the same healthy diets that, by construction, have almost identical utility functions. In other applications, it would be good to estimate the LES system econometrically. In such estimation, however, one should be very aware of the desired domain of applicability of the demand system. Much of the estimation literature has focused on more flexible functional forms that work over wider domains. That is not really relevant for what we want from the demand system in this model. We want a good description of household behavior around the starting point to explore adaptation strategies. We do not need a demand system that is designed to analyze the impact of changes over decades or is valid for large differences in income.

While the LES is convenient for our purposes, there is a vast literature on estimating a variety of expenditure systems. For use in simulation models, an important issue is to be able to specify how households under stress might move off the demand system in order to adapt. The LES supports a very natural way to do that.

By supporting a two-stage demand analysis in a unified LES/entropy model framework, this simulation modelling approach allows us to use any specification of food commodities that is convenient (essentially no limit on number of commodities), and then incorporate the vast body of knowledge in economics on demand at the more aggregated level of food groups and nonfoods.

Finally, this household simulation model, which treats prices as exogenous, is designed to be consistent and linkable with other kinds of simulation models such as computable general equilibrium (CGE) models which simulate the operation of commodity markets and so treat prices as endogenous variables.

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Tables: Myanmar (MYN)

Table MYN-1: Food and Nonfood Expenditure Shares

	Expenditure shares (%), base prices				
Food Groups	**Hills-Mtns**	**DryZone**	**Delta**	**Coastal**	**Yangon**
Staples	15.0	15.1	13.5	11.9	14.6
Pulses	5.2	4.1	3.9	4.9	5.0
Fish-meat-egg	31.1	31.6	29.1	29.6	25.2
Dairy	4.7	6.1	5.6	8.1	8.5
DGLV	8.3	8.1	9.2	10.2	8.5
Other-veg	14.9	14.0	17.9	16.3	14.0
Fruit	10.4	11.2	12.3	9.9	13.9
Fats-oils	4.8	5.4	3.6	4.2	3.2
Other-Food	5.5	4.3	4.8	4.8	7.2
Total food	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Nonfood share of total	26.1	27.1	27.6	20.8	33.3

Table MYN-2: Nutrient Shares in Food Groups for Average Household

	Staples	Pulses	Fish-meat-egg	Dairy	DGLV	Other-veg	Fruit	Fats-oils	Other-Food
kcal	54.24	7.34	8.01	1.86	1.87	3.88	4.95	12.22	5.61
protein	33.11	15.17	25.90	10.30	5.93	5.48	2.43	0.86	0.82
lipid	4.07	3.91	22.29	2.58	1.01	0.98	1.54	60.29	3.34
carbs	71.72	7.36	0.06	0.04	1.32	5.26	6.77	0.10	7.37
calcium	6.14	4.69	17.53	31.93	22.97	9.56	2.84	0.28	4.05
iron	20.71	17.98	17.22	6.18	25.39	7.60	3.22	0.74	0.95
magnesium	26.20	16.76	5.55	4.91	24.23	11.80	7.84	1.07	1.65
phosphorous	34.67	14.92	18.62	8.88	7.15	9.12	3.85	0.85	1.95
potassium	13.67	16.55	8.07	2.41	19.04	22.94	15.58	0.55	1.19
sodium	3.41	3.35	60.27	19.39	6.60	2.30	0.73	0.04	3.90
zinc	40.42	17.67	14.84	5.45	7.05	9.90	2.91	0.82	0.93
copper	32.47	22.08	4.51	2.11	15.11	10.40	11.26	1.43	0.62
manganese	46.02	43.62	0.41	0.27	1.12	7.10	0.77	0.65	0.05
selenium	31.03	2.64	38.39	21.11	1.15	3.16	0.79	0.26	1.47
vitC	1.78	0.67	0.22	0.00	45.46	33.95	17.79	0.00	0.14
thiamin	27.52	25.49	9.34	0.95	12.01	14.19	7.47	1.31	1.71
riboflavin	16.32	9.68	19.49	3.68	28.44	11.65	7.73	0.29	2.73
niacin	39.97	5.57	19.96	4.45	11.33	9.37	6.36	1.92	1.06
vitB6	32.46	10.63	9.32	0.08	16.31	22.65	7.58	0.47	0.50
folate	7.12	39.90	3.97	0.42	23.13	16.72	6.64	1.35	0.76
vitB12	0.00	0.00	61.04	38.07	0.00	0.00	0.00	0.00	0.88
vitA	0.46	0.18	10.23	15.33	53.49	13.23	5.94	0.00	1.14
vitE	1.83	2.94	5.77	0.67	16.25	8.88	8.39	54.53	0.74
vitD	0.00	0.00	62.37	34.84	0.00	0.00	0.00	0.00	2.79

Notes: Rows sum to 100

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Table MYN-3: Number of Commodities by Food group and Household

	Hills-Mtns	DryZone	Delta	Coastal	Yangon
Staples	12	12	13	6	11
Pulses	11	13	9	1	8
Fish-meat-egg	18	14	25	9	24
Dairy	4	6	5	3	5
DGLV	5	6	5	3	5
Other-veg	19	17	16	13	18
Fruit	8	11	9	5	9
Fats-oils	5	4	4	2	4
Other-Food	7	7	8	3	7
Total	**89**	**90**	**94**	**45**	**91**

Notes: Total number of commodities is 124

Table MYN-4: Percent Change in Value of Commodities/Aggregates in Base Prices

		Simulation			
	Household	**PShk**	**PShkBeta**	**YShk**	**YshkBeta**
Food commodities	Hills-Mtns	-9.2	-6.2	-11.5	-8.3
	DryZone	-9.0	-6.8	-11.5	-8.8
	Delta	-10.4	-8.0	-11.4	-8.9
	Coastal	-10.8	-8.3	-12.1	-9.6
	Yangon	-8.8	-6.5	-10.9	-8.4
All goods	Hills-Mtns	-10.7	-10.8	-15.0	-15.0
	DryZone	-10.6	-10.6	-15.0	-15.0
	Delta	-12.3	-12.5	-15.0	-15.0
	Coastal	-12.3	-12.6	-15.0	-15.0
	Yangon	-10.6	-10.8	-15.0	-15.0

Table MYN-5: Average Absolute Percentage Point Change in Commodity Shares in Food Groups

Food Group	Household	PShk	PShkBeta	YShk	YshkBeta
Staples	Hills-Mtns	4.3	0.8	3.3	1.8
	DryZone	4.9	0.5	5.5	1.5
	Delta	3.9	0.9	5.3	1.5
	Coastal	9.5	1.9	15.8	3.2
	Yangon	4.8	1.2	8.1	2.4
Pulses	Hills-Mtns	1.9	1.2	3.9	1.4
	DryZone	1.0	0.2	1.8	0.2
	Delta	1.6	0.6	1.9	0.6
	Yangon	1.1	0.4	1.1	0.5
Fish-meat-egg	Hills-Mtns	8.5	3.8	8.8	4.5
	DryZone	7.1	2.1	8.1	2.4
	Delta	3.0	1.3	2.8	1.2
	Coastal	7.8	3.5	5.4	3.0
	Yangon	1.8	0.8	1.3	0.8
Dairy	Hills-Mtns	0.2	0.3	1.6	0.2
	DryZone	0.8	0.1	1.6	0.1
	Delta	0.8	0.3	0.9	0.3
	Coastal	0.4	0.1	0.7	0.1
	Yangon	1.5	0.6	1.4	0.7
DGLV	Hills-Mtns	1.4	0.9	2.0	1.1
	DryZone	5.1	2.5	2.6	2.9
	Delta	10.0	5.1	6.4	4.9
	Coastal	13.8	8.2	10.3	8.1
	Yangon	8.6	4.0	5.8	4.3
Other-veg	Hills-Mtns	2.2	0.9	2.8	1.1
	DryZone	2.8	0.5	5.2	0.7
	Delta	0.8	0.3	1.1	0.3
	Coastal	2.2	0.9	2.4	0.9
	Yangon	0.5	0.2	0.6	0.2
Fruit	Hills-Mtns	3.7	0.9	7.3	1.4
	DryZone	3.8	0.5	7.0	0.9
	Delta	2.6	0.9	3.4	1.0
	Coastal	6.4	2.2	8.1	2.4
	Yangon	1.5	0.5	1.7	0.7
Fats-oils	Hills-Mtns	0.5	0.2	1.3	0.2
	DryZone	7.8	0.4	16.8	1.0
	Delta	1.3	0.1	2.9	0.3
	Coastal	4.5	0.3	9.5	1.0
	Yangon	1.6	0.3	3.1	0.8

Other-Food	Hills-Mtns	6.2	1.1	14.5	1.7
	DryZone	6.0	0.5	12.4	0.9
	Delta	1.9	0.5	3.2	0.6
	Coastal	4.8	1.8	6.4	1.6
	Yangon	2.9	1.0	3.3	1.3

Table MYN-6: Percentage Point Change in Expenditure Shares by Aggregates

		Simulation			
Aggregates	**Household**	**PShk**	**PShkBeta**	**YShk**	**YshkBeta**
Staples	Hills-Mtns	-0.79	0.15	0.45	2.17
	DryZone	-0.76	0.37	0.46	2.45
	Delta	-0.79	0.15	0.41	1.80
	Coastal	-0.81	0.22	0.32	1.89
	Yangon	-0.65	0.13	0.47	1.71
Pulses	Hills-Mtns	-0.27	0.53	0.16	0.86
	DryZone	-0.21	0.06	0.13	0.39
	Delta	-0.23	0.11	0.12	0.40
	Coastal	-0.33	0.14	0.13	0.45
	Yangon	-0.22	-0.04	0.16	0.32
Fish-meat-egg	Hills-Mtns	-1.63	-1.30	0.93	0.87
	DryZone	-1.59	-1.58	0.96	0.64
	Delta	-1.71	-1.64	0.89	0.70
	Coastal	-2.00	-1.99	0.79	0.35
	Yangon	-1.12	-1.01	0.82	0.74
Dairy	Hills-Mtns	-0.25	-0.31	0.14	0.04
	DryZone	-0.31	-0.34	0.19	0.10
	Delta	-0.33	-0.38	0.17	0.10
	Coastal	-0.55	-0.70	0.22	0.01
	Yangon	-0.38	-0.32	0.27	0.27
DGLV	Hills-Mtns	1.83	2.19	0.25	0.74
	DryZone	1.80	2.20	0.25	0.68
	Delta	1.95	2.70	0.28	1.07
	Coastal	2.27	3.60	0.27	1.71
	Yangon	1.78	2.35	0.28	0.87
Other-veg	Hills-Mtns	3.30	3.27	0.45	0.44
	DryZone	3.09	2.96	0.42	0.25
	Delta	3.79	3.64	0.55	0.38
	Coastal	3.61	3.41	0.44	0.24

	Yangon	2.93	2.88	0.46	0.40
Fruit	Hills-Mtns	2.31	2.23	0.31	0.26
	DryZone	2.48	2.41	0.34	0.27
	Delta	2.61	2.51	0.38	0.30
	Coastal	2.20	2.08	0.27	0.19
	Yangon	2.89	2.82	0.45	0.38
Fats-oils	Hills-Mtns	-0.25	-0.26	0.15	0.25
	DryZone	-0.27	-0.19	0.16	0.37
	Delta	-0.21	-0.17	0.11	0.25
	Coastal	-0.28	-0.38	0.11	0.12
	Yangon	-0.14	-0.08	0.10	0.27
Other-Food	Hills-Mtns	-0.29	-0.29	0.17	0.16
	DryZone	-0.22	-0.20	0.13	0.17
	Delta	-0.28	-0.27	0.15	0.16
	Coastal	-0.32	-0.32	0.13	0.11
	Yangon	-0.32	-0.28	0.23	0.27
Nonfood	Hills-Mtns	-3.97	-6.21	-3.00	-5.79
	DryZone	-4.01	-5.69	-3.04	-5.32
	Delta	-4.80	-6.65	-3.06	-5.16
	Coastal	-3.79	-6.06	-2.68	-5.08
	Yangon	-4.77	-6.44	-3.24	-5.22

Table MYN-7: Expenditure Shares (%) of Discretionary Income (Beta Parameters)

	Household	**base**	**PShkBeta**	**YshkBeta**
Staples	Hills-Mtns	8.55	12.44	16.54
	DryZone	8.40	13.05	17.61
	Delta	7.41	11.55	13.85
	Coastal	7.65	12.14	14.93
	Yangon	7.04	10.26	12.76
Pulses	Hills-Mtns	2.98	6.33	6.25
	DryZone	2.30	3.39	3.53
	Delta	2.15	3.67	3.44
	Coastal	3.17	5.25	4.66
	Yangon	2.41	3.18	3.15
Fish-meat-egg	Hills-Mtns	17.71	19.06	17.39
	DryZone	17.58	17.63	16.10
	Delta	16.00	16.29	15.09
	Coastal	18.96	19.01	16.92
	Yangon	12.15	12.62	11.81
Dairy	Hills-Mtns	2.69	2.43	2.22
	DryZone	3.42	3.29	3.01
	Delta	3.10	2.90	2.75
	Coastal	5.20	4.54	4.24
	Yangon	4.09	4.33	4.05
DGLV	Hills-Mtns	4.69	6.17	6.96
	DryZone	4.53	6.17	6.52
	Delta	5.07	8.37	8.72
	Coastal	6.56	12.38	13.21
	Yangon	4.13	6.47	6.87
Other-veg	Hills-Mtns	8.45	8.32	8.45
	DryZone	7.77	7.25	6.97
	Delta	9.87	9.17	9.10
	Coastal	10.42	9.51	9.51
	Yangon	6.78	6.60	6.54
Fruit	Hills-Mtns	5.91	5.57	5.67
	DryZone	6.24	5.94	5.92
	Delta	6.78	6.36	6.43
	Coastal	6.34	5.82	5.98
	Yangon	6.71	6.38	6.37
Fats-oils	Hills-Mtns	2.75	2.73	3.23
	DryZone	3.00	3.34	3.95
	Delta	1.98	2.15	2.61

	Coastal	2.66	2.22	2.70
	Yangon	1.53	1.77	2.29
Other-Food	Hills-Mtns	3.14	3.12	3.11
	DryZone	2.42	2.51	2.58
	Delta	2.65	2.71	2.72
	Coastal	3.08	3.10	3.01
	Yangon	3.48	3.65	3.63
Nonfood	Hills-Mtns	43.13	33.83	30.19
	DryZone	44.34	37.43	33.80
	Delta	44.99	36.83	35.29
	Coastal	35.97	26.02	24.85
	Yangon	51.68	44.74	42.53

Table MYN-8: Nutrient Values, ratio (%) to EAR standard

Nutrient	Household	base	PShk	PShkBeta	YShk	YshkBeta
kcal	Hills-Mtns	100	100	100	100	100
	DryZone	100	100	100	100	100
	Delta	100	100	100	100	100
	Coastal	100	100	100	100	100
	Yangon	100	100	100	100	100
protein	Hills-Mtns	206	201	207	195	203
	DryZone	204	196	201	189	197
	Delta	205	200	203	197	199
	Coastal	214	204	208	200	204
	Yangon	211	207	207	203	203
calcium	Hills-Mtns	104	96	97	95	95
	DryZone	118	108	109	106	107
	Delta	113	111	109	108	108
	Coastal	90	90	87	85	87
	Yangon	111	108	107	105	106
iron	Hills-Mtns	126	124	129	121	127
	DryZone	145	141	142	138	140
	Delta	139	140	141	135	140
	Coastal	128	129	128	122	128
	Yangon	133	135	133	130	132
magnesium	Hills-Mtns	131	124	130	125	129
	DryZone	140	131	134	131	134
	Delta	143	136	140	135	140
	Coastal	138	129	133	131	135
	Yangon	129	124	125	124	126
phosphorous	Hills-Mtns	182	183	185	178	182
	DryZone	168	169	167	164	165
	Delta	173	173	173	169	170
	Coastal	178	176	175	171	173
	Yangon	163	165	163	162	161
zinc	Hills-Mtns	100	100	102	98	101
	DryZone	107	105	108	100	107
	Delta	106	106	107	104	106
	Coastal	101	101	102	99	101
	Yangon	104	104	104	102	103
copper	Hills-Mtns	267	263	272	265	270
	DryZone	267	253	265	248	263
	Delta	273	263	270	264	270

	Coastal	251	241	248	238	249
	Yangon	256	246	251	243	249
vitC	Hills-Mtns	246	211	218	216	225
	DryZone	208	176	183	179	187
	Delta	210	176	186	179	193
	Coastal	200	156	174	160	181
	Yangon	187	161	168	164	173
thiamin	Hills-Mtns	126	120	127	122	125
	DryZone	122	117	120	119	118
	Delta	119	118	120	116	119
	Coastal	103	99	103	99	102
	Yangon	113	112	112	108	111
riboflavin	Hills-Mtns	81	90	85	85	85
	DryZone	85	90	85	85	85
	Delta	81	90	85	85	85
	Coastal	80	90	85	85	85
	Yangon	83	90	85	85	85
niacin	Hills-Mtns	126	114	120	112	119
	DryZone	128	117	123	116	123
	Delta	131	124	128	124	127
	Coastal	132	121	126	123	127
	Yangon	121	118	119	117	118
vitB6	Hills-Mtns	132	126	128	129	128
	DryZone	132	128	129	126	130
	Delta	133	128	129	128	130
	Coastal	136	129	133	128	133
	Yangon	117	116	115	115	116
folate	Hills-Mtns	148	148	154	148	150
	DryZone	170	166	166	163	165
	Delta	168	169	171	164	169
	Coastal	199	192	203	188	198
	Yangon	156	158	155	153	155
vitB12	Hills-Mtns	105	103	101	93	95
	DryZone	137	121	126	109	118
	Delta	141	144	136	134	129
	Coastal	108	98	98	94	93
	Yangon	244	237	234	225	221
vitA	Hills-Mtns	135	146	133	136	137
	DryZone	143	133	133	127	133
	Delta	131	124	125	121	127
	Coastal	116	112	112	108	116
	Yangon	141	133	135	130	135

Tables: Papua New Guinea (PNG)

Table PNG-1: Food Group and nonfood shares, base simulation

	Expenditure shares (%), base prices			
Food Groups	**ARoB**	**E-Sepik**	**Madang**	**W-Sepik**
Staples	28.7	35.0	26.7	31.2
Vegetables	10.7	14.3	16.8	13.1
Fruits	21.9	21.0	33.2	21.3
Proteins	34.9	24.4	17.4	29.1
Oil	3.9	5.3	5.9	5.3
Total food	**100.0**	**100.0**	**100.0**	**100.0**
Nonfood share of total	23.2	25.2	18.9	23.2

Table PNG-2: Nutrient Shares in Food Groups for Average Household

	Staples	Vegetables	Fruits	Proteins	Oil
kcal	55.17	5.24	7.36	18.92	13.31
protein	14.49	11.20	2.59	68.67	3.04
carbs	81.07	5.24	11.89	0.64	1.15
calcium	14.41	60.66	2.90	20.70	1.32
iron	29.15	31.46	2.75	28.85	7.78
magnesium	33.20	28.47	12.58	19.92	5.83
phosphorous	23.14	20.25	3.33	47.54	5.74
zinc	25.39	28.45	3.09	37.03	6.05
copper	30.27	31.85	7.21	18.32	12.34
selenium	15.65	2.13	1.81	74.13	6.28
vitC	41.37	24.68	33.11	0.06	0.78
thiamin	49.91	25.20	2.96	20.83	1.09
riboflavin	18.13	47.74	6.94	26.41	0.79
niacin	27.42	18.94	5.46	46.83	1.35
vitB6	41.93	17.13	18.58	21.25	1.11
folate	40.64	36.52	9.84	10.07	2.94
vitB12	0.00	0.00	0.00	100.00	0.00
vitA	16.51	71.19	5.69	6.60	0.00
vitE	30.16	22.61	5.26	29.04	12.94

Notes: Rows sum to one.

Table PNG-3: Number of Commodities by Food group and Household

	ARoB	E-Sepik	Madang	W-Sepik
Staples	9	9	6	8
Vegetables	6	6	4	5
Fruits	4	3	3	3
Proteins	6	5	2	4
Oil	2	2	2	2
Total	**27**	**25**	**17**	**22**

Total number of commodities: 44

Table PNG-4: Percent Change in Value of Commodities/Aggregates in Base Prices

		Simulation			
	Household	**PShk**	**PShkBeta**	**YShk**	**YshkBeta**
Food commodities	ARoB	-9.3	-8.3	-11.9	-10.8
	E-Sepik	-9.7	-8.9	-11.6	-10.9
	Madang	-14.7	-12.4	-12.3	-10.6
	W-Sepik	-9.8	-9.3	-11.9	-11.4
All goods	ARoB	-10.8	-10.7	-15.0	-15.0
	E-Sepik	-11.4	-11.4	-15.0	-15.0
	Madang	-16.8	-16.6	-15.0	-15.0
	W-Sepik	-11.4	-11.3	-15.0	-15.0

Table PNG-5: Average Absolute Percentage Point Change in Commodity Shares in Food Groups

Food Group	Household	Simulation PShk	PShkBeta	YShk	YshkBeta
Staples	ARoB	1.2	0.9	1.5	1.3
	E-Sepik	1.4	1.1	1.8	1.6
	Madang	4.5	3.2	4.5	3.5
	W-Sepik	1.5	1.3	2.2	2.0
Vegetables	ARoB	0.3	0.2	0.4	0.3
	E-Sepik	1.7	1.3	1.9	1.4
	Madang	14.3	6.6	11.5	5.2
	W-Sepik	0.0	0.0	0.0	0.0
Fruits	ARoB	0.4	0.3	0.7	0.5
	E-Sepik	0.0	0.0	0.1	0.1
	Madang	1.0	0.5	0.9	0.5
	W-Sepik	0.2	0.2	0.3	0.3
Proteins	ARoB	1.5	1.0	2.3	1.6
	E-Sepik	0.8	0.6	1.3	1.2
	Madang	11.9	6.1	9.2	4.3
	W-Sepik	1.4	1.2	1.9	1.7
Oil	ARoB	0.1	0.1	0.2	0.2
	E-Sepik	0.2	0.2	0.3	0.3
	Madang	0.5	0.2	0.3	0.2
	W-Sepik	0.1	0.1	0.1	0.1

Table PNG-6: Percentage Point Change in Expenditure Shares by Aggregates

		Simulation			
Aggregates	**Household**	**PShk**	**PShkBeta**	**YShk**	**YshkBeta**
Staples	ARoB	-1.60	-0.81	0.82	1.81
	E-Sepik	-1.99	-1.64	1.03	1.39
	Madang	-2.62	-2.02	0.68	1.34
	W-Sepik	-1.84	-1.44	0.89	1.35
Vegetables	ARoB	2.42	2.35	0.30	0.25
	E-Sepik	3.14	3.35	0.42	0.68
	Madang	3.30	3.68	0.43	1.09
	W-Sepik	2.94	2.89	0.37	0.34
Fruits	ARoB	4.96	4.78	0.62	0.42
	E-Sepik	4.64	4.51	0.62	0.50
	Madang	6.51	5.57	0.84	-0.03
	W-Sepik	4.76	4.68	0.60	0.53
Proteins	ARoB	-1.95	-1.98	0.99	0.92
	E-Sepik	-1.39	-1.26	0.72	0.83
	Madang	-1.70	-0.45	0.44	1.35
	W-Sepik	-1.71	-1.71	0.83	0.82
Oil	ARoB	-0.22	0.01	0.11	0.38
	E-Sepik	-0.30	-0.22	0.16	0.23
	Madang	-0.58	-0.28	0.15	0.43
	W-Sepik	-0.31	-0.22	0.15	0.26
Nonfood	ARoB	-3.62	-4.36	-2.84	-3.78
	E-Sepik	-4.10	-4.74	-2.95	-3.64
	Madang	-4.90	-6.51	-2.54	-4.16
	W-Sepik	-3.83	-4.21	-2.84	-3.29

Table PNG-7: Expenditure Shares (%) of Discretionary Income (Beta Parameters)

	Household	base	PShkBeta	YshkBeta
Staples	ARoB	17.41	20.68	22.00
	E-Sepik	20.34	21.82	22.01
	Madang	17.80	21.03	20.84
	W-Sepik	18.93	20.62	21.08
Vegetables	ARoB	6.47	6.20	6.21
	E-Sepik	8.28	9.18	9.48
	Madang	11.23	13.24	14.28
	W-Sepik	7.96	7.77	7.78
Fruits	ARoB	13.26	12.52	12.35
	E-Sepik	12.22	11.68	11.68
	Madang	22.11	17.11	18.07
	W-Sepik	12.89	12.55	12.53
Proteins	ARoB	21.15	21.03	20.83
	E-Sepik	14.17	14.70	14.66
	Madang	11.57	18.31	15.76
	W-Sepik	17.64	17.68	17.63
Oil	ARoB	2.37	3.31	3.63
	E-Sepik	3.06	3.38	3.42
	Madang	3.96	5.59	5.24
	W-Sepik	3.22	3.64	3.71
Nonfood	ARoB	39.34	36.27	34.98
	E-Sepik	41.93	39.24	38.74
	Madang	33.32	24.72	25.81
	W-Sepik	39.36	37.75	37.27

Table PNG-8: Nutrient Values, ratio (%) to EAR standard

Nutrient	Household	base	PShk	PShkBeta	YShk	YshkBeta
kcal	ARoB	100	100	100	100	100
	E-Sepik	100	100	100	100	100
	Madang	100	100	100	100	100
	W-Sepik	100	100	100	100	100
protein	ARoB	258	245	244	239	238
	E-Sepik	232	216	218	212	214
	Madang	240	191	216	196	214
	W-Sepik	241	225	225	219	219
calcium	ARoB	164	151	150	150	149
	E-Sepik	96	90	90	90	90
	Madang	115	111	106	113	111
	W-Sepik	120	105	105	104	105
iron	ARoB	257	249	248	249	248
	E-Sepik	214	195	197	192	194
	Madang	180	150	161	153	163
	W-Sepik	227	204	205	199	200
magnesium	ARoB	159	154	152	156	153
	E-Sepik	146	134	135	132	133
	Madang	148	122	127	126	131
	W-Sepik	152	136	137	134	134
phosphorous	ARoB	284	272	270	268	266
	E-Sepik	223	206	207	202	203
	Madang	203	168	182	172	183
	W-Sepik	220	201	202	195	196
zinc	ARoB	111	108	107	108	107
	E-Sepik	95	90	90	90	90
	Madang	94	90	90	90	90
	W-Sepik	101	92	93	91	91
copper	ARoB	378	357	359	353	355
	E-Sepik	348	321	323	317	319
	Madang	307	251	267	258	272
	W-Sepik	370	333	335	328	330
vitC	ARoB	296	267	269	266	268
	E-Sepik	197	175	176	174	175
	Madang	229	180	189	185	194
	W-Sepik	231	200	202	199	200
thiamin	ARoB	329	314	316	309	311
	E-Sepik	221	202	204	198	200
	Madang	322	281	287	280	286
	W-Sepik	245	221	223	216	217

riboflavin	ARoB	145	136	134	138	136
	E-Sepik	142	128	129	128	129
	Madang	168	141	147	145	152
	W-Sepik	156	139	139	137	137
niacin	ARoB	276	262	262	255	256
	E-Sepik	218	204	205	202	202
	Madang	209	168	183	173	185
	W-Sepik	210	193	194	189	189
vitB6	ARoB	209	196	197	194	195
	E-Sepik	213	192	193	188	189
	Madang	262	216	226	220	228
	W-Sepik	231	206	207	200	202
folate	ARoB	385	364	367	359	363
	E-Sepik	247	226	228	223	225
	Madang	229	206	204	210	211
	W-Sepik	241	214	216	212	213
vitB12	ARoB	621	562	566	528	532
	E-Sepik	423	391	394	380	382
	Madang	436	394	428	391	410
	W-Sepik	492	458	458	439	438
vitA	ARoB	171	150	152	150	151
	E-Sepik	144	128	129	130	131
	Madang	188	181	172	184	180
	W-Sepik	163	142	142	142	143