Incorporating Food-away-from-Home into the Thrifty Food Plan

By Ge Zhang

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Wen You, Chair
George Davis, Co-chair
Daniel B. Taylor
Biing-Hwan Lin

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ABSTRACT

This study explores the impact of incorporating Food-away-from-Home (FAFH) into the Thrifty Food Plan (TFP). The new model of this study, FLEX, uses similar sets of datasets on prices, nutrition and average consumption pattern as those used in the TFP model. The 2001-2002 National Health and Nutrition Examination Survey (NHANES) data is used to generate average consumption and nutrient profiles. The relative price ratio of FAFH to FAH is assumed and fixed at 1.77. We compared nutrient intake, food intake and food expenditure amount across the FLEX, TFP, and the current low-income consumers' consumption pattern. The overall finding is that moderate amount of FAFH can be a part of a balanced and nutritious diet and allowing FAFH as another food sources makes the diet recommendations relatively easier to follow. With the relative price assumption used in this study, considering FAFH does not make the diet plan unaffordable.

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1.1 Problem Statement

1.1.1 Supplemental Nutrition Assistance Program (SNAP)

Food security—access by all people at all times to enough food for an active, healthy life—remains a great issue in the U.S. today. In 2006, 89% of American households were food secure; the remaining 11%, 12.6 million households, were food insecure at least some time during the year (ERS report, No. 49, 2007). As stated in an ERS report, about one-third of food insecure households (4.0% of all U.S. households) had very low food security, which means "the food intake of one or more adults was reduced and their eating patterns were disrupted at times during the year because the household lacked money and other resources for food" (ERS report, No. 49, 2007). This recurring and involuntary lack of food can lead to serious medical conditions like malnutrition.

To provide resources to food insecure households, the USDA Food and Nutrition Service (FNS) administers 15 domestic food and nutrition assistance programs, the largest of which is the Supplemental Nutrition Assistance Program (SNAP) (i.e., the original Food Stamp Program). In 1977 the current program structure was created with a goal to "end hunger and improve nutrition and health" and to "help low-income households buy the food they need for a nutritionally adequate diet" (FNS Office, 2000). The benefits of the program are provided monthly in the form of a benefit card which is called an Electronic Benefit Transfer (EBT). In order to receive benefits, the household must have gross incomes below 130 percent of the poverty line and meet some other qualifying resources criteria, employment, and also immigration status. In FY 2004, the SNAP provided an average of $28.6 billion in benefits and helped put food on the table for 25.7 million people a month (http://www.fns.usda.gov/FSP/faqs.htm). Since established, the SNAP has been playing a vital role in helping to improve nutrition of low-income people.

In FY 2006, of all the SNAP households, 49 percent of the participants are children(less than 18 years), and 61 percent of them live in single-parent households; 76 percent of all benefits go to households with children, 16 percent go to households with disabled persons, and 9 percent go to households with elderly persons (http://www.fns.usda.gov/FSP/faqs.htm). The single-parent family has occupied 33 percent of households with children, the overwhelming majority of which were female-headed. From the description of the participants' characteristics, we know that the SNAP is helping to provide a nutritious diet to the most needy people. Moreover, as discussed below, most of these demographic groups are the groups who may lack time to prepare food at home. Meanwhile, in order to improve the ability of the SNAP participants to make healthy choices within a limited budget, the USDA Food and Nutrition Service (FNS) has started a corresponding education program: SNAP Nutrition Education. The FNS actively encourages states to provide nutrition education for SNAP participants while the states have the option of providing nutrition education to SNAP recipients as part of their program operations.

The basis for maximum SNAP allotments is the Thrifty Food Plan (TFP). The TFP, established in 1975, serves as a national standard for a nutritious diet at minimal cost. The TFP has been revised three times: 1983, 1999 and 2006.

The latest version, the Thrifty Food Plan 2006, was revised by USDA's Center for Nutrition Policy and Promotion (CNPP), with assistance from USDA's Food and Nutrition Service (FNS), Economic Research Service (ERS), and Agricultural Research Service (ARS). The new version was released in April 2007. It is based on the 2005 Dietary Guidelines for Americans as well as the 2005 MyPyramid Food Guidance System and uses the latest data on food consumption, nutrient content, and food prices: the 2001-2002 National Health and Nutrition Examination Survey and 2001-2002 CNPP Food Price Database. The inflation-adjusted cost is the same as the previous TFP. The new TFP reflects recent changes in dietary guidelines and updated information on food composition, consumption patterns, and food prices while maintaining the cost level of the previous food recommendations (TFP2006).

The TFP 2006 recommends a nutritious (satisfying all the recommended nutrition requirements,) minimal-cost diet, which we will refer to in this thesis as "the TFP recommendations". Cost updates of the SNAP benefit are based on the list of foods and quantities specified in the TFP recommendations. Also, the recommendations are used in nutrition and consumer education programs designed to help people eat a healthful diet on a minimal-cost budget.

For the nutrient intakes, as stated in the documentation of "The Thrifty Food Plan, 2006", there is an obvious improvement between the TFP recommendations and the observed low-income people's average nutrient intakes reported in National Health and Nutrition Examination Survey 2001-2002 (NHANES 2001-2002). The report shows that, compared with observed consumption patterns, the TFP recommendations for the family of four contains more vegetables, milk products, fruits, and grains; the same amount of meat and beans; and less other foods, such as fats, oils, and sweets. With more consumption of vegetables, milk and fruit and less fat, oils and sweets, the TFP recommendations really shows the potential to improve the low income people's diet.

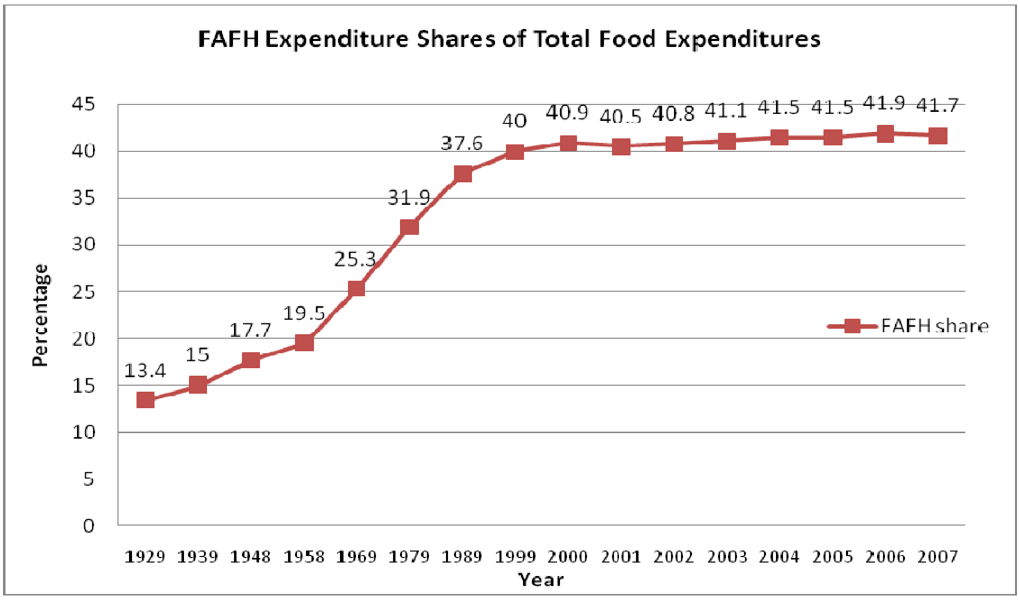
However, TFP assumes that foods consumed are all produced at home or food-at-home (FAH). Meanwhile, the corresponding dimension is food-away-from-home (FAFH), which is produced away from home.

There are two reasons for TFP's assumption. First, the SNAP has certain restrictions on eligible foods that can be purchased by the program benefits: participants are not allowed to buy alcohol, non-food items, food that can be eaten in the store, and hot food. FAFH are among the not-allowed-to-buy-food. In other words, the SNAP benefits do not allow FAFH purchases. Second, the TFP is the most economical plan and is targeted on the poor. Since FAFH usually costs more than FAH, it is reasonable to consider only FAH to meet the affordability goal. However, not allowing FAFH will limit low-income families' choices when they meet time, budget, cooking ability and other constraints. Moreover, the current consumption trend is changing; people are consuming more and more FAFH. It makes people doubt whether the current SNAP benefits can meet the poor's real consumption needs.

1.1.2 The Current Consumption Trend

The consumption of FAFH has been increasing steadily. Between 1992 and 2002, expenditures on FAFH have increased by 23 percent net of inflation (Stewart et al., 2004). Economists anticipate that households will continue to increase their spending on FAFH at an annual rate of about 1.2 percent in real (inflation-adjusted) terms (Blisard et al., 2003). In 1996, FAFH income elasticities were already 0.20, suggesting that the FAFH are necessary goods for U.S. society (Byrne, Capps, and Saha, 1996).

USDA ERS has tracked the FAFH expenditure shares of total household food expenditures from 1929 through 2007. Figure 1.1 is calculated from this data series.



Source: calculated from data provided by USDA-ERS:

http://www.ers.usda.gov/briefing/cpifoodandexpenditures/data/table12.htm

Figure 1.1 FAFH Expenditure Shares of Total Food Expenditures for Household

In this figure, the increasing line shows the trend of the FAFH expenditure share (i.e. the ratio of FAFH expenditure over the total food expenditure) from 1929 to 2007. The figure clearly reflects the increasing trend of FAFH consumption. From 1920 to 2000, there is a sharp increase of FAFH consumptions, the share from 13.4% to 40.9%. From 2000 until now, the FAFH consumption shares are quite stable, around 41%. However, the definition of FAFH here differs slightly from our definition. In this figure, FAFH spending mainly refers to food consumed away from home while in the thesis the FAFH spending mainly refers to food prepared away from home. For example, delivery food is prepared away from home but consumed at home. This slight difference should not affect the main trend shown in this figure.

There are several reasons for the steadily increasing FAFH consumption. FAFH has its own irreplaceable features to attract people. First, it frees household members from shopping, cooking and cleaning. Meanwhile, the special atmosphere makes FAFH a good choice for social activities. People may go to restaurants to celebrate festivals or anniversaries, or just hang out with friends. Sometimes they may choose to go to a certain restaurant which relates to some of their life experiences. Moreover, FAFH is more accessible today; people can eat different kinds of cuisines outside they cannot cook themselves. Fourth, the most important reason may be lack of time. Nowadays, under heavy stress, people tend to work longer and longer hours. Also, more and more women, whose traditional role is cooking and doing other housework, have taken full-time work outside the home. Research results support this trend. A household with an employed female head is more likely to eat away from home than a household with a non-working female head (Lee and Brown 1986). Fast food expenditures have been shown to increase along with the number of hours worked by a household head in the labor force (Byrne, Capps, Saha, 1998). As stated before, among the SNAP participants, 34 percent of households with children were headed by a single parent. This is also in accordance with the observed trend of the increasing FAFH consumption, especially the highly increased fast food consumption since single parents may face even more time or efforts constraints (Park and Capps, 1997).

1.1.3 The Research Needs

The TFP assumes all foods consumed are prepared at home. Meanwhile, it has been shown that the SNAP participants need and actually are consuming a considerable amount of FAFH. The average low-income household spends about 27% of its food dollars away from home (Stewart and Blisard, 2006). Therefore, consumption of FAFH generates a gap between TFP recommendations and the real consumptions and cause adaptability problem.

There are two reasons for incorporating FAFH into the TFP. First, FAH and FAFH have different nutrition and cost characteristics. Second, low-income people face time, budget, cooking ability and food accessibility constraints. Adding FAFH into the TFP gives the SNAP participants more flexibility to choose food and thus it will make the recommendations of the model closer to the current consumption patterns. Since expanding the TFP model to FAFH dimension provides flexibility to the food choices, we call our new model “FLEX”, and the output of “FLEX” model “FLEX recommendations”.

With different recipes and cooking methods, FAH and FAFH nutrient contents are quite different. Fast food and restaurant food are two main categories of FAFH. Both categories of FAFH are generally less healthful than at-home foods. Analysis of food consumption surveys has indicated that meals eaten in restaurants are generally of lower nutritional quality than meals eaten at home (e.g., Guthrie et al., 2002; Lin and Frazao, 1999). FAFH usually contains higher fat and calorie content (Lin and Frazao 1997). Evidence has also shown that the nutritional quality of meals and snacks of fast food is even poorer than the food traditionally consumed at full-service restaurants; fast food tends to be higher in fat, cholesterol, and sodium, but lower in saturated fats (Lin and Frazao, 1999). The so-called “junk food,” fast food, has even been suited to aggravate people’s obesity (foxnews, 2002).

FAH and FAFH also have different prices. FAFH usually involves labor’s price and a lot more costs in it, so it is expected that the price of FAFH will be larger than the price of FAH.

1.1.4 Objective

The goal of the paper is to incorporate FAFH into the Thrifty Food Plan. Three specific objectives are:

First, examine the composition changes in food group consumption and nutrition intake between FAH and FAFH of the recommendations (TFP recommendations and FLEX recommendations) after introducing FAFH.

Second, examine the cost changes after introducing FAFH and how the TFP allotments need to be adjusted in order to incorporate the FAFH consumptions.

Third, examine the cost constraint's impact on FAFH and FAH consumption by conducting sensitivity analysis on cost constraint.

1.2 Organizations of the Thesis

This chapter briefly introduced the SNAP and the TFP, described the current food consumption trend and presented the research need and goal of the project. Chapter II and Chapter III will give detailed description of the conceptual model and the data requirement in this project. Chapter IV will present the results while Chapter V will show some discussion points.

Chapter II: Model Framework

2.1 Conceptual Overview of Diet Problem

This study builds upon a rich literature on identifying diets that meet certain objectives using optimization approaches: the “diet problem.” The problem is one of the earliest optimization problems to be studied back in the 1930s and ‘40s. The literature started with Nobel Laureate George Stigler’s 1945 paper, “The Cost of Subsistence,” in which he estimated the minimum-cost diet that satisfies recommended daily requirements of nutrients for an active adult weighing 154lb and living in a city. Lacking any sophisticated method of solving such a problem, Stigler was forced to utilize heuristic methods in order to find a solution. After the simplex method was formulated by Dantzig in 1963, the linear programming (LP) solution for Stigler’s case study was obtained in 1947 by Laderman and Dantzig. Dantzig (1963) proved that Stigler’s results are practically as good as the LP solutions. However, the optimal diet solution from Stigler’s paper focused on minimum cost and neglected the palatability of the diet.

In order to make the Stigler model’s optimal diet outcomes more reasonable and feasible, researchers tried to incorporate palatability into the minimum-cost diet. Smith (1959) included only the widely consumed foods and added “conventional” constraints (for example, leafy salad vegetables must be with dressings) in the model in order to improve the palatability problem. The more commodities and conventional constraints are added in the model, the higher the cost of the diet. Peryam (1958) suggested solving for a minimum-cost meal from a set of menu items. He argued that the commodities used in earlier models were not conforming to the traditional menus, so they are not palatable. This is the first provocation of the idea of “menu planning.” The “menu planning” model was successfully conducted by Leung et al (1992), in which they solved for minimum-cost meals using 217 regional representative menus from Hawaii. Since the food ingredients were all selected based on the widely used menus in Hawaii, the diet recommendations are more palatable and easier to access. Using integer programming, the cost yields in this paper are almost four times the minimum cost diet estimated by just optimizing over the same set of food inputs.

Leung et al. (1995) argued that the full cost of homemade food should include both the cost of purchased input and the cost of time involved in cooking. Non-Inferior Set Estimation method (NISE) has been used and the model can be solved for the optimal diet either by the objective to minimize cost or to minimize cooking and preparation time. The results show a clear trade-off between achieving the goals of cost and time. The larger the cost is, the less preparation time is needed.

Many math programming methods and techniques have been applied to the diet problem, such as nonlinear programming (Darmon, Ferguson and Briend, 2002), goal programming (McCann-Rugg, White and Endres, 1983), mixed-integer programming (Forsberg, Guttormsen, 2006), quadratic programming (Lancaster, Balintfy and Taj, 2005), the multi-objectives model (Mitani, Nakayama,1998) and fuzzy optimization (Cadenas et.al, 2003). The diet problem has been applied to a wide range of studies, from animal food (Barbieri, Cuzon, 1979) to a human diet (Leung et al, 1992); from a certain age-gender group (McCann-Rugg, White and Endres, 1983) to the particular population in one area (Leung et al, 1992). Among these models and techniques, the most commonly used techniques are still linear programming and non-linear programming.

For the past 30 years, the CNPP has used a quadratic mathematical optimization programming model to develop the TFP. Because dietary habits are difficult to change, CNPP has attempted to identify food consumption patterns that deviate from the prevailing average pattern as little as possible while meeting certain dietary and cost constraints. Specifically, the TFP model is to minimize the sum of the logged deviations of the TFP consumption from the average consumption of numerous food groups. The TFP objective function also serves to consider palatability and adaptability. Smaller deviation represents that the TFP is closer to the average consumption and has better palatability and easier adaptability.

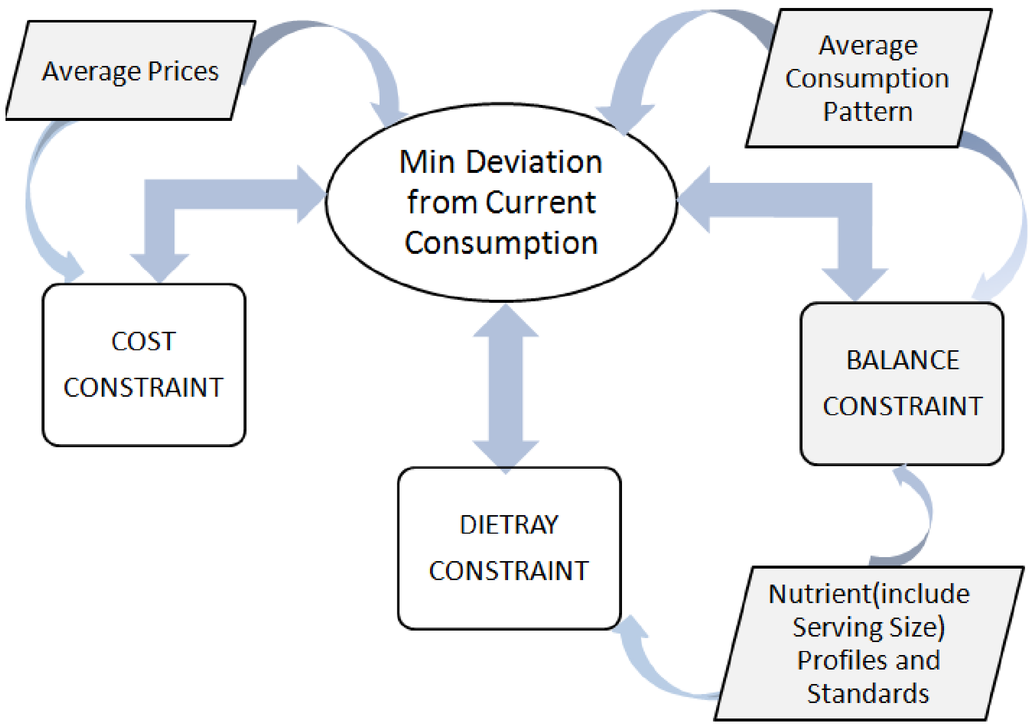
Our study will build on CNPP’s basic approach. Our contribution is to relax the requirement that the meal has to be home-made. To achieve our objective, the prevailing average consumption is divided into two groups — FAH and FAFH.

Specifically, we will identify meal patterns that differ least from the prevailing food consumption patterns in two dimensions (i.e., FAH and FAFH) under the constraints on nutrition, balance and cost.

2.2 Conceptual Overview of the Current TFP

As stated in section 2.1, the CNPP has used a computerized quadratic mathematical optimization programming model to develop the TFP. The objective of the model is to minimize the deviations of the TFP recommendations from the current average consumption pattern. As illustrated in figure 2.1, the inputs are average consumptions, prices, and nutrient serving size profiles of the food categories. The constraints in the model are dietary constraints (including both nutrient intake constraint and food group serving size constraints), cost constraints and balance constraints.

The flow chart of the model is as following:



Note: the shapes represent different components of the math programming model. Oval: Objective Functions; Squares: constraints; Parallelogram: input data.

Figure 2. 1 Flowchart of the Original TFP Model

For a certain group of people, the mathematical structure outline can be represented by the following “pseudo” model:

(1) Min $\sum_f (FBS_f)(\ln(TFP_f) - \ln(OBS_f))^2$, f=1, 2…F…………Objective Function

s.t.

(2) $\sum_f (TFP_f)\ (P_f) \leq C$……………………………………………Cost Constraint

(3) $\sum_f (TFP_f)(N_{if}) \geq NL_i^l$, i=1, 2…I…………………………Lower nutrition constraints

(4) $\sum_f (TFP_f)(N_{jf}) \leq NL_j^u$, j=1, 2…J…………………………Upper nutrition constraints

(5) $\sum_f (TFP_f)(S_{kf}) \geq S_k$, k=1,2…K……. ……………………Serving size constraints

(6) $\sum_f$(TFP recommendations) ≤ Boundary Values……Balance constraints

(7) $(TFP_f) > 0$,……………………………………………………Non-negativity constraints

Definitions:

f: food categories(F=58)

FBS: food budget share

TFP_f: TFP recommend consumptions of food category f

OBS_f: Observed consumption of food category f

Pf: Price of food category f

C: cost

N_{if} : Nutrient i in food category f(I=27)

N_{jf} : Nutrient j in food category f(J=27)

NL^l_i :Lower limits of nutrition i

NL^u_j :Upper limits of nutrition j

S_{kf}: TFP recommended serving size of food group k (K=7)

S_k: MyPyramid recommended serving size of food group k

2.2.1 Objective Function

In order to be consistent with the eating habits of the low-income population, the objective function (equation (1)) is to minimize the deviation of the recommended diet from the average current consumer’s diet. The deviation stands for the differences between the TFP recommendations and the observed consumption patterns. The smaller the deviation is, the closer TFP recommendations are to the observed consumption patterns.

2.2.2 Constraints

The TFP model imposes dietary standard constraints, cost constraints and balance constraints to solve for a nutritious minimal cost diet.

Cost Constraint

In order to obtain the minimum cost, the cost of the TFP recommendations is constrained to below a given upper bound (equation (2)). Recommendations that cost more than the maximum allowance are not allowed in the TFP model.

Lower/Upper Nutrition Constraints

For each nutrient, the TFP model imposed a lower bound of its intake (equation (3)). Some nutrient also has an upper bound (equation (4)). The lower bounds are the least amounts adequate to meet the known nutrition needs of healthy people and the upper bound is set in order that nutrients can be safely eaten on a continual basis and not cause an adverse effect on most healthy people. For example, for a male from 20 to 50, the calcium intake per day is recommended to be above 1000mg and below 2500mg.

If the actual nutrition intakes deviate too much from the nutrition guidelines, the constraints may be relaxed slightly in order to get feasible solutions. For this kind of nutrition, meeting the dietary standards will require people change their current consumption patterns substantively, which is neither practical nor realistic. For example, the actual consumptions involve much more sodium intakes than the recommendations. In order not to deviate from the current consumption pattern too much, the upper bounds of Sodium intake must be relaxed to the median consumption level of the observed consumption patterns.

Serving Size Constraint

To maintain a healthy diet, people need to consume enough of each major food group. The TFP model sets a lower bound on the major food groups' serving sizes (equation (5)) in order to ensure enough food group intakes of the TFP recommendations. Take the food group of fruit for example: males from 20 to 50 are recommended to consume at least 2.62 cups of fruit per day.

Balance Constraints

Balance Constraints are defined as constraints restricting the TFP recommendations in a certain range; in other words, the constraints have put some boundaries to the TFP recommendations (equation (6)). There are two kinds of balance constraints.

First, in order to get a palatable diet, the food categories' recommendations must be above 0 and cannot exceed 10 times the average current consumptions. The lower bounds are used to ensure that the TFP recommendations include all the food items which have been actually consumed. The upper bounds ensure that the TFP recommendations do not include too much more than the actual consumptions. Thus no one food category dominated the overall TFP recommendations. For instance, recommendations of food category "milk and milk-based foods-regular fat" for males 20-50 should be larger than 0 and less than 741g/day—10 times the current average consumptions.

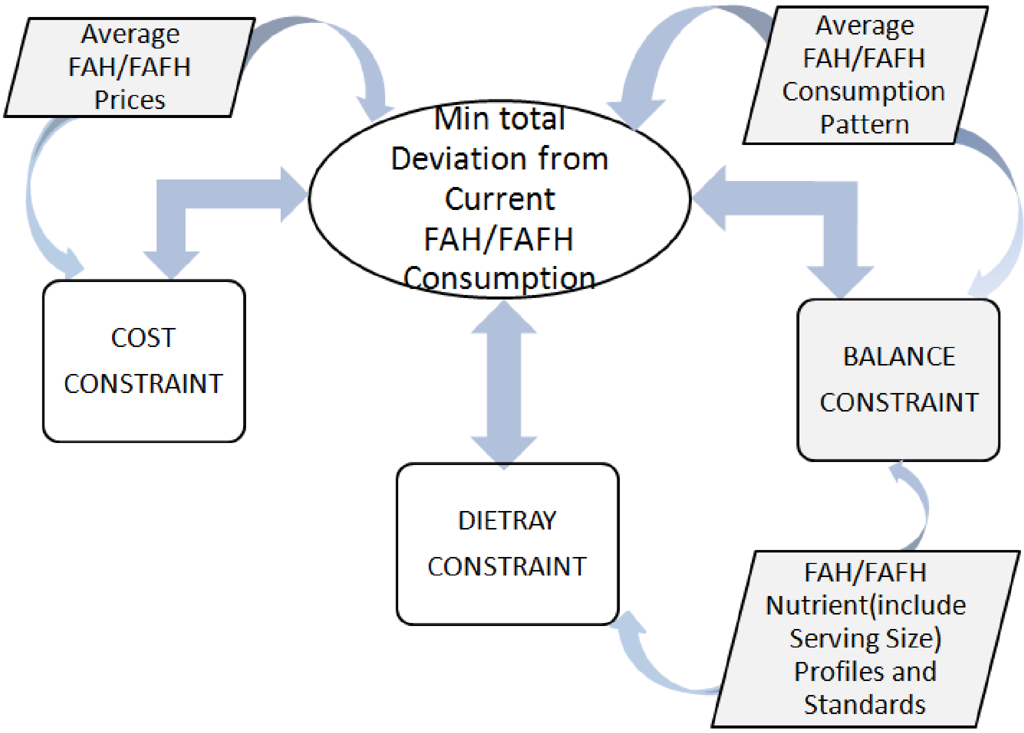
Second, there are some constraints for certain food subgroups recommendations. For example, whole grain (which is a subgroup of grain) consumption should be larger than 50% of total grain consumptions.

Non-negativity Constraint

It's not reasonable to assume food consumption amounts to be negative, and also the observed average consumptions are all above 0, so here the TFP recommendations must be larger than 0 (equation (7)).

2.3 Conceptual Overview of the FLEX Model Including FAFH

The FLEX model incorporates FAFH into the original TFP model. FAFH provides new choices when people are facing some constraints: e.g. time, budget, human capital, food accessibility, etc. As illustrated in Figure 2.2, the new objective function is to minimize the deviation of consumptions in two dimensions: FAH and FAFH. The inputs (average prices, average consumptions, nutrient and serving sizes profiles) have changed from FAH only to both of the FAH and FAFH.



Note: the shapes represent different components of the math programming model. Oval: Objective Functions; Squares: constraints; Parallelogram: input data.

Figure 2. 2 Flowchart of FLEX model

The mathematical form of the FLEX model is represented by the “pseudo” model:

$$(1') \text{ Min } \sum_f (FBS_f^{FAH})(\ln(FLEX_f^{FAH}) - \ln(OBS_f^{FAH}))^2$$

$$+ \sum_f (FBS_f^{FAFH})(\ln(FLEX_f^{FAFH} + 0.00001) - \ln(OBS_f^{FAFH}))^2, f = 1, 2 \dots F$$

……Objective Function

s.t.

$(2') \sum_f (FLEX_f^{FAH})(P_f^{FAH}) + \sum_f (FLEX_f^{FAFH})(P_f^{FAFH}) \leq C$ ……………………………Cost Constraint

$(3') \sum_f (FLEX_f^{FAH})(N_i^{FAH_f}) + \sum_f (FLEX_f^{FAFH})(N_i^{FAFH_f}) \geq NL_i^l$, i=1, 2…I

……Lower nutrition constraints

$(4') \sum_f (FLEX_f^{FAH})(N_j^{FAH_f}) + \sum_f (FLEX_f^{FAFH})(N_j^{FAFH_f}) \leq NL_i^u$, j=1, 2…J

……Upper nutrition constraints

$(5') \sum_f (FLEX_f^{FAH})(S_k^{FAH_f}) + \sum_f (FLEX_f^{FAFH})(S_k^{FAFH_f}) \geq S_k$, k=1, 2…K...Serving size constraints

$(6') \sum_f$(FLEX recoomendations of FAH) $+ \sum_f$(FLEX recoomendations of FAFH) ≤Boundary Values ……………………………………………………………………………Balance Constraints

$(7')FLEX_f^{FAH} > 0$…………………………………………………………Non-negativity constraints

$(8')FLEX_f^{FAFH} \geq 0$……………………………………………………………Non-negativity constraints

Definitions:

f: Food categories(F=58)

$FBS_f^{FA(F)H}$: Budget share of FA(F)H category f

$FLEX_f^{FA(F)H}$: FLEX model recommend consumptions of FA(F)H category f

$OBS_f^{FA(F)H}$: Observed consumption of FA(F)H category f

$P_f^{FA(F)H}$: Price of FA(F)H category f

C: cost

$N_i^{FA(F)H_f}$: Nutrient i in FA(F)H category f(I=27)

$N_j^{FA(F)H_f}$: Nutrient j in FA(F)H category f(J=10)

NL^l_i : Lower limits of nutrition i

NL^u_j : Upper limits of nutrition j

$S_k^{FA(F)H_f}$: FLEX model recommended serving size of FA(F)H group k(K=7)

S_k: MyPyramid recommended serving size of food group k

OBS_f: Observed consumption of food category f including both FAH and FAFH

2.3.1 Objective Function

In FLEX model, the objective function (equation (1')) is to minimize the sum of deviations for both FAH and FAFH of the recommended diet from the average current consumer's diet. The smaller the sum of deviation is, the more similar the FLEX recommendations are to the observed consumption patterns. We add a very small number of 0.00001 in the objective function in order to allow FAFH recommendations to be 0.

2.3.2 Constraints

The FLEX model also imposes dietary standard, cost, and balance constraints to solve for a nutritious minimal cost diet as the TFP model does. The only difference is that FLEX recommendations contain FAFH.

Cost Constraint

Initially, the FLEX recommendations are constrained to cost no more than the previous TFP recommendations, in real terms (equation (2')). If there isn't a feasible solution, the cost constraints will be increased gradually in order to get a feasible solution.

Lower/Upper Nutrition Constraints

The sum of nutrition intakes from both FAH and FAFH of the FLEX model recommendations must satisfy the originally lower (equation (3')) and upper bounds (equation (4')) used in the TFP model. Corresponding to the example of calcium in 2.2.2.2, for a male from 20 to 50, the total calcium intake per day from both FAH and FAFH is recommended to be above 1000mg and below 2500mg. The lower and upper bounds—1000mg and 2500mg—remain the same.

Meanwhile, we also keep the relaxed nutrition standard the same as in the TFP model (there is no need to relax the standards any more, since in FLEX model, they already yield feasible solutions). For example, in the TFP model, the upper bound of sodium intake has been relaxed to the median intake of the observed consumption pattern. So in the FLEX model, the total sodium intake from both FAH and FAFH should be less than the median intake.

The intuition for using the same bundles of nutrient standards is that the nutrition required for maintaining good health will not change as the consumption pattern changes.

Serving Size Constraint

For major food groups, the total daily intake from FAH and FAFH must be above the lower bounds used in original TFP model (equation (5')). The intuition is quite the same as that of the nutrition constraints. Take the fruit group for example again, a male from 20 to 50's total consumptions from FAH and FAFH are recommended to be at least 2.62 cups of fruit per day.

Balance Constraint

For the two kinds of balance constraints, the intuitions are the same: the total consumptions of FAH and FAFH must satisfy the same constraints of the TFP model (equation (6')).

First, for consumptions of food categories, the sum of FAH and FAFH consumption recommendations must be above 0 and below 10 times of the average current consumptions. For instance, in the TFP model, recommendations of food category "milk and milk-based foods-regular fat" for a male 20-50, should be larger than 0 and less than 741g/day. Here in the FLEX model, the total recommendations of "milk and milk-based foods-regular fat" from both FAH and FAFH should be larger than 0 and less than 741g/day.

Second, for food subgroup consumptions, the total consumptions of subgroups from FAH and FAFH should satisfy the same percentage constraints with respect to the total food group consumptions from FAH and FAFH. For example, total recommendations of whole grain consumptions from FAH and FAFH, should be larger than 50% of total grain consumptions from FAH and FAFH.

Non-negativity Constraint

The FAH recommendations must be larger than 0 (equation (7')). The FAFH recommendations are allowed to be as low as 0 (equation (8')).

2.4 Discussion of Model Differences and Expected Outcome Differences

The main differences between the models are their dimensions. The TFP model has only one dimension of FAH while the FLEX model has two dimensions: FAH and FAFH.

From the TFP model to the FLEX model, the inputs (consumption, cost, nutrient and serving size profiles) changed from one dimension to two dimensions. The objective function has been revised to minimize the sum of deviations from both FAH and FAFH recommendations to actual consumptions. All the constraints now need to be met by total recommendations from FAH and FAFH. For cost constraint, we may need to increase the upper bounds in order to get feasible solutions since FAH and FAFH have different prices.

The output of the FLEX and the TFP models are expected to have some similarities and also some differences.

The FLEX and the TFP will have some similarities since the two models have the same nutrition and serving size constraints. So nutrition intakes and major food group consumptions from total FLEX recommendations are expected to be similar to TFP recommendations in terms of meeting the nutrition standards.

Differences of outputs are also expected. From a mathematical standing, the more flexibility you have, the closer the outputs will be to the global optimal. From this perspective, the FLEX recommendations are expected to be closer to actual consumption patterns since it incorporates one sizable part of the current consumption food source into the model: FAFH.

Meanwhile, the cost of FLEX recommendations is expected larger than the TFP recommendations since those of FLEX have incorporated FAFH into it. FAFH is usually more expensive than FAH. If the price difference is not too big, the FLEX recommendations have greater potential to be implemented in the real life.

2.5 Chapter Summary

This chapter mainly describes the conceptual model framework. First it gives a brief introduction of development of the Diet Problem. Then it use flowcharts to illustrate the conceptual flow of the models and explain the mathematical forms by equations. The two mathematical models both contain similar equations, and include the objective function, the cost constraint, the upper and lower nutrition constraints, the serving size constraint, the balance constraint and the non-negativity constraint. The difference between the two models is that the FLEX has incorporated FAFH dimensions; thus, all the input and equations need to consider both dimensions. Finally, it discusses the differences of the expected outcomes. The two outcomes are expected to be similar in food group consumptions and nutrition intakes. The FLEX outcomes are expected to be much closer to the observed consumption patterns.

Chapter III: Data

3.1 Overview of Data Requirements and Measurements of FLEX Model

There are two kinds of data required in the FLEX model.

First, data describing FAH and FAFH is needed, which includes average consumption amounts, average nutrient compositions, average serving size profiles and average costs. The first three datasets are drawn from NHANES 2001-2002 (see Appendix 1 for a brief introduction of NHANES 2001-2002.) The average cost is calculated based on the average consumption data and the price data. The FAH price can be directly drawn from CNPP Price database (see Appendix 2 for a brief introduction of CNPP Price database.) FAFH price database is created by introducing a variable: relative price, *r*, which will be discussed in 3.3.2.

Second, datasets describing consumption standards are need, such as cost standards, nutrition intakes' upper and lower bounds and serving size lower bounds. The cost standards are the TFP cost of the 2001-2002 period since the average consumption patterns are also calculated from 2001-2002 period. The nutrition intakes' upper and lower bounds, MyPyramid serving size lower bounds are all belong to the "dietary constraints/constraints". The dietary constraints are drawn from the "dietary data" which includes (see Appendix 3 for a brief introduction of the dietary data): (1) the 1997-2005 Dietary Reference Intakes, which include Recommended Dietary Allowances (RDAs), Adequate Intakes (AIs), and Acceptable Macronutrient Distribution Ranges (AMDRs); (2) the 2005 Dietary Guidelines for Americans; and (3) the 2005 MyPyramid Food Guidance System.

3.2 Data Requirements and Measurements of FLEX Model

3.2.1 Fundamental Data Requirements and Measurements

Before going into the model, we will first illustrate two fundamental datasets which are used as the basis to construct the model: the age-gender groups and the food categories.

First, there are in total 15 age-gender groups in the study, and each age-gender group has its own FLEX model due to the different standards for consumptions. The age-gender groups are listed in table 3.1. The first columns are the five children age-gender groups, including one-year-old children, two-to-three-year-old children, four-to-five-year-old children, six-to-eight-year-old children and nine-to-eleven-year-old children. The second and the third columns are the female age-gender groups and male age-gender groups. Both the female and male adults are also divided into five age-gender groups according to their ages: twelve-to-thirteen, fourteen-to-eighteen, nineteen-to-fifty, fifty-one-to-seventy and above seventy.

Table 3. 1 15 Age-gender Groups

Children groups	Female groups	Male groups
Child 1	Female 12-13	Male 12-13
Child 2-3	Female 14-18	Male 14-18
Child 4-5	Female 19-50	Male 19-50
Child 6-8	Female 51-70	Male 51-70
Child 9-11	Female 70+	Male 70+

The SNAP reference family of four includes: one male (age 20 to 50), one female (age 20 to 50), one child (age 6 to 8), and one child (age 9 to 11).

Second, there are 58 food categories in the TFP model (see appendix 4). In FLEX model, we divide each of these 58 food categories into two dimensions: FAH and FAFH. For example, if, in the TFP model, there is a food category "milk and milk-based foods-regular fat," then in FLEX model, it has been converted to two food categories: "milk and milk-based foods-regular fat-*FAH*" and "milk and milk-based foods-regular fat-*FAFH*," representing consumptions from FAH and FAFH respectively. So in FLEX model, there are 58 FAH categories and 58 FAFH categories.

The distinguishing processes of FAH and FAFH are based on one variable in NHANES 2001-2002. The variable is "whether the food is consumed at home or not." That tells us whether or not the reported food was consumed at home. We used this variable as the criteria to identify consumption from FAH and FAFH. Although it is not a perfect indicator, because FAFH consumption should be defined by where the food was prepared, this variable can be a reasonable index. This was the best available data to identify FAH and FAFH when the research was ongoing. Starting from NHANES 2003-2004, the information on where food was prepared has been collected. Not only can FAH and FAFH be distinguished, but various FAFH sources have been identified, including fast food and restaurants with waiting service. The reason we have to use NHANES 2001-2002 rather than NHANES 2003-2004 is that the 2003-2004 MyPyramid Equivalent Database has not been released, so the constraints on meeting the serving sizes recommendations for the seven food groups cannot be constructed.

3.2.2 Data Requirements and Measurements of FLEX Model by Equations

In this section, we will describe the detailed data requirements and measurements of FLEX model in sequence of the objective function and constraints.

<u>Data Requirements and Measurements for Objective function</u>

The FLEX objective function:

equation $(1')\ \mathrm{Min}\ \sum_f(\mathrm{FBS}_f^{\mathrm{FAH}})(\ln(\mathrm{FLEX}_f^{\mathrm{FAH}})\ - \ln(\mathrm{OBS}_f^{\mathrm{FAH}}))^2$

$$+\sum_f(\mathrm{FBS}_f^{\mathrm{FAFH}})(\ln(\mathrm{FLEX}_f^{\mathrm{FAFH}}+0.00001)\ -\ln(\mathrm{OBS}_f^{\mathrm{FAFH}}))^2, \mathrm{f}=1,2\ldots\mathrm{F},$$

is to minimize the deviation of consumptions from the FLEX recommendations and the observed average consumption pattern for both FAH and FAFH.

For all the 15 age-gender groups, the calculation of the weighted average consumptions of FAH and FAFH were conducted separately. The procedures for constructing the FAFH component of the model nearly mirror the procedures CNPP has taken to build the FAH component. The weights were based on the consumption amount of each food item and the sample person's weight (sample persons who have consumed the food items) in the age-gender group.

The model does allow zero consumption of food groups in FAFH dimension by adding a very small number to the log form of the FAFH consumption. The small number avoids the conditions of (log0) which are introduced by the zero consumptions of FAFH. We cannot use 1 instead of the small number here since log1 equals 0.

Data Requirements and Measurements for Cost Constraint

For cost constraint: equation$(2') \sum_f (\mathrm{FLEX}_f^{\mathrm{FAH}})(\mathrm{P}_f^{\mathrm{FAH}}) + \sum_f (\mathrm{FLEX}_f^{\mathrm{FAFH}})(\mathrm{P}_f^{\mathrm{FAFH}}) \leq \mathrm{C}$, we need data of the weighted average price of FAH and FAFH categories for each age-gender group and the cost standard data.

The cost standards are the TFP cost of the 2001-2002 period since the average consumption patterns are also calculated from NHANES 2001-2002.

The weighted average prices for the same food category of different age-gender groups may be different, since people in different age-gender groups have different consumption amounts of different food items. The weights are based on the consumption amount of the food items and the sample persons' weight (the weights have been provided by NHANES data) in the age-gender group. Either a large food item's consumption amount or a larger sample person's weight will make this food item's price more important in determining this food category's weighted average price. So the prices are calculated separately for each age-gender group.

The price of FAH items can be directly drawn from the CNPP price database. A major difficulty for this research is to construct prices for FAFH. There is no national data set that will allow us to generate database similar to that CNPP has generated for food prepared at home. With very limited resources, constructing such a database seems to be impossible. We tried to construct the FAFH price database using the same logic as the construction of CNPP price database, but the process also failed because we don't have the data needed (see Appendix 5.)

In fact, this diet problem has two overall general goods: FAH and FAFH. It is the relative price that matters for choices, so we will define a variable '*r*' to denote the relative price of FAFH to FAH within the same food category for the same age-gender group ($r = \frac{P_{fafh}}{P_{fah}}$). Then with FAH's price and *r*, FAFH's price for each category can be constructed.

The relative price will enable us to use the current CNPP FAH price database to generate the associated FAFH price database according to the distribution assumptions of the relative price factor, *r*. For this thesis, *r* is set to a constant value across all the food groups and for all the age-gender groups. The future work will be to replace the constant with a reasonable distribution and may also allow *r* to have different values for different food categories.

This method of FAFH price construction does not require many assumptions to fill in FAFH price and is easy to implement for discrete value choices of *r*. The disadvantage is that if we want to specify a distribution for *r* and trace the distribution of the consumption pattern and costs, the computation burden may be huge because *r* enters into both objective function and constraints.

<u>Data Requirements and Measurements for Lower and Upper Nutrition Constraints</u>

For Lower and Upper Nutrition constraints:

$$(3') \sum_f \left(FLEX_f^{FAH}\right)\left(N_i^{FAH_f}\right) + \sum_f \left(FLEX_f^{FAFH}\right)\left(N_i^{FAFH_f}\right) \geq NL_i^l, \text{ i=1, 2...I}$$

$$(4') \sum_f \left(FLEX_f^{FAH}\right)\left(N_j^{FAH_f}\right) + \sum_f \left(FLEX_f^{FAFH}\right)\left(N_j^{FAFH_f}\right) \leq NL_i^u, \text{ j=1, 2...J}$$

we need the nutrition standard data and the nutrition content of the FAH and FAFH categories for each age-gender group.

The nutrition standards are from two sources: the 1997-2005 Recommended Dietary Allowances (RDAs) and Dietary Guidelines for Americans.

RDAs mainly include three parts: the RDA/AI (Adequate Intakes), the UL (the tolerable Upper Intake Level) and the AMDRs (Acceptable Macronutrient Distribution Ranges.)

The RDA/AI provides recommended dietary allowances for vitamin A, vitamin C, vitamin B6, vitamin E, vitamin B12, thiamin, riboflavin, niacin, calcium, phosphorus, magnesium, iron, folate, zinc, copper, fiber and potassium. RDAs and AIs can both be used as goals for individual intake. RDAs are set to meet the needs of up to 97-98 percent individuals in a certain age-gender group. The AI is the mean intake standard for healthy breastfed infants (Food and Nutrition Board, Institute of Medicine, National Academies, 2002). There is no solution for vitamin E to meet the RDA and for potassium to meet the AI in some age-gender groups. CNPP has made several adjustments to relax these age-gender groups' constraints, such as, for vitamin E, for a female 20-50, they can just meet 70 to 78 percent of the vitamin E RDA.

UL is the upper bounds of nutrition intakes. For vitamin A, vitamin C, vitamin B6, vitamin E, calcium, phosphorus, iron, folate, zinc, and copper, their total intakes from both FAH and FAFH for each age-gender group had to fall below UL.

Dietary Guidelines for Americans recommends that all healthy people ages 2 and over consume less than 10 percent of calories per day from saturated fat, less than 2,300 mg per day of sodium and 300 mg or less per day (Dietary Guideline for Americans). The TFP model also applied the guidelines to 1-year-olds, because this age group was assigned to the 1,000 calorie food pattern and this pattern uses these saturated fat, sodium, and cholesterol guidelines (TFP 2006 Report). Except for sodium, all the guidelines can be met by TFP recommendations. For sodium, the TFP model has relaxed upper bounds for some age-gender groups. For FLEX model, we keep the same adjustments as TFP model did.

The weighted average nutrient profiles of FAH and FAFH are calculated from NHANES 2001-2002. The relevant data in NHANES is the nutrient content of all the food items people reported eating and the average consumption amount of each food item. The weights are also based on the intake amount of the nutrients and the sample persons' weights.

Data Requirements and Measurements for Serving Size Constraints

For Serving size Constraints, $(5')\ \sum_f \left(\mathrm{FLEX}_f^{\mathrm{FAH}}\right)\left(\mathrm{S}_k^{\mathrm{FAH}_f}\right) + \sum_f \left(\mathrm{FLEX}_f^{\mathrm{FAFH}}\right)\left(\mathrm{S}_k^{\mathrm{FAFH}_f}\right) \geq S_k$, $\mathrm{k}=1, 2 \ldots \mathrm{K}$, we need the serving size standard data and the serving size information of FAH and FAFH categories for each age-gender group.

The serving size standards come from MyPyramid. According to MyPyramid documents, there are seven main food groups: grains, vegetables, fruits, oils, milk, meat and beans and discretionary calories (see Appendix 6.) The CNPP has converted the 58 FAH categories into 7 MyPyramid food groups, excluding alcohol. Most of the time, one food category can be converted to only one MyPyramid food group; for example, "rice and pasta—whole grain" can only be converted to the main food group of grains. A few other food categories are related to several MyPyramid food groups;

for example, “milk-based drinks and desserts—regular fat” are related to main food groups of milk product, grains, fruits and other foods (TFP 2006 reports). We assume the FAFH food categories have the same conversion of main food groups as the corresponding FAH food categories.

Data Requirements and Measurements for Balance Constraint

The balance Constraints are as follows:

$(6') \sum_f(\text{FLEX recoomendations of FAH}) + \sum_f(\text{FLEX recoomendations of FAFH}) \leq \text{Boundary Values}$

The first kind of balance constraints are that the sum of FAH and FAFH consumption recommendations must be above 0 and below 10 times of the average current consumptions. We just need the average consumption data for each age-gender group.

The second kind of balance constraints are for food subgroup consumptions: the total consumptions of subgroups from FAH and FAFH should satisfy the same percentage constraints with respect to the total food group consumptions from FAH and FAFH. MyPyramid serving size profiles and the subgroup consumption standards are needed. MyPyramid serving size profiles are calculated in 3.2.2.4. The subgroup consumptions standards are also based on the 2005 MyPyramid food intake recommendations (see Appendix 6 for all the constraints of subgroups) such as: at least 50 percent of the total amount from the grain group had to be whole grains.

Data Requirements for Non-negativity Constraints

No extra data is needed for Non-negativity constraints:

$(7')\text{FLEX}_f^{\text{FAH}} > 0$

$(8')\text{FLEX}_f^{\text{FAFH}} \geq 0$

3.3 Chapter Summary

This chapter summarizes the data requirements and measurements of the FLEX model by equations and gives the readers a general idea of the model’s input calculations. We need two kinds of data. First, data describing FAH and FAFH which includes average consumption amount, average nutrient compositions, average serving size profiles and average cost. The first three datasets are drawn from NHANES 2001-2002. The average cost is calculated based on price data. The FAH price can be directly drawn from CNPP Price database. FAFH price database is created by introducing a variable: relative price, *r*. Second, we need data describing standards. Cost standards are from previous TFP cost, nutrition, serving size standards and balance standards are from the 1997-2005 Dietary Reference Intakes, the 2005 Dietary Guidelines for Americans and the 2005 MyPyramid Food Guidance System.

Chapter IV Results

4.1 Major Food Groups Consumptions or Recommendations Comparisons

4.1.1 General Comparisons of OBS Consumptions, TFP and FLEX Recommendations

In this section, we compare the FLEX recommended consumptions (FLEX), the TFP recommended consumptions (TFP) and the observed low-income family consumptions (OBS). The FLEX and TFP recommendations are generated from the FLEX model and the TFP model respectively, while the observed consumptions are calculated from NHANES 2001-2002. Parameter "*r*" is assigned a fixed value of 1.77. The reason for choosing this value is that according to USDA, the relative food price ratio of restaurant prices to retail store prices was 1.77 in 2007 (USDA, ERS, 2008). Approximately, we treat restaurant prices as FAFH prices and retail store prices as FAH prices. The comparisons are based on a standard reference family, which contains four members: one female and one male whose ages are from 20 to 50, one child from 6 to 8 and one children from 9 to 11.

The food intake composition comparison is based on the seven major food groups from MyPyramid. As listed in Chapter III, they are: grains (GR), vegetables (VE), fruits (FR), oils (OI), milk (MI), meat and beans (MB) and Discretionary Calories (DC). MyPyramid Adequacy Ratio (AR) is used in the comparisons, which is defined as the ratio of the consumption or recommendation to the recommended MyPyramid serving size. If the food group's consumption or recommendation's Adequacy Ratio is equal to 1, that means the consumptions and recommendations have reached the MyPyramid suggested level. If the AR is less than 1, that means the corresponding consumption or recommendation does not satisfy the MyPyramid Requirement. Oppositely, if the AR is greater than 1, that means the consumption or recommendations are more than the MyPyramid suggested amount. Figure 4.1 shows the values of ARs of the FLEX recommendations, the TFP recommendations, as well as the observed consumption pattern.

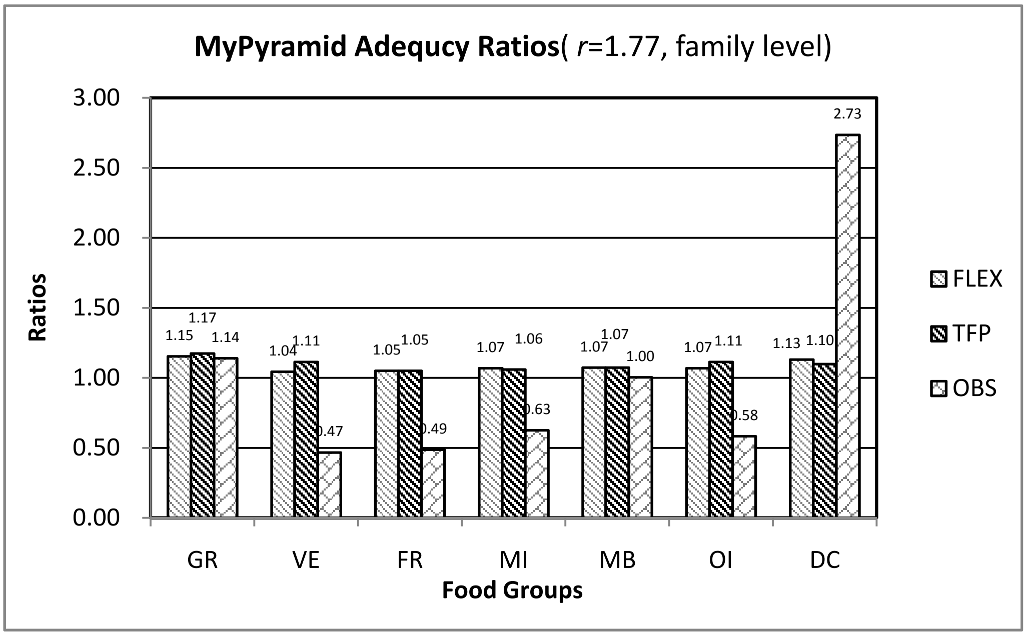


Figure 4.1 FLEX-TFP-OBS MyPyramid Adequacy Ratios

In Figure 4.1, it shows that the observed low-income consumption patterns are not very healthy. The ARs of vegetables, fruits, milk and oils are less than 1; the low-income people consume less than the MyPyramid Recommendations (i.e. VE=0.47, FR=0.49, MI=0.63, OI=0.58). Vegetables and fruits are even less than 50% of the recommended amount. However, those two food groups provide nutrients vital for health and maintenance of human bodies, reduce risk of some chronic diseases and are considered as the most healthful food. For discretionary calories, the AR of the observed low-income average consumptions are 2.73, which means they consume almost three times of the MyPyramid recommended amounts. The results reflect that there is a need to improve the diet qualities of the observed consumption patterns.

For the FLEX and TFP recommendations, all the food groups have satisfied the level of MyPyramid recommended consumptions by construction. For discretionary calories, both the FLEX and TFP recommendations are only slightly beyond the MyPyramid recommendations. So after construction, the FLEX and TFP recommendations are healthier than the Observed consumption patterns. That’s because both models include the MyPyramid serving size constraints. Meanwhile, adding FAFH to the TFP model does not alter dramatically the optimal solutions in terms of food groups. If we keep only MyPyramid serving size constraints in both models (no other objectives or constraints), the MyPyramid Adequacy Ratios of FLEX and TFP recommendations will all be 1.

4.1.2 Comparisons of FLEX and TFP Recommendations

Comparisons of Total Food Intake Recommendations

In figure 4.1, the total recommendations of the TFP and FLEX's don't have significant differences. The reason is that the two recommendations are satisfying similar sets of MyPyramid serving size constraints.

However, the total recommendations will still have slight differences due to two reasons. First, except for the MyPyramid serving size constraints, there are some other constraints, such as cost and nutrients, which impact the final results of the FLEX model. Second, although the two models use a similar set of constraints, the FLEX model has incorporated the FAFH dimension, which brings in different nutrient profile and costs of FAFH than the FAH profiles of TFP.

Table 4.1 is a supplement of the figure 4.1. The first two columns are food groups' name and units (same as the MyPyramid recommendations). The third column is the difference between FLEX and TFP recommendations.

Table 4.1 The Differences between FLEX and TFP Total Recommendations (*r*=1.77)

Food Groups	UNIT	FLEX-TFP
Grains	oz equivalents	-0.52
Vegetables	cups	-0.80
Fruits	cups	0.00
milk products	cups	0.11
meat and beans	oz equivalents	0.00
Oils	g	-4.93
Discretionary Calories	kcal	36.14

In Table 4.1, the FLEX recommendations of most food groups are smaller than the TFP ones. This trend indicates two things. First, the FLEX recommendations are much closer to MyPyramid Adequcy Ratios. It can be treated as an improvement from the TFP recommendations, since the FLEX recommendations don't over-consume the major food groups. Second, although the FLEX and TFP recommendations are both healthier than the OBS consumptions, FLEX recommendations are closer to the observed food intake consumption patterns. So compared to the TFP recommendations, the FLEX recommendations will be easier for low-income people to follow. In fact, although the comparisons here are technically true, the differences are still quite small.

<u>Comparison of FAH and FAFH Compositions</u>

Figure 4.2 shows the FAH percentages in the total FLEX recommendations, the TFP recommendations and the OBS consumptions.

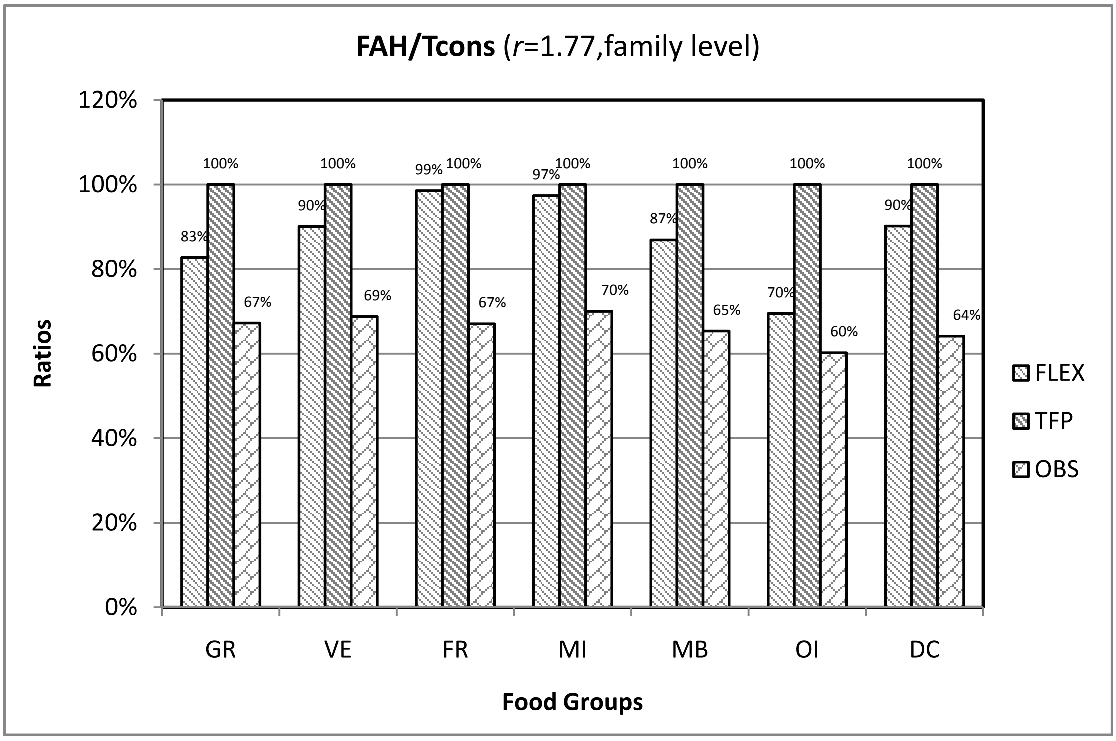


Figure 4.2 FAH Percentages in Total Recommendations or Consumptions

The figure shows the similarity of the two recommendations: towards the observed consumptions, the two recommendations have higher FAH recommendations percentages. This indicates that both models suggest that the low-income people need to consume more FAH. The reason lies in the nature of FAFH: FAFH is relatively more expensive (in this section, we assume FAFH costs 77%

more than FAH), yet generally of lower nutrient quality. For fruits and milk products, both the FLEX and TFP model recommends 100% FAH (for FLEX recommendations, just a little less than 100%). It's not hard to find the reason, since fruits or milk product prepared away from home usually contain a lot more sugars and cost much more than the same food prepared at home. Meanwhile, the FLEX and TFP recommendations are still different. For TFP recommendations, the ratios of FAH across all the major food groups are 100%. But for the FLEX recommendations, most of the FAH ratios are between 70% and 90%.

The reason for the FAH percentage not to be 100% in the FLEX model lies in the objective functions. The objective function of the FLEX model is to minimize the deviations of recommendations with observed consumptions for both FAH and FAFH. If the FAFH consumptions are 0, there will be a huge increase of the total deviations. However, if we change the objective of the FLEX model to minimize the deviation of total recommendations to total observed consumptions without distinguishing FAH and FAFH, we expect that the FAH percentage of total FLEX recommendations will increase.

The difference between the FAH/FAFH compositions of the two recommendations also indicates that the FLEX recommendations are much easier for low-income people to follow. The TFP recommendations of 100% FAH are not realistic. It should not be a surprise that people are consuming much more FAFH now. Since people face constraints of time, labor, and accessibility (discussed in section 1.1.3), they have needs for FAFH. If the TFP are to be implemented, people need to change a lot of their current consumption patterns.

Meanwhile, compared to the TFP recommendations, the relatively high percentage of FAFH in FLEX recommendations gives people more options to choose from when they face real-life constraints. After adding another dimension, FAFH, into the FLEX, people are allowed to buy not only FAH, but also FAFH.

4.2 Nutrition Intake Comparisons

4.2.1 General Comparisons of OBS Consumptions, TFP and FLEX Recommendations

As in section 4.1, we compare main nutrition intakes from the FLEX recommended consumptions (FLEX), the TFP recommended consumptions (TFP) and the observed consumptions (OBS). Similarly, the FLEX and TFP recommended nutrition intakes are generated from the FLEX model and the TFP model respectively, while the observed consumptions are calculated from NHANES 2001-2002. Parameter "*r*" is assigned value of 1.77 and the comparisons are based on a standard reference family.

The main nutritions discussed here are calcium, iron, niacin, phosphor, riboflavin, thiamin, Vitamin C (VC) and Vitamin A_rae[1] (VA_rae). These nutrients are the common sets of nutrients discussed and compared in the current literature on the nutrition effect of food assistance programs (e.g. Price et al, 1978, Basiotis et al, 1983, Devaney and Moffitt, 1991). The Nutrient Adequacy Ratio, which equals the quotient of nutrition intake level to the DRI recommended amounts, is used in this section. Figure 4.3 shows the Nutrient Adequacy Ratios for the selected nutrients from the FLEX, TFP recommendations, and OBS consumption patterns.

[1] Recommended intakes for vitamin A are given as "Retinol Activity Equivalents." This helps to account for the differences between carotenoids and retinol, which are two main dietary sources of vitamin A. Retinol, one of the most active and usable forms of vitamin A, is often called preformed vitamin A. It can be converted to retinal and retinoic acid, other active forms of the vitamin A family. It takes about 12 units of beta-carotene or 24 units of other carotenoids to make 1 unit of retinol in the body (FCS8639, 2006)

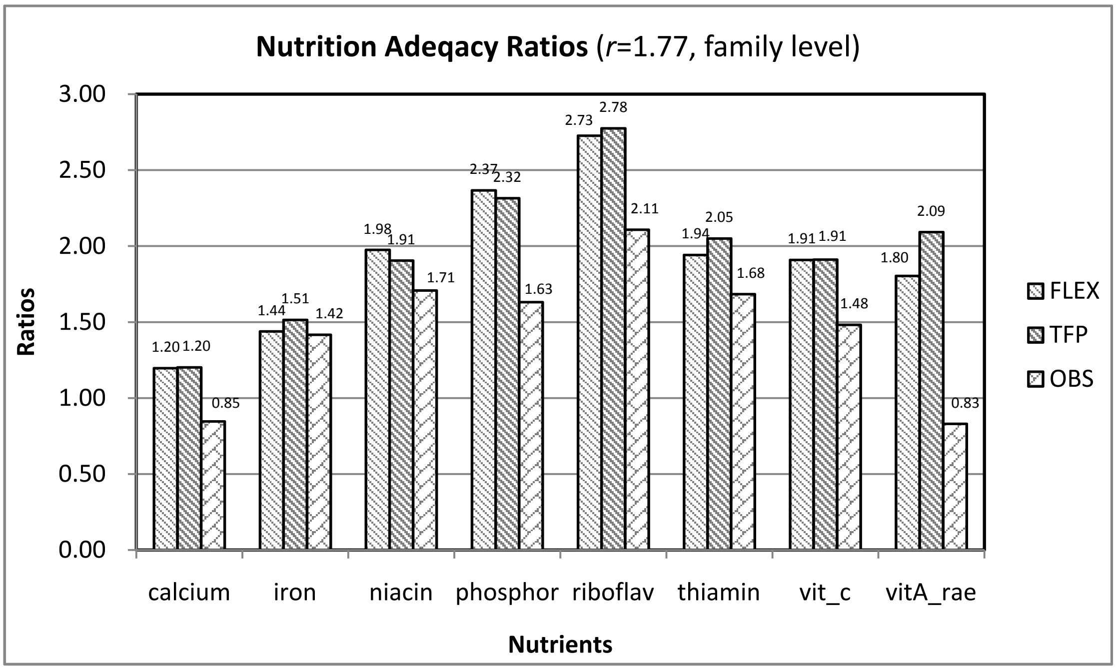


Figure 4.3 FLEX-TFP-OBS MyPyramid Adequacy Ratios

Figure 4.3 shows that all Nutrition Adequacy Ratios of the FLEX and TFP consumption patterns are larger than 1, which means the nutrition intakes have reached the recommended level. However, for the observed consumption patterns, calcium and VA_rae cannot reach the standard. That means the two recommendations contain more nutrients than the observed pattern.

Calcium is an essential nutrient for the normal growth and maintenance of bones and teeth, and its requirements must be met throughout a lifetime. The National Academies Press (1997) stated that "Long-term calcium deficiency can lead to rickets and poor blood clotting and in case of a menopausal woman, it can lead to osteoporosis, in which the bone deteriorates and there is an increased risk of fractures. While a lifelong deficit can affect bone and tooth formation, over-retention can cause hypercalcemia (elevated levels of calcium in the blood), impaired kidney function and decreased absorption of other minerals."

Emphasized in the Dietary Supplement Fact Sheet, Vitamin A also plays a significant role in human health. "It's important to vision, bone growth, reproduction, cell division, and cell differentiation. It helps regulate the immune system and helps lymphocytes (a type of white blood cell) fight infections more effectively. Meanwhile, it promotes healthy surface linings of the eyes and the respiratory, urinary, and intestinal tracts. In addition, it also helps the skin and mucous membranes function as a barrier to bacteria and viruses" (National Institutes of Health, 2005).

Aside from the eight nutrients mentioned in Figure 4.3, there are still 19 other kinds of nutrients in the FLEX model, including elements, macronutrients and vitamins. Most of the nutrients in the observed consumption patterns have been overtaken, with Nutrient Adequacy Ratios more than 1.5. A few of them are undertaken, such as magnesium (Nutrient Adequacy Ratio equals 0.90). However, in the FLEX and TFP model, the upper and lower nutrition constraints in FLEX model ensure that all the 27 nutrients' intakes are within ranges safe to human being (RDAs and Dietary Guidelines for Americans).

In all, since both recommendations have satisfied the nutrients' upper and lower bounds and are richer in nutrition, they show significant improvements towards the observed consumption patterns of nutrition intakes.

4.2.2 Comparisons of FLEX and TFP Recommendations

<u>Comparisons of Total Recommendations</u>

Figure 4.3 shows that the TFP and FLEX total recommendations don't have significant differences since they satisfy the same nutrition constraints. However, since there are some other constraints, such as cost, MyPyramid serving size, and also the objective functions in the two models, we expect there are some slight differences between the two recommendations.

Table 4.2 is a supplement of Figure 4.3. The first two columns are the nutrients' names and the units. The third column is the differences between FLEX and TFP recommendations.

Table 4.2 The Differences between FLEX and TFP total recommendations (*r*=1.77)

Nutrients	Units	FLEX-TFP
calcium	mg/d	-20.05
iron	mg/d	-3.34
niacin	mg/d	3.50
phosphor	mg/d	162.64
riboflav	mg/d	-0.19
thiamin	mg/d	-0.41
vit_c	mg/d	-0.39
vitA_rae	ug/d	-751.42

Table 4.2 shows three quarters of nutrients of the FLEX recommendations are smaller than the TFP ones. Taking the other 19 nutrients not in the table into consideration, it's hard for all the nutrients to exhibit the same trend, such as, all the nutrients intakes are higher in TFP recommendations than in FLEX recommendations. The reasons lie in two aspects. First, for both FAH and FAFH, different food categories have different nutritional content. For example, "milk and milk-based foods-regular fat-*FAH*" and "milk and milk-based foods-low fat-*FAH*" have different nutrition compositions; similarly, "milk and milk-based foods-regular fat-*FAFH*" and "milk and milk-based foods-low fat-*FAFH*" also have different nutrition compositions. Second, between FAH and FAFH, the same food category has different nutrition compositions; for example, the nutrition contents of "milk and milk-based foods-regular fat-*FAH*" and "milk and milk-based foods-regular fat-*FAFH*" are different too. The differences of two dimensions make it difficult to for all the 27 nutrients to exhibit the same trend between the two recommendations.

<u>Comparison of FAH/FAFH Compositions</u>

Figure 4.4 presents the FAFH nutrients' intakes percentages in the total FLEX recommendations, the TFP recommendations and the OBS consumptions.

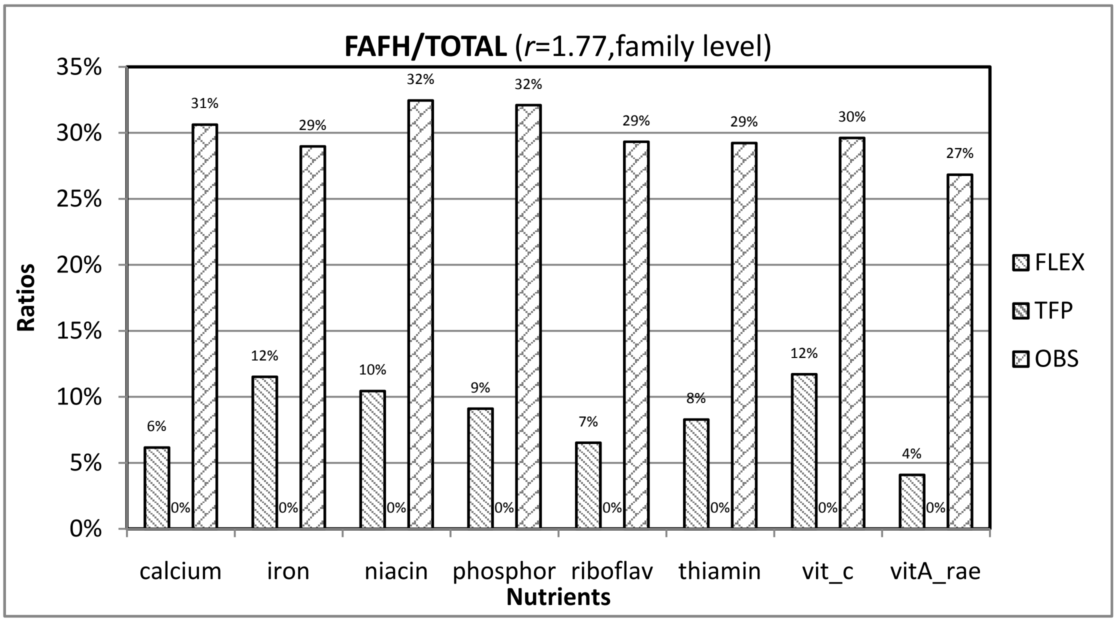


Figure 4.4 FAFH nutrients intakes' Percentages

Shown in the figure, towards the observed consumptions, the two kinds of recommendations have much higher FAH nutrition intake percentages and much smaller FAFH nutrition intake percentages. It leads to the same conclusion that both the FLEX and TFP model recommends low-income people to increase the percentages of nutrient intake from FAH; in other words, both the two models suggest low-income people to consume more FAH. The relatively high percentages of FAFH nutrient intake of the observed consumption patterns reflect that in real life people really desire FAFH. The different nutrition characteristics of FAH and FAFH also contribute to the different percentages. FAFH's nutrition intakes are usually accompanied by high fat, sodium and sugar. For example, the milk product is the main source of calcium. However, the milk product prepared away from home usually accompanies a great amount of sugar and fat.

Meanwhile, the nutrition intake percentages between the FLEX and the TFP recommendations are quite different. For the TFP recommendations, all the nutrition intakes come from FAH, since all the TFP recommendations are FAH. But for the FLEX recommendations, about 90% of nutrients come from FAH. For observed consumptions, only 70% of nutrients come from FAH. So for nutrition intake distributions, the FLEX recommendations are closer to the observed consumptions than the TFP ones. This further illustrates that the FLEX recommendations are much easier for low-income people to follow.

4.3 Cost Comparisons

4.3.1 General Comparison of OBS Consumptions, TFP and FLEX Recommendations

In this section, we will compare costs of the FLEX, TFP recommendations and the observed consumptions. Parameter "*r*" is still set at 1.77 and the comparisons are based on the four age-gender groups which constitute a standard reference family and the whole family. The total cost is calculated by adding FAH cost and FAFH cost. FAH cost is calculated by multiplying the FAH consumptions (recommendations) amount with FAH prices. Similarly, FAFH cost is calculated by multiplying the FAFH consumptions (recommendations) amount with FAFH prices.

Table 4.3 lists the different costs for FLEX, TFP recommendations and Observed consumptions of the four different age-gender groups. The costs are measured in dollars per one week.

Table 4.3 Total Cost of FLEX, TFP, and OBS for Different Age-gender Groups (*r*=1.77)

Age-gender Groups	FLEX	TFP	OBS
Child6-8	22.25	22.25	32.02
Child9-11	26.35	26.35	35.52
Female20-50	30.05	27.25	47.97
Male20-50	34.30	30.1	61.31
Family	112.95	105.95	176.82

Unit: $/week

From Table 4.3, we find that both the FLEX and TFP's total costs are much smaller than the observed cost. Combined with the information shown in the tables before, the observed consumption pattern has inadequate food groups intakes and nutrients intakes with the highest cost while TFP and FLEX outputs have smaller cost and abundant nutrition and food groups intake. This indicates that TFP and FLEX outputs are healthier and more economical than the observed consumption pattern. Meanwhile, the findings have great meaning for the low-income people. It indicates a way for them to save money yet eat a healthy diet if they follow the FLEX recommendations for food consumptions.

4.3.2 Comparisons of Costs of FLEX and TFP Recommendations

Comparisons of Total Costs of the Two Recommendations

Table 4.4 describes the total cost differences between FLEX and TFP recommendations. For the children groups, the FLEX costs and the TFP costs are equal. For the two adult groups, FLEX recommendations cost higher than the TFP recommendations. The cost increases are due to the FAFH dimension we added into the FLEX model. In FLEX model, for the same food category, the price of the food prepared away from home is 1.77 times of the price of food prepared at home. In TFP, the recommendations are all assumed to prepare at home, so the prices in TFP are the same as the prices of FAH dimension in FLEX model. The relative price difference makes the total costs of the two models' recommendations different (we will further explore the cost compositions in details in section 4.3.2.2).

Table 4.4 The Differences between FLEX and TFP total costs(*r*=1.77)

Age-gender Groups	FLEX-TFP
Child6-8	0.00
Child9-11	0.00
Female20-50	2.80
Male20-50	4.20
Family	7.00

Unit: $/week

For the FLEX model, the cost constraint is first set to the same allotment amount as the cost constraint in the TFP model. If the model cannot yield a feasible solution, $0.1/day is added to the cost constraint allotment. We repeat this procedure until there is a feasible solution. When r equals 1.77, the cost constraints need to increase by

$0.4 for female ages from 20 to 50, $0.6 for male with the same age range. Thus the increases of total cost for the reference family are equal to the sum of the increases of all the age-gender groups' costs. As we can see in the table, the FLEX total cost for the reference family of four is only slightly higher than TFP cost ($7 per week). This very small difference indicts that the FLEX recommendations are easy to adapt to for either the consumers (this thesis mainly refers to the low-income people) or the policy makers (such as CNPP).

We also notice that when *r* equals 1.77, only the adult groups need to increase cost from the TFP recommendations to the FLEX recommendations. The reason is that adults consume FAFH more frequently and usually consume a larger amount and hence need to pay more for FAFH. Since the adults consume more FAFH and FAFH is relatively more expensive than FAH in the model, adults will feel more pressured under the budget constraint. Therefore, adding FAFH into TFP will have bigger impact on adult groups.

Comparison of FAH/FAFH Compositions

Figure 4.5 shows the FAH expenditure share in FLEX and TFP recommendations.

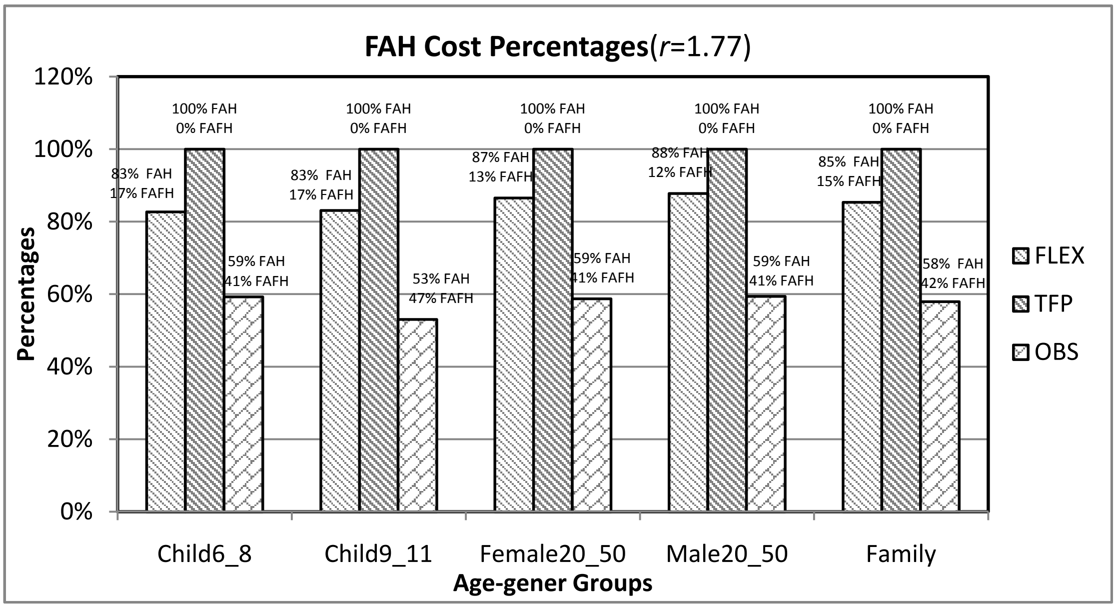


Figure 4.5 FAH cost percentages in three different costs(*r*=1.77)

Figure 4.5 reflects both the similarities and differences between the FLEX and TFP costs. The similarity concerns the cost of observed consumptions; the two recommendations have higher FAH cost percentages. That means both the FLEX and TFP models recommend low-income people to increase the percentages of FAH expenditure. In other words, both the two models suggest low-income people to consume more FAH.

The differences are that the TFP recommends 100% FAH share in the total costs, while the FLEX recommends 85% FAH share for the reference family of four. The FAH cost share of the FLEX recommendations is closer to the observed consumptions, which is around 60%. The difference indicates the FLEX recommendations have better adaptability than the TFP recommendations.

4.3.3 Shadow Prices of Cost Constraints

The shadow price is the amounts changed in the objective function value if we relax the constraint by one unit. The signs of shadow prices indicate the directions of the constraints' effect on the objective function values. The absolute values of the shadow prices suggest the magnitude of the effects. To study how the relaxations of cost constraint influence the objective functions values, we calculated the cost constraint's shadow prices from the FLEX model. To exempt the effect of *r*, we assigned *r* three different values, 1.2, 1.77 and 3. Table 4.5 shows the shadow prices of the four different age-gender groups of three different *r* values.

As stated in 4.3.2, we need to increase the cost constraint allotment if the model cannot yield a feasible solution. The biggest increase is for male from 20 to 50 when *r* equals 3, which is 0.9 dollars per day. In order to consistently compare shadow prices, we increase the cost constraint's allotment by 0.9 dollar per day for all the cases: for all three different *r* values and the four age-gender groups.

Table 4.5 Shadow Prices of Cost Constraints

Age-gender groups	*r*=1.2	*r*=1.77	*r*=3
Child6-8	-0.54	-0.98	-2.07
Child9-11	-0.76	-1.99	-4.10
Female20-50	-2.83	-6.86	-14.99
Male20-50	-5.30	-14.51	-107.05

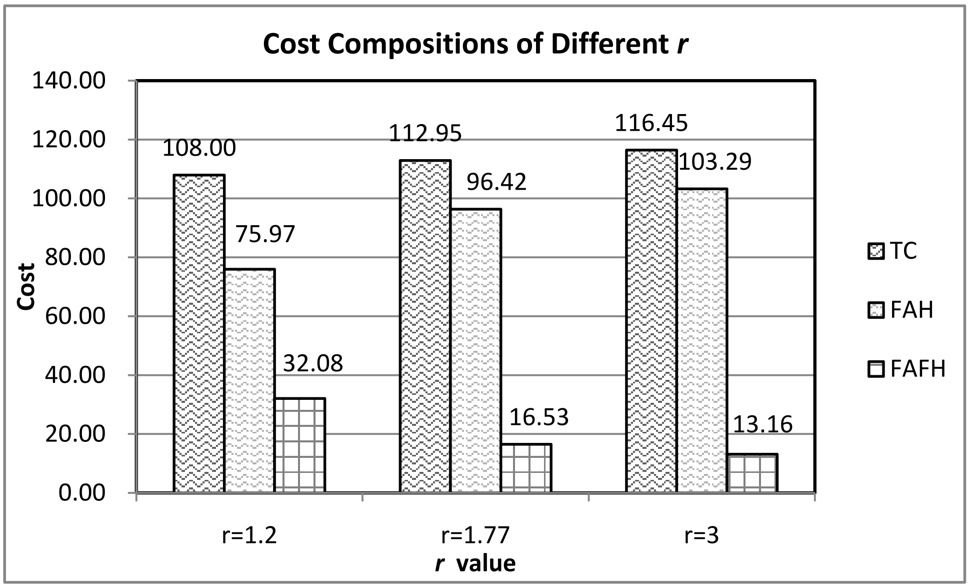
In Table 4.5, all the shadow prices are negative. That means if we increase the cost allotments, the FLEX recommendations' deviations from the observed consumption patterns will decrease—the FLEX recommendations will be much closer to the observed consumption patterns. Moreover, the shadow prices are quite large, which means the cost constraints have a very significant effect on the objective function values. Relaxation of the cost constraints can effectively decrease the differences. Take male from 20 to 50, for example, when the relative price equals 1.77. If we increase the cost allotment by 1 dollar per day, the total deviation from the FLEX recommendations to the observed consumptions will decrease by 14.51.

4.4 Sensitivity Analysis of r and Reduced Cost Analysis of FLEX Model

4.4.1 Sensitivity Analysis of r

The result analysis in the first three sections (4.1, 4.2 and 4.3) is based on *r* equals 1.77. Unquestionably, different *r* will give us different total costs. In this part, we will study the effects of changes of *r* on cost and deviations. Both the cost and deviations are based on a reference family.

Figure 4.6 lists the total costs (FAH costs and FAFH costs) of FLEX model recommendations across three different *r* values. The costs are measured in dollars per one week for a reference family of four.



Unit: $/week

Figure 4.6 The Costs of FLEX Recommendation Change across Different *r* Values

The parameter *r* is the relative ratio of FAFH price to FAH price. In the FLEX model, as *r* changes, FAFH prices change and the FLEX recommendation on food intake and nutrient intake will change accordingly. Figure 4.6 shows the changes.

As *r* increases, total cost increases from $108 to $112.95, and then $116.45. FAH expenditure increases from $75.97 to $97.52, and then to $103.29, while the FAFH expenditure shows an opposite trend. There are three forces driving this trend: the cost constraints, and the different price and nutrition characteristics of FAH and FAFH. Only when three assumptions are true will these downward trends of FAFH costs and upward trends of FAH costs hold: the cost constraint must hold constant, FAFH category must contain less nutrition amount for all the nutrients than the corresponding FAH category, and FAFH category must cost relatively more than FAH. The first assumption is easily defeated by the description before; as *r* increases, the cost constraints have been increasing in order to get a feasible solution. Second, although we can say that FAFH is less healthy than FAH, we cannot say that FAFH contains a smaller amount of nutrients for all the nutrients. For example, for the same food group like 'all cheese,' FAFH contain more sodium than FAH. Third, the relative price ratio *r* is assumed to be larger than 1 in the thesis. We cannot deny the opportunity for *r* to be less than 1 for some food categories. In all, since the above three assumptions don't hold, there is not enough evidence that this trend will hold forever either.

In fact, these three assumptions can be also used to explain the trend of the deviations across different *r*. In table 4.6, the deviation exhibits a trend first increasing and then decreasing. No constant trend exists. However, if the above three assumptions hold—the cost constraint holds constant, FAFH category contains less nutrition amount for all the nutrients than the corresponding FAH category, and FAFH category costs relatively more than FAH—as *r* increases, people will be forced to consume less FAFH, and the total deviations will keep increasing.

Table 4.6 Deviation of Different *r*

	FLEX Deviation
r=1.2	43.05
r=1.77	52.21
r=2	82.43
r=3	71.38

4.4.2 Reduced Cost Analysis

The reduced cost is the change in the objective function value of an optimization problem obtained by changing the variables in the problem by one unit. It reflects how important a variable is to the optimal objective function value. Looking back, the variables in the FLEX model are the FLEX recommendation amounts of the 58 FAH categories and the 58 FAFH categories. Since a lot of the variables have a very small value, their reduced costs are 0. However, the remaining significant reduced costs all have strong indications.

Take, for example, the reduced cost for four food categories: "cakes, pies, and other sweet bakery products—whole grain-*FAH*" (WFAH), "cakes, pies, and other sweet bakery products—whole grain-*FAFH*" (WFAFH), "cakes, pies, and other sweet bakery products—non-whole grain-*FAH*" (NWFAH) and "cakes, pies, and other sweet bakery products—non-whole grain-*FAFH*” (NWFAFH). The reduced cost for WFAH and NWFAH are 4.86E-8 and 5.83E-9 respectively. Both the positive numbers indicate that if we increase the WFAH and NWFAH recommendations by 100g, the total deviation of FLEX recommendations to observed consumption will increase by 4.86E-8 and 5.83E-9 respectively. And 4.86E-8 is slightly larger than 5.83E-9, which indicts that at home, whole grain recommendations have larger impact than the non-whole grain ones on the change of total deviations. The reduced cost for WFAFH and NWFAFH are -3.63E-9 and 1.46E-9. That means, in real life, people consume more whole grain made cakes and pies outside of the home rather than non-whole grain made cakes and pies. So when you increase FAFH whole grain made cakes and pies recommendations, the deviation will decrease.

4.5 Chapter Summary

In this chapter, we compared the major food group consumptions, nutrition intakes and cost of FLEX and TFP recommendations as well as the observed consumption patterns. From the comparisons of major food group consumptions and nutrition intakes, we can conclude that the two recommendations are much healthier than the observed pattern. Compared with the TFP recommendations, the FLEX model has incorporated FAFH, so the FLEX recommendations are closer to the actual consumptions and will be much easier for people to adapt. Both the FLEX and TFP recommendations cost much less than the observed patterns. The FLEX recommendations only cost a little more than the TFP ones. Meanwhile, the shadow prices of cost constraints show that if the cost allotment increases, the objective function value will decrease. Finally, we conducted sensitivity analysis of *r* and studied some significant reduced costs.

Chapter V. Conclusion and Future Work

5.1 Conclusion

5.1.1 The Constructions of the Thesis

The current TFP recommendations don't allow FAFH, which is hard to adapt to in real life. In section 1.1.3, we analyzed the change of food consumption trends and the demographic characteristics of the SNAP participants, which show that the SNAP participants do have needs for FAFH since they face time, accessibility and other constraints. Meanwhile, from the American Dietetic Association's point of view "the total diet or overall pattern of food eaten is the most important focus of a healthful eating style. All foods can fit within this pattern, if consumed in moderation with appropriate portion size and combined with regular physical activity"(The American Dietetic Association). We conclude that what really matters is not how much FAH or FAFH you eat, but the overall quality of your diet. So we expand the TFP model with FAFH dimensions to satisfy the low-income people's FAFH need.

Thus, in the FLEX model, there are two dimensions: FAH and FAFH. The objective function has been revised to minimize the sum of deviations from both FAH and FAFH recommendations to actual consumptions. All the constraints now need to be met by total recommendations from FAH and FAFH. For some cost constraint, we need to increase the upper bounds in order to get feasible solutions since FAH and FAFH have different prices.

From the TFP model to the FLEX model, the inputs changed from one dimension to two dimensions. The FLEX model uses the similar datasets of price, nutrition and average consumption for FAH in the TFP. The NHANES data is used to generate average consumption and nutrient profiles for FAFH. The relative price ratio of FAFH to FAH is assumed and fixed at 1.77.

5.1.2 The Conclusions and Contributions of the Thesis

Having added the FAFH, we are able to get feasible solutions from the FLEX model, which means the total recommendations of the FLEX model (including both

FAH and FAFH) satisfy the entire nutrition intake and food group serving size requirements just as the TFP model does. The food group consumptions and nutrition intakes may come from both FAH and FAFH (FAH and FAFH have different nutrition compositions), but the whole FLEX recommendations are of high dietary quality and have a great potential to improve the diet quality of the low-income people.

Compared to the TFP recommendations, the FLEX ones are much closer to the low-income people's actual food consumptions—the deviations from FLEX recommendations to the observed consumption patterns have been greatly decreased from that of the TFP recommendations (from 103 to 52). Thus, the FLEX recommendations are much easier for them to adopt—SNAP participants don't need to change as much as the TFP requires them to in order to achieve a healthful and economical diet.

After incorporating FAFH, the weekly cost of the FLEX recommendations is only 7 dollars higher than the TFP recommendations for weekly food expenditure for a family of four. Compared to the actual food expenditures of low-income people, the FLEX recommendations are still 64 dollars less. The relatively small cost of the FLEX recommendations reflects its easy affordability. If, in real life, the relative prices between FAFH and FAH are similar to what we used in the study, 1.77 (i.e., FAFH costs 77% more than FAH,) people can eat FAFH in moderation proportion and achieve the goal of eating healthfully at minimal costs. So the FLEX recommendations have provided more flexibility to the SNAP participants. They are no longer constrained to FAH and their needs for FAFH have been satisfied. Compared to the TFP recommendations, the FLEX recommendations will be easier to adopt for the low-income people.

5.2 Future Work

Due to limited time and data sources, the thesis does have some imperfections. We need to expand them in future studies.

First, the identification process of FAH and FAFH is not very precise. Simply assuming that food consumed at home amounts to food prepared at home, and food consumed away from home equals food prepared away from home will introduce some errors. A lot of food consumed at home may be prepared away from home, such as pickup and delivery food. Meanwhile, some of the food consumed away from home may prepare at home, such as food taken to work, a potluck dinner and so on.

Starting with NHANES 2003-2004, the information on where food was prepared has been collected. Not only can FAH and FAFH be distinguished, but various FAFH sources have been identified, including fast food and restaurants with waiting service. The reason we have to use NHANES 2001-2002 rather than NHANES 2003-2004 is that the 2003-2004 MyPyramid Equivalent Database has not been released, so the constraints on meeting the serving size recommendations for the seven food groups cannot yet be constructed. After the 2003-2004 MyPyramid Equivalent Database has been released, we can construct a new set of inputs from the 2003-2003 NHANES and MyPyramid Equivalent Database, and thus this problem will be solved.

Second, the construction of FAFH price has also limited the model's ability in reflecting the real world scenarios. What value is suitable for the relative price *r*? Are the *r* values the same across all the food categories? Obviously for different food groups, *r* values can be different. And it requires a lot of further research to choose reasonable yet accurate values for all the food categories.

One proposal to resolve this problem is to construct a nationwide FAFH price dataset using the same procedures as the CNPP FAH price database constructions. We need to collect two datasets in order to implement this proposal: national databases of recipes to decompose food codes into food items (ingredients) that are purchasable by the restaurants; national price databases for those ingredients prices the restaurants face.

The other proposal will be the hedonic regression approach. First, collect the national price databases for the typical FAFH and decompose each FAFH item into 58 FAFH categories. Then use hedonic regression to estimate the price for each FAFH category.

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Appendix A Brief Introduction of NHANES 2001-2002

NHANES 2001-2002 data provides average consumption amounts, average nutrient compositions, average MyPyramid profiles and average cost. With proper sample weights, NHANES 2001-2002 is a complex, multistage probability sample of the civilian noninstitutionalized population of the United States (NHANES 2001-2002). And it provides very detailed information on the sample persons' demographic and socioeconomic characteristics, food consumptions, nutrition intakes as well as the health conditions.

The useful data in NHANES 2001-2002 for this project includes the demographic statistics and the food intake data. Age, gender information can help to group the total population into the 15 age-gender groups. Pregnancy status variable can help to identify the pregnant women and exclude them from the sample[2]. The variable of poverty income ratio will be used to pick up the low-income population. "Low-income" is defined as those households with before-tax income at or below 130 percent of the U.S. poverty threshold (USDHHS), which is the gross income cutoff for eligibility in the Supplemental Nutrition Assistance Program (TFP 2006 Report). The variable "whether the foods are consumed at home" are used to distinguish FAH and FAFH. And the food consumption and nutrient intake information are used to calculate the average consumption amounts and nutrient content of FAH and FAFH.

[2] The TFP has also excluded the pregnant women. This is mainly because pregnant women have different nutrition intake characteristics and requirements. They cannot be included in any female age-gender group.

Appendix B Brief Introduction of CNPP Price database

FAH price data are drawn from the 2001-2002 CNPP Food-at-Home Price Database. This database is created by CNPP with assistance from USDA's Economic Research Service and Food and Nutrition Service by merging food consumption data with national food price data from the 2001-2002 Nielsen Homescan Panel. The price database includes the prices paid for food items by 16,821 households, selected and weighted to reflect the U.S. population, in the 48 coterminous States.

Appendix C Brief Introduction of the Dietary Data

The dietary data includes: (1) the 1997-2005 Recommended Dietary Allowances (RDAs); (2) the 2005 Dietary Guidelines for Americans; and (3) the 2005 MyPyramid food intake recommendations.

RDAs provide recommended dietary allowances for vitamin A, vitamin C, vitamin B6, vitamin E, vitamin B12, thiamin, riboflavin, niacin, calcium, phosphorus, magnesium, iron, folate, zinc, copper, fiber and Potassium.

The federal government's Dietary Guidelines for Americans, which are updated every five years by a panel of eminent nutritionists, medical professionals and fitness experts to reflect the latest scientific and medical knowledge by the departments of Agriculture (USDA) and Health and Human Services (HHS). The guidelines provide science-based advice of special nutrition’s for healthy eating and active living.

MyPyramid was released by USDA on April 19, 2005. It translates recommendations from the Dietary Guidelines for Americans into the types and amounts of food people can eat to achieve a healthy diet by assigning people into different MyPyramid Intake patterns. In addition, MyPyramid also has some food subgroup requirements:

Appendix D 58 Food Categories

As stated in TFP 2006 Report, these 58 food categories are mainly based on the classification of the 1999 TFP food categories used in the 1989-91 CSFII, with modifications suitable to meet the recommendations from the 1997-2005 Dietary Reference Intakes, the 2005 Dietary Guidelines for Americans, food intake patterns of MyPyramid, and for TFP models(TFP 2006 Report). The 58 food categories are listed in the following table:

Table A-1 58 Food Categories in the TFP 2006 Report

Main Food Groups	#	Food categories
Milk Products	1	Milk and milk-based foods—regular fat
	2	Milk and milk-based foods—low fat
	3	cheese
	4	Milk-based drinks and desserts—regular fat
	5	Milk-based drinks and desserts—low fat
Meat and Beans	6	Red meats—regular discretionary solid fat, low cost
	7	Red meats—regular discretionary solid fat, regular cost
	8	Red meats—low discretionary solid fat, low cost
	9	Red meats—low discretionary solid fat, regular cost
	10	Fish—regular discretionary solid fat, low cost
	11	Fish—regular discretionary solid fat, regular cost
	12	Fish—low discretionary solid fat, low cost
	13	Fish—low discretionary solid fat, regular cost
	14	Poultry—regular discretionary solid fat, low cost
	15	Poultry—regular discretionary solid fat, regular cost
	16	Poultry—low discretionary solid fat, low cost
	17	Poultry—low discretionary solid fat, regular cost
	18	Lunch meats, sausages, and bacon—regular fat

	19	Lunch meats, sausages, and bacon low fat
	20	Eggs and egg mixtures
	21	Meat, poultry, and fish mixtures—regular discretionary solid fat
	22	Meat, poultry, and fish mixtures—low discretionary solid fat
	23	Lentil-meat
	24	Lentil-vegetable
	25	Nuts and seeds
Grains	26	Breads, yeast and quick—whole grain
	27	Breads, yeast and quick—non-whole grain
	28	Breakfast cereal—non-whole grain
	29	Breakfast cereal—whole grain, low calories
	30	Breakfast cereal—whole grain, regular calories
	31	Rice and pasta—whole grain
	32	Rice and pasta—non-whole grain
	33	Cakes, pies, and other sweet bakery products—whole grain
	34	Cakes, pies, and other sweet bakery products—non-whole grain
	35	Grain-based snacks—whole grain
	36	Grain-based snacks—non-whole grain
	37	Grain mixtures—regular fat
	38	Grain mixtures—low fat
Vegetables and Fruits	39	Citrus fruits, melons, and berries juices
	40	Citrus fruits, melons, and berries
	41	Fruit juices other than citrus, melon, and berry
	42	Fruit other than citrus, melon, and berry
	43	Potato products—regular fat
	44	Potato products—low fat
	45	Dark-green vegetables—added fat
	46	Orange vegetables—added fat

	47	Dark-green vegetables—no-added fat
	48	Orange vegetables—no-added fat
	49	Other vegetables—added fat
	50	Tomatoes—added fat
	51	Other vegetables—no added fat
	52	Tomatoes—no-added fat
	53	Mixed vegetables—added fat
	54	Mixed vegetables—no-added fat
Other Foods	55	Fats, oils, salad dressings, sauces, and condiments
	56	Coffee and tea
	57	Fruit drinks, soft drinks, and ades—regular calorie
	58	Fruit drinks, soft drinks, and ades—low calorie
	58	Sugars and sweets

Appendix E The Construction of CNPP Price Database and Why It Failed To Construct the FAFH Price Database Using The Same Logic

In the figure below, the left part is showing the logic flow to construct the FAH price database (represented by the solid arrows and boxes), while the right part is showing the logic flow to construct the FAFH price database assuming that we have all the resources needed to construct a similar database for FAFH prices (represented by the dashed arrows and boxes).

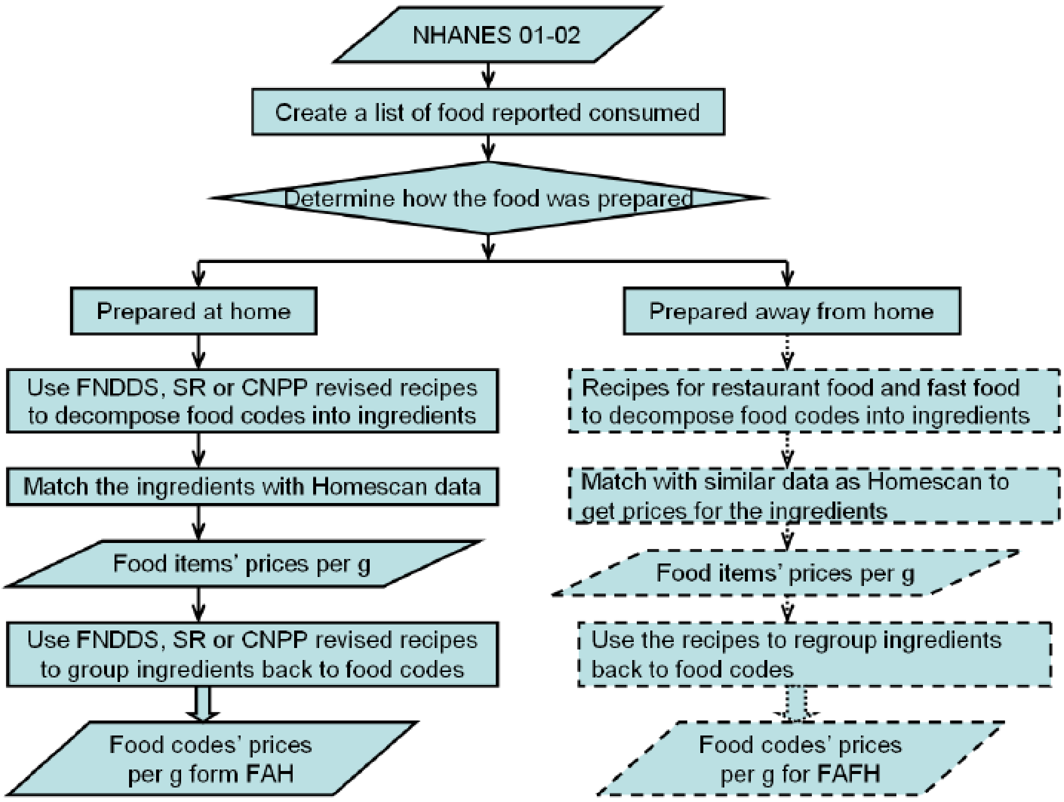

Figure A-1 Flowchart of Construction of Price Database

As shown in the figure, the creation of the food price database mainly includes the following six steps:

(1) The first step is to create a list of food consumed and identify FAH and FAFH from all the foods reported in NHANES 2001-2002. The identifying procedures are as same as before and using the same variable "whether the food was consumed at home". If the variable value indicts that the food was consumed at home, the food will be identified as FAH.

(2) The second step is to identify the form of the food when it was purchased,

ready-to-serve or ready-to-heat form or purchased as ingredients for recipes to be prepared at home. Many foods' level of convenience can be distinguished by the USDA food codes. For the same kinds of food, there are different food codes representing the convenience levels. An example is listed in TFP 2006 report: "macaroni and cheese has codes that detail whether it is made from scratch, made from a box mix, or purchased as a frozen entrée". For the foods which cannot be determined the format when purchased, CNPP use the most frequently purchased form as its purchase form.

(3) The third step is breaking down FAH into specific ingredients using data from version 1 of the USDA's Food and Nutrient Database for Dietary Studies (FNDDS). As mentioned in the report TFP 2006, some recipes need to be modified to match ingredients that people could reasonably purchase in stores, such that some food ingredients which are rarely find in stores will be replaced by common items.

(4) The fourth step is to apply cooking and waste conversion factors that adjust for the loss or gain in weight due to cooking and preparation to all relevant ingredients.

(5) The fifth is pricing ready-to heat or ready-to-serve foods and ingredients by using data from the 2001-2002 Nielsen Homescan™ Panel. Picking up the 1,429 low-income households in the panel for a 2-year period, the average price paid by these low-income households for each food item bought was calculated. For the same food item purchased by the same household, each purchase occasion counts when calculating the average price. A food item should be purchased more than 75[3] times by the low-income family in order to be eligible to calculate the average price. Otherwise if the purchases are less than 75[3] times, the price will be calculated with the purchases by all households. After achieving all the prices, the food which is in ready-to-eat form are matched to the corresponding prices directly. For foods which are prepared from scratch, CNPP first priced all the ingredients and then regrouped the ingredients into the food code and get the total

[3] This minimum sample size, recommended by Nielsen, ensured statistical reliability of the average price.

price of the food code. All the foods were priced per 100 grams.

(6) For the infrequently purchased food, CNPP use the closest substitute for the food item or food services found on the internet to determine its price.

Then consider using the same logic to construct the FAFH price database. The process involves a strong assumption that we have the all the data information we need to construct the database. In fact, in order to accomplish this logic, we still need:

a. National databases of recipes to decompose food codes into food items (ingredients) those were purchasable by the restaurants.
b. National price databases for those ingredients prices the restaurants face.

However, those data sets do not exist. Also the fact that FAFH involves service charges requires further assumptions to calculate the meal prices. It seems impossible to follow the same logic of CNPP to create a price database for FAFH.

Appendix F MyPyramid Major Food Groups and Food Subgroup Constraints

There are seven major food groups from the 2005 MyPyramid food intake recommendations. The descriptions are as follows:

- Grains, include refined grains and whole grains
- Vegetables, includes dark green vegetables, orange vegetables, starchy vegetables, dry beans and peas and other vegetables
- Fruits, any fruit or 100% fruit juice counts as part of the fruit group. Fruits may be fresh, canned, frozen, or dried, and may be whole, cut-up, or pureed
- Oils, refer to the fats that are liquid at room temperature, like the vegetable oils used in cooking.
- Milk, includes fluid milk and many other milk-based products
- Meat and beans, includes meats, fish, poultry as well as more beans, peas, nuts, and seeds
- Discretionary calories, represented by the narrow tip of each colored band, including items such as candy, alcohol, or additional food from any other group.

MyPyramid also contains certain food subgroup consumptions constraints:

- Grains: at least 50 percent of the total amount from the grain group had to be whole grains.
- Fruits: at least 50 percent of the amount from the fruit group had to be non-juice fruit.
- Vegetables: all vegetable subgroups had to be incorporated at levels that were specified in MyPyramid.
- Discretionary calories: the amounts of solid fats and added sugars had to sum to no more than the discretionary calorie allowance for the assigned food intake pattern.