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The Asymmetric Effect of Dietary Knowledge on Nutrient Intake In China: Implications for Dietary Education Programs

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Abstract

This paper demonstrates that dietary knowledge can influence nutrient intake differently depending on whether expected food availability is increasing or decreasing. Using data from China, we find that overall dietary knowledge has larger and more statistically significant effects on total calorie intake and the intake of three macro nutrients (carbohydrate, fat, and protein) when expected food availability increases than when it decreases. Without distinguishing the direction of changes in expected food availability, most of the corresponding effects become smaller and statistically insignificant. Thus, the effect of dietary knowledge on nutrient intake might have been underestimated in previous studies. We discuss the implications of these findings for the design and implementation of dietary education programs.

Dietary education is recognized as an important factor in preventing and reducing the global prevalence of malnutrition. For example, approximately one billion overweight adults (WHO 2010), 925 million undernourished people (FAO 2010), and 1.62 billion anemic people (mainly as a result of iron deficiency) (WHO 2008), have been reported. Although several studies have examined the relationship between dietary (or health) information and the consumption of certain nutrients and foods to deduce direct or indirect implications for the effect of dietary education, the studies generally assume that the relationship is constant regardless of changes in expected food availability, the so-called conventional framework (See, for example, Barreiro-Hurler et al. 2010; Lin and Yen 2008; Variyam 2008; Drichoutis et al. 2004 block et al. 2004; Finke and Huston 2003; Weaver and Finke 2003; Kaabia et al. 2001; and Kim et al. 2000). However, we may reasonably expect the effect of dietary education (or knowledge) to differ depending on whether households expect their food availability increases or decreases. For example, households may take into account more dietary options available to implement what has been learned in dietary education programs when expected food availability increases than when it decreases, or households may care more about the costs of diet-related diseases when expected food availability decreases than when it increases. Thus, this paper builds upon the previous studies by proposing a new framework in which the effect of dietary knowledge on nutrient intake may differ depending on whether expected food availability is increasing or decreasing (the so-called asymmetric framework). This study empirically demonstrates that the asymmetric framework has different implications from the conventional framework for the design and implementation of dietary education programs.

First, we define the asymmetric effect of dietary knowledge by constructing a simple consumption model. The model clarifies the fact that observed asymmetric changes in nutrient intake can be due to two distinct sources: asymmetric responses to changes in total food availability and asymmetric effects of dietary knowledge. In our empirical analysis, we use data from the China Health and Nutrition Survey (CHNS) for 2000, 2004 and 2006. We employ an individual fixed-effects model with proxies to estimate the effect of dietary knowledge on nutrient intake (intake of calories, carbohydrates, fat and protein). To measure dietary knowledge, we use data on all nine diet-related questions in the CHNS in which subjects choose whether they 'agree', 'disagree', or 'unknown' (i.e., do not know about) a diet-related statement (see Table 1). We construct an index of overall dietary knowledge by applying the principal component factor method to the nine questions. In addition, to examine the effect of more specific dietary knowledge, we construct a set of indicators for each question: no change in the answer to the question (NC), the answer changed to a correct one (CR), and the answer changed to a wrong one (IC). Changes in expected food availability are measured by the fitted values obtained from the regression of changes in calorie consumption per household member between 2004 and 2006 on lagged changes (between 2000 and 2004) in household per capita income and prices of six food groups, and the initial conditions (in 2004) of age, sex, household-head characteristics, household demographics, and residential location. Using these measures, we test whether the effect of dietary knowledge on nutrient intake is significantly different when expected food availability increases from when it decreases.

This paper contributes to the existing literature in three important ways. First, if there is significant asymmetry in the effects of dietary knowledge on nutrient intake, previous studies may underestimate or overestimate the effect of dietary knowledge on nutrient intake depending on whether expected food availability increases or decreases. This is because the estimates in previous studies may average asymmetric estimates that may have opposite signs and/or different levels of statistical significance depending on the direction of changes in expected food availability. Second, the underestimation (or overestimation) can lead to overestimating (or underestimating) the optimal level of investment on dietary education. Lastly, our framework allows us to examine whether knowledge about certain nutrients and/or foods may influence the intake of unrelated (or unintended) nutrients and/or foods (e.g., the influence of knowledge about vegetable consumption on fat intake). Clarifying this influence may provide a more comprehensive picture of how narrowly focused dietary information influences overall diets, which could help to design better methods of presenting information in dietary education.

Conceptual Framework

To formally introduce our hypotheses, we construct a simple two-period consumption model. In the model, individuals follow a two-stage utility maximization: inter-temporal allocation of total food consumption (first stage), and allocation across two food groups within each time period (second stage).

First Stage: Inter-temporal Allocation of Total Food Consumption

First, the individual maximizes the two-period household utility $U = u(F_1; K_1) + E[u(F_2; K_2)]$ subject to an inter-temporal budget constraint $p_1F_1 + p_2F_2 = y_1 + y_2$, where F_t is a total food consumption at time t; K_t is a vector of taste shifters at time t; p_t is the vector of food prices at time t; and $y_t$is the income for foods at time t. While y_1 is assumed to be predetermined, y_2 is assumed to follow the stochastic process, $y_2 = y_1 + v_2$, where v_2 is stochastic and a source of income uncertainty. We assume that the household observes y_2 at the beginning of time 2. Note that K includes dietary knowledge (DK), and only DK in the taste shifters may change over time to provide implication on the effect of nutrition education. For simplification, we assume that

DK affects only the allocation across food groups (i.e., the second stage optimization) and does not affect inter-temporal allocation of total food consumption (i.e., the first stage optimization).

The utility function is assumed to be strictly concave and differentiable with $u'(0) = +\infty$ and $u''(.) < 0$. Solving the first-order conditions (FOCs) yields the optimal levels of total food consumption for each time period F_t^*. Once F_1^* is determined, F_2^* is also uniquely determined from the budget constraint. Because F_1^* is a unique solution regardless of the direction of changes in y, the household caloric intake responds symmetrically to decreases and increases in income available for food.

However, there is sufficient theoretical and empirical evidence to suspect the symmetry of the response. That is, we may observe $\Delta F^{*+} \neq \Delta F^{*-}$, where ΔF^{*+} denotes $F_2^* - F_1^*$ when y increases and ΔF^{*-} denotes $F_2^* - F_1^*$ when y decreases. For example, Shimokawa (2010) conceptually examines an asymmetry in caloric intake resulting from budget constraints or loss aversion and empirically demonstrates a significant asymmetry in the effect of food availability on caloric intake (see Shimokawa 2010 for more references). We refer to this asymmetry in the first stage as asymmetric responses to total food availability.

It is important to emphasize that the primary goal of our model is to distinguish the asymmetric effect of dietary knowledge from other possible explanations for asymmetric changes in nutrient intakes (i.e., asymmetric responses to total food availability). Thus, our current model may suffice for this goal, although it cannot provide any testable implications to identify a unique theory behind the asymmetry.

Second Stage: Allocation across Food Groups

In the second stage, the individual decides how to allocate the predetermined F_t^* between two food groups, staple foods (S) and fatty foods (L), at each time period by maximizing

$U_t(f_{St}, f_{Lt}; K)$, where f_{St} and f_{Lt} are the levels of consumption of staple foods and fatty foods at time *t*, respectively, and $F_t^* = f_{St} + f_{Lt}$. Now, to clarify the change in dietary knowledge (DK), we explicitly write DK as a taste shifter while suppressing other fixed taste shifters i.e., $U_t(f_{St}, f_{Lt}; DK_t)$. We also assume that dietary preference depends on DK. This is represented by a subjective weight on staple food consumption $w_S(DK_t) \in (0, 1)$, where a weight on fatty food consumption is $w_L(DK_t) = (1 - w_S(DK_t))$. Then, the second-stage optimization problem can be defined as: $max_{f_{St}}\, U_t = w_S(DK_t)u(f_{St}; DK_t) + (1 - w_S(DK_t))\, u(F_t^* - f_{St}; DK_t)$ subject to $p_{St}f_{St} + f_{Lt} \leq y_t$. Solving the FOCs, the optimal consumption of staple foods can be expressed as $f_{St}^* = f_{St}^*(F_t^*, p_{St}, y_t; w_S(\text{DK}))$ for t = 1, 2.

The effect of DK on f_{St}^* can be expressed as $\frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK}$. Our key question is whether this effect differs depending on the direction of changes in income for foods i.e., $\left[\frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK}\right]^+ \neq \left[\frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK}\right]^-$, where + and – indicate an increase and a decrease in y, respectively. For example, when y decreases, correct dietary knowledge may make people more anxious about the costs of diet-related diseases and motivate them pay more attention to less-fatty foods (i.e., $\left[\frac{\partial w_S}{\partial DK}\right]^+ < \left[\frac{\partial w_S}{\partial DK}\right]^-$). By contrast, people may have more dietary options when y increases, so it may be easier for them to follow their dietary preference when y increases than when it decreases (i.e., $\left[\frac{\partial f_S^*}{\partial w_S}\right]^+ > \left[\frac{\partial f_S^*}{\partial w_S}\right]^-$). Both of these effects may hold at the same time. Existing economic theories predict little about the existence and the patterns of such asymmetric effects, which are rather empirical questions. This asymmetry in the second stage is referred to as asymmetric effect of dietary knowledge.

Combining the results of the first-stage and the second-stage optimizations, the change in staple food consumption can be written in the symmetric framework as $\Delta f_S^* = \frac{\partial f_S^*}{\partial F^*}\frac{\partial F^*}{\partial y}\Delta y + \frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK}\Delta DK$. In our asymmetric framework, the change is expressed as $\Delta f_S^{*+} = \left[\frac{\partial f_S^*}{\partial F^*}\frac{\partial F^*}{\partial y}\right]^+ \Delta y + \left[\frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK}\right]^+ \Delta DK$ if $\Delta y > 0$, and $\Delta f_S^{*-} = \left[\frac{\partial f_S^*}{\partial F^*}\frac{\partial F^*}{\partial y}\right]^- \Delta y + \left[\frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK}\right]^- \Delta DK$ if $\Delta y < 0$. The same principle will be applied to derive Δf_L^*, Δf_L^{*+}, and Δf_L^{*-}. Similarly, in the symmetric framework, the change in nutrient intake can be written as

$$\Delta N^* = \frac{\partial N^*}{\partial f_S^*}\Delta f_S^* + \frac{\partial N^*}{\partial f_L^*}\Delta f_L^* = \left(\frac{\partial N^*}{\partial f_S^*}\frac{\partial f_S^*}{\partial F^*} + \frac{\partial N^*}{\partial f_L^*}\frac{\partial f_L^*}{\partial F^*}\right)\frac{\partial F^*}{\partial y}\Delta y + \left(\frac{\partial N^*}{\partial f_S^*}\frac{\partial f_S^*}{\partial w_S}\frac{\partial w_S}{\partial DK} + \frac{\partial N^*}{\partial f_L^*}\frac{\partial f_L^*}{\partial w_L}\frac{\partial w_L}{\partial DK}\right)\Delta DK$$

$$= \lambda_{N,y}\Delta y + \lambda_{N,DK}\Delta DK$$

where *N* is nutrient intake and $\frac{\partial N^*}{\partial f_j^*}$ is the partial effect of consuming food f_j on nutrient *N* for *j* = S, L. In our asymmetric framework, $\Delta N^{*+} = \lambda_{N,y}^+\Delta y + \lambda_{N,DK}^+\Delta DK$ and $\Delta N^{*-} = \lambda_{N,y}^-\Delta y + \lambda_{N,DK}^-\Delta DK$.

A main objective of this paper is to identify the existence of the asymmetric effect of dietary knowledge on nutrient intake by testing the null hypothesis $\lambda_{N,DK}^d = \lambda_{N,DK}^- - \lambda_{N,DK}^+ = 0$. It should also be emphasized that the observed asymmetry in ΔN^* can be due to the asymmetry in $\lambda_{N,y}$, the asymmetry in $\lambda_{N,DK}$, or both. Thus, to empirically identify the asymmetry in $\lambda_{N,DK}$ empirically by using data on ΔN^*, we must also control for the asymmetry in $\lambda_{N,y}$.

When the Measure of Dietary Knowledge is Discrete

To examine the effect of specific dietary knowledge, we employ a discrete measure of DK because the answer for a specific dietary question is discrete and cannot be converted into a continuous variable. We define three difference status based on changes in dietary knowledge. That is, in the second period, the individual remains the same answer to a question (NC), changed to a correct answer (CR), or changed to an incorrect answer (IC). In the symmetric framework, the changes in nutrient intake for the three cases can be expressed as ΔN_{NC}^{*}, ΔN_{CR}^{*}, and ΔN_{IC}^{*}. To measure the effect of dietary knowledge on nutrient intake, we examine pair-wise differences across ΔN_{UK}^{*}, ΔN_{CR}^{*}, and ΔN_{IC}^{*} as follows: $\lambda_{N,CR-UK} = \Delta N_{CR}^{*} - \Delta N_{UK}^{*}$, $\lambda_{N,IC-UK} = \Delta N_{IC}^{*} - \Delta N_{UK}^{*}$, and $\lambda_{N,CR-IC} = \Delta N_{CR}^{*} - \Delta N_{IC}^{*}$.

In the asymmetric framework, we estimate $\Delta N_{\Delta DK}^{*}$ for $\Delta y > 0$ ($\Delta N_{\Delta DK}^{*+}$) and for $\Delta y < 0$ ($\Delta N_{\Delta DK}^{*-}$) separately, where ΔDK = *UK*, *CR* and *IC*. $\lambda_{N,DDK}^{+}$ and $\lambda_{N,DDK}^{-}$ for each pair-wise difference can be defined in a similar manner, where *DDK* = *CR-UK, IC-UK*, and *CR-IC*. To examine the potential asymmetry in the effect of dietary knowledge on nutrient intake, we test the null hypothesis $\lambda_{N,DDK}^{d} = \lambda_{N,DDK}^{-} - \lambda_{N,DDK}^{+} = 0$ for each pair-wise difference.

Empirical Strategy

As a dependent variable, we employ the total nutrient intake rather than the consumption of specific food items. The advantage of this approach is that the estimated effect of dietary knowledge includes the effects of all substitutions and complements among food and non-food items.

The basic model for the change in nutrient intake of individual *i* in household *h* in community *v* between periods t–1 and t is

$$\Delta \ln(\mathrm{N_{ihvt}}) = \alpha + \lambda_{\mathrm{N,DK}}\Delta \mathrm{DK_{it}} + \lambda_{\mathrm{N,y}}\Delta\hat{y}_{\mathrm{ht}} + \alpha_{\mathrm{X}}\Delta \mathrm{X_{ihvt}} \quad (1)$$

$$+\Delta\mu_{\mathrm{it}} + \Delta\mu_{\mathrm{ht}} + \Delta\mu_{\mathrm{vt}} + +\Delta\nu_{\mathrm{ihvt}},$$

where $\Delta\ln(\mathrm{N_{ihvt}})$ is a change in log nutrient intake for individual *i* from t–1 to t; ΔDK is the change in a measure of dietary knowledge for individual *i* from t–1 to t (the measure will be discussed in more details in the data section). $\Delta\hat{y}$ is the change in expected food availability for household *h* from t-1 to t. $\Delta \mathrm{X_{ihvt}}$ is the vector of changes in other time-variant individual-, household- and community-level characteristics that may affect individual nutrient intake from t–1 to t. $\Delta\mu_{it}$, $\Delta\mu_{ht}$ and $\Delta\mu_{vt}$ reflect changes in the unobservable time-variant nutrient requirements specific to an individual, a household and a community, respectively. $\Delta\nu_{ihvt}$ is the remaining error.

In equation (1), time-invariant unobserved factors are eliminated by differencing across years within the same individual. To control for the effects of remaining unobserved time-variant factors ($\Delta\mu_{it}$, $\Delta\mu_{ht}$ and $\Delta\mu_{vt}$), we use several proxies: gender and age dummies at t-1 (A_{it-1}) for the individual-specific nutrient requirement $\Delta\mu_{it}$, household head characteristics and household demography at t-1 (S_{ht-1}) for the household-specific nutrient requirement $\Delta\mu_{ht}$, and location dummies of residence at t-1 (R_{vt-1}) for the community-specific nutrient requirement $\Delta\mu_{vt}$. Because gender and age are controlled, the nutrient intake N_{ihvt} need not be normalized using age- and gender-specific nutrient requirements. Therefore, equation (1) can be rewritten as

$$\Delta\ln(N_{ihvt}) = \alpha + \lambda_{N,DK}\Delta DK_{it} + \lambda_{N,y}\Delta\hat{y}_{ht} + \alpha_X\Delta X_{ihvt} + \qquad (2)$$

$$+\alpha_A A_{it-1} + \alpha_S S_{ht-1} + \alpha_R R_{vt-1} + \Delta\nu_{ihvt}\ .$$

In this equation, $\lambda_{N,DK}$ measures the partial effect of dietary knowledge on the individual's intake of nutrient N where DK is a continuous variable. Using a similar strategy, the changes in expected food availability ($\Delta\hat{y}$) are estimated using the following regression model:

$$\Delta y_{ht} = \beta + \beta_M\Delta M_{ihv(t-1)} + \beta_A A_{it-1} + \beta_S S_{ht-1} + \beta_R R_{vt-1} + \Delta\tau_{ihvt},$$

where Δy_{ht} is changes in household calorie consumption per household member from t-1 to t, and $\Delta M_{ihv(t-1)}$ is the vector of changes in other time-variant individual-, household- and community-level characteristics that may affect food availability per household member from t–2 to t-1.

To allow the effect of dietary knowledge to change depending on whether household food availability increases or decreases, we introduce a dummy variable for a household *h* to indicates a decrease in y from t-1 to t ($\mathrm{NEG_{ht}}$) as follows:

$$\Delta\ln(\mathrm{N_{ihvt}}) = \alpha + \lambda^{+}_{\mathrm{N,DK}}\Delta\mathrm{DK_{it}} + \lambda^{\mathrm{d}}_{\mathrm{N,DK}}(\mathrm{NEG_{ht}})\Delta\mathrm{DK_{it}} + \lambda^{+}_{\mathrm{N,y}}\Delta\hat{y}_{\mathrm{ht}} + \lambda^{\mathrm{d}}_{\mathrm{N,y}}(\mathrm{NEG_{ht}})\Delta\hat{y}_{\mathrm{ht}} + \quad (3)$$

$$+\alpha_{\mathrm{NEG}}\mathrm{NEG_{ht}} + \alpha_{\mathrm{X}}\Delta\mathrm{X_{ihvt}} + \alpha_{\mathrm{A}}\mathrm{A_{it-1}} + \alpha_{\mathrm{S}}\mathrm{S_{ht-1}} + \alpha_{\mathrm{R}}\mathrm{R_{vt-1}} + \Delta\nu_{\mathrm{ihvt}} .$$

In this equation, $\lambda^{+}_{\mathrm{N,DK}}$ measures the partial effect of dietary knowledge when the household food availability increases. The partial effect of dietary knowledge when the household food availability decreases will be measured by $\lambda^{-}_{\mathrm{N,DK}} = \lambda^{+}_{\mathrm{N,DK}} + \lambda^{\mathrm{d}}_{\mathrm{N,DK}}$. To examine the existence of asymmetry in the effect, we test the null hypothesis $\lambda^{\mathrm{d}}_{\mathrm{N,DK}} = 0$.

In addition, we focus on people who answered “unknown” to a specific question in 2004, and we construct the indicators for changes in the knowledge about the question in 2006: obtain correct dietary knowledge (CR), obtain incorrect dietary knowledge (IC), and remain unknown (UK). Note that it is practically difficult to include the indicators for all five questions together because a sample size is significantly reduced by focusing on people who answered “unknown” to even one dietary question. Thus, to control for the effects of other dietary knowledge, we also include the summary measure of dietary knowledge, DK. The estimation equations for the symmetric and the asymmetric models are

$$\Delta\ln(\mathrm{N_{ihvt}}) = \alpha + \lambda_{\mathrm{N,DKI}}\mathrm{DKI_{iqt}} + \lambda_{\mathrm{N,y}}\Delta\hat{y}_{\mathrm{ht}} + \alpha_{\mathrm{DK}}\Delta\mathrm{DK_{it}} + \quad (4)$$

$$+ \alpha_{\mathrm{X}}\Delta\mathrm{X_{ihvt}} + \alpha_{\mathrm{A}}\mathrm{A_{it-1}} + \alpha_{\mathrm{S}}\mathrm{S_{ht-1}} + \alpha_{\mathrm{R}}\mathrm{R_{vt-1}} + \Delta\nu_{\mathrm{ihvt}} ,$$

$$\Delta\ln(\mathrm{N_{ihvt}}) = \alpha + \lambda^{+}_{\mathrm{N,DKI}}\mathrm{DKI_{iqt}} + \lambda^{\mathrm{d}}_{\mathrm{N,DKI}}(\mathrm{NEG_{ht}})\mathrm{DKI_{iqt}} + \lambda^{+}_{\mathrm{N,y}}\Delta\hat{y}_{\mathrm{ht}} + \lambda^{\mathrm{d}}_{\mathrm{N,y}}(\mathrm{NEG_{ht}})\Delta\hat{y}_{\mathrm{ht}} + \quad (5)$$

$$+\alpha_{\mathrm{NEG}}\mathrm{NEG_{ht}} + \alpha_{\mathrm{DK}}\Delta\mathrm{DK_{it}} + \alpha_{\mathrm{X}}\Delta\mathrm{X_{ihvt}} + \alpha_{\mathrm{A}}\mathrm{A_{it-1}} + \alpha_{\mathrm{S}}\mathrm{S_{ht-1}} + \alpha_{\mathrm{R}}\mathrm{R_{vt-1}} + \Delta\nu_{\mathrm{ihvt}} ,$$

where $\mathrm{DKI_{iqt}}$ is the vector of two indicators from the three indicators CR, IC and UK for a question q. In the symmetric framework, $\lambda_{\mathrm{N,DKI}}$ measures the average difference in the effect of dietary knowledge between the represented DK group and the excluded DK group. For example, if the DKI consists of CR and IC (i.e., UK is the excluded group), the coefficient of CR (i.e., $\lambda_{N,CR}$) measures the average difference between the effect of CR on ln(N) and the effect of UK on ln(N). That is, $\lambda_{N,CR}$ corresponds to $\lambda_{N,CR-UK}$ in our conceptual framework. The same principle will be applied to interpreting the coefficients in the asymmetric model.

Data

We use data from the CHNS in 2000, 2004 and 2006. The CHNS started collecting data on dietary knowledge in 2004, and data in 2000 is used only for estimating changes in expected food availability between 2004 and 2006. Our analytical sample includes 2,673 adults aged 18 or above who provided all information needed for our empirical analysis.

The CHNS asked nine dietary questions in which subjects choose either 'agree', 'disagree', or 'unknown' for each question (see Table 1). Using the answers to the questions, we construct two different types of measures of dietary knowledge. First, we construct a summary index of dietary knowledge by using the principal component factor method in 2004 and 2006. To construct the index, for each of the nine questions, we generate an indicator that takes the value1 for correct answer, -1 for incorrect answer and 0 for choosing 'unknown'. We use the scores predicted from the first and second principal component factors across these nine indicators as our summary index of dietary knowledge (DKI), which explains 58.7% of the variation in the indicators. ΔDK is computed by taking difference in the measure between 2004 and 2006. A limitation of this approach is that the effect of specific knowledge is unclear. To remedy this limitation, we also construct a set of indicators for each question separately, where the set consists of indicators of people whose dietary knowledge did not change (NC), people whose dietary knowledge changed to a correct one (CR), and people whose dietary knowledge changed to an incorrect one (IC). We perform regression analysis for each question by including two of the three indicators. This approach allows us to clarify the effect of a specific dietary knowledge and the differences among the effects of obtaining correct knowledge, obtaining incorrect knowledge, and no change in dietary knowledge. Summary statistics of these measures are presented in Table 1. The table also shows that the conditions of dietary knowledge are similar regardless of the direction of changes in expected food availability.

Table 2 presents key characteristics of our analytic sample. As dependent variables, we use total calorie intake (kcal) and intake of three macronutrients (carbohydrate (g), fat (g) and protein (g)) at the individual level, which were computed from average food intakes over three consecutive days and the China Food Composition Table 2004. Table 2 presents the initial nutrient intakes in 2004 and mean changes in nutrient intakes between 2004 and 2006. Although the mean changes in nutrient intakes are relatively small, their standard deviations are large.

In estimating expected food availability, we use calorie consumption per household member as a dependent variable rather than income or food expenditures per household member, for two reasons. First, food expenditure data are not collected in the CHNS. Second, although total household income are available in the CHNS, changes in total household income may not properly measure changes in household food expenditures because of both consumption smoothing and Engel's law (Mangyo 2008). In fact, our sample shows a relatively low correlation between calorie consumption per household member and income per household member (0.13). As determinants of expected food availability, we also included lagged variables X in equation (2) i.e., changes from 2000 to 2004. Summary statistics for the lagged variables are suppressed from Table 2 for simplification. Based on the measure of expected food availability, we construct an indicator of an increase in expected food availability (POS) and a decrease in expected food availability (NEG). The data show that 26.3% of our sample experienced an increase in their expected food availability during 2004-2006.

As control variables X in equations (2)-(5), we include changes in ln(income per household member) and changes in the logarithm of the prices of seven food groups (cereal, beans, pork, chicken, vegetables, eggs, and oil). As the proxies in the equations, we include the following variables measured in 2004: a female dummy, age in years (a quadratic form), ln(household size), proportions of age groups within a household (2-5y, 6-11y, 12-17y, 18-24y, 25-59y, 60y+), an indicator of secondary or higher education, household head characteristics (gender, age, and an indicator of secondary or higher education), an urban dummy, and dummies for nine provinces. We also included dummies for the combinations of survey months in 2004 and 2006 to control for seasonal differences in food demand.[1]

Empirical Results

Table 3 presents summary results for estimating equations (2) - (5). The first panel presents results for the summary index of dietary knowledge, and the following nine panels present results for five diet-related questions (Q1 – Q9). In each of the panels, the first sub-panel presents results for symmetric models (Sym), whereas the second sub-panel presents results for asymmetric models (Asym). In the panels for Q1 – Q9, each sub-panel presents three pair-wise differences across three groups: people whose dietary knowledge did not change (NC), people whose dietary knowledge changed to a correct one (CR), and people whose dietary knowledge

[1] Because the observations in August, September, November and December are relatively small, we constructed three dummies (Aug & Sep, Oct, and Nov & Dec) in each year. As a result, we obtain eight dummies, although some dummies are dropped in some subsamples because of a lack of observation.

changed to an incorrect one (IC). For example, CR-NC indicates the difference between the effect of CR and the effect of NC. In the Asym sub-panel, for each pair-wise difference, we present an estimate when household food availability decreases (NEG), an estimate when household food availability increases (POS), and the difference of NEG minus POS (Diff).

Overall, our results demonstrate that dietary knowledge is associated with nutrient intakes differently when people expect their food availability increases from when they expect their food availability decreases. We find that improving overall dietary knowledge significantly reduces an increase in total calorie intake (-2.2%) and intakes of carbohydrate (-1.9%), fat (-3.4%) and protein (-1.8%) when expected food availability increases, while insignificantly affects nutrient intake when expected food availability decreases (models 1 and 2 in Table 3). In symmetric models, we find a significant effect of dietary knowledge only on fat intake, and the magnitude of the effect (-0.016) is less than a half of the corresponding effect observed in an asymmetric model (-0.034). Thus, without distinguishing the direction of changes in expected food availability, we can overlook or underestimate the effect of dietary knowledge on nutrient intakes.

We further examine the partial effect of a specific dietary knowledge on nutrient intake while controlling for overall dietary knowledge. For this purpose, we examine how the effects of the specific dietary knowledge on nutrient intakes are different across three groups: people whose dietary knowledge did not change (NC), people whose dietary knowledge changed to a correct one (CR), and people whose dietary knowledge changed to an incorrect one (IC). Six key findings are listed below.

1) We find significant asymmetry in the effect of knowledge about fruit and vegetable consumption (Q1) on fat and protein intakes. The effect is statistically significant when expected food availability decreases, while insignificant when expected food availability

increases. The IC group reduces fat intake 10.1% less than the CR group and 15.7% less than the NC group when expected food availability decreases. The CR group reduces protein intake 3.5% more than the NC group and 7.3% more than the IC group when expected food availability decreases. The magnitudes of the corresponding effects in symmetric models are much smaller, and most of the estimates are statistically insignificant.

2) We find significant asymmetry in the effect of knowledge about sugar consumption (Q2) on total calorie intake and carbohydrate and protein intakes. The effect is statistically significant when expected food availability increases, while insignificant when expected food availability decreases. The CR group increased total calorie intake 12.1% less than the IC group and 7.9% less than the NC group when expected food availability increases. Similarly, compared to the IC group, the CR group increases carbohydrate intake 13.8% less and protein intake 12.2% less when expected food availability increases. The corresponding estimates are statistically insignificant in symmetric models. Also, while we find significant differences in protein and fat intakes between the CR and the NC groups in symmetric models, the corresponding differences in asymmetric models become substantially larger when expected food availability increases.

3) We find significant asymmetry in the effect of knowledge about a diet in high fat (Q4) on carbohydrate and fat intakes. The effect on carbohydrate intake is statistically significant when expected food availability increases, while insignificant when expected food availability decreases. The opposite patterns are observed for the effect on fat intake. The IC group increases carbohydrate intake 9.7% more than the CR group and 7.6% more than the NC group when expected food availability increases. When expected food availability

decreases, the CR group reduces fat intake 8.1% more than the IC group and 3.8% more than the NC group.

4) We find significant asymmetry in the effect of knowledge about animal fat consumption (Q7) on total calorie intake and fat intake. The effect is statistically significant when expected food availability increases, while insignificant when expected food availability decreases. Compared to the NC group, the CR group increases total calorie intake 6.0% less and fat intake 16.9% less when expected food availability increases. Also, compared to the corresponding differences in symmetric model, the differences between the CR and the NC groups in terms of the effects on total calorie and fat and protein intakes became much larger when expected food availability increases.
5) We find significant asymmetry in the effect of knowledge about dairy product consumption (Q8) on protein intake. The effect is statistically significant when expected food availability increases, while insignificant when expected food availability decreases. The CR group increases protein intake 19.5% less than the IC group and 12.7% less than the NC group. Also, all the significant differences observed in symmetric models are substantially smaller than the corresponding differences observed in asymmetric models when expected food availability increases.
6) We find significant asymmetry in the effect of knowledge about bean product consumption (Q9) on fat intake. The effect is statistically significant when expected food availability increases, while insignificant when expected food availability decreases. The CR group increases fat intake 17.3% less than the IC group when expected food availability decreases. Also, we find that the CR group increases fat intake 11.5% less than the NC group when

expected food availability increases, whereas the corresponding estimate in a symmetric model is statistically insignificant (-2.5%).

Conclusions

The purpose of this paper has been to demonstrate that the effect of dietary knowledge on nutrient intake can differ significantly depending on whether households expect their food availability to increase or decrease. Our results show that overall dietary knowledge has larger and more statistically significant effects on nutrient intakes when expected food availability increases, whereas it has relatively small effects on nutrient intakes when food availability decreases. In the framework without distinguishing the direction of changes in expected food availability (i.e., the conventional framework), the effects of dietary knowledge become much smaller and statistically less significant. These findings indicate that previous studies may underestimate the effect of dietary knowledge on nutrient intake and that asymmetric effects may underlie the apparently mixed findings of previous studies on the relationship between dietary (or health) information and the intake of nutrients and foods.

The findings also provide important implications for dietary education. First, observing that improving dietary knowledge mitigates an increase in total calorie intake and fat intake when expected food availability increases, we may reasonably expect that dietary education can be a useful measure to prevent and/or slow down increasing obesity.

Second, considering the significant asymmetry in the effect of dietary knowledge on nutrient intake, we may need a different resource allocation for dietary education depending on whether expected food availability increases or decreases. For example, if the government conducts a policy under which households expect their food availability to increase (e.g., introduce food subsidies), combining dietary education with the policy may be effective to mitigate an undesirable increase in total calorie intake and fat intake; thus, a suitable amount of resources should be allocated to dietary education. By contrast, if households expect their food availability to decrease as a result of some policy changes (e.g., discontinue food subsidies), dietary education may be ineffective to mitigate the undesirable nutritional effects of the policy changes. Moreover, despite its ineffectiveness, investing in dietary education has the potential to reduce the resources available for more effective alternatives (e.g., promoting exercise) and to generate significant deadweight loss. In such a case, we may be better off reallocating resources for dietary education to alternatives.

Third, the observed cross effect of dietary knowledge sheds light on the importance of balanced dietary education. More specifically, a statement on certain nutrients and foods may need to be complemented by another statement on apparently unrelated nutrients and foods to avoid an undesirable effect of the first statement on the unrelated nutrients and foods. For example, according to our results, a campaign on increasing fruit and vegetable consumption can induce an unnecessary decline in protein intake. In this case, the campaign should also emphasize an importance of taking alternative protein-rich and low-fat foods such as beans and bean products.

Lastly, our asymmetric framework may be applicable to other related issues, such as the effect of maternal nutrition knowledge on children's nutrient intake. Also, from a methodological perspective, our framework can be a new useful tool for future research and policy makers to examine the cost-effectiveness of dietary or health education programs.

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Table 1: Summary Information about Our Measures of Dietary Knowledge

		Total		ΔE(FA) > 0		ΔE(FA) < 0	
		# of Obs	Mean (SD)	# of Obs	Mean (SD)	# of Obs	Mean (SD)
Dietary Knowledge Index		2,673	0.106 (1.23)	704	0.091 (1.34)	1,969	0.111 (1.19)
			(%)		(%)		(%)
Q1. Choosing a diet with a lot of fresh fruits and vegetables is good for one's health.	Improve	436	16.3%	102	14.5%	334	17.0%
	Worsen	483	18.1%	159	22.6%	324	16.5%
	No Change	1,754	65.6%	443	62.9%	1,311	66.6%
Q2. Eating a lot of sugar is good for one's health	Improve	427	16.0%	116	16.5%	311	15.8%
	Worsen	386	14.4%	99	14.1%	287	14.6%
	No Change	1,860	69.6%	489	69.5%	1,371	69.6%
Q3. Eating a variety of foods is good for one's health	Improve	372	13.9%	80	11.4%	292	14.8%
	Worsen	441	16.5%	131	18.6%	310	15.7%
	No Change	1,860	69.6%	493	70.0%	1,367	69.4%
Q4. Choosing a diet high in fat is good for one's health.	Improve	502	18.8%	145	20.6%	357	18.1%
	Worsen	445	16.6%	132	18.8%	313	15.9%
	No Change	1,726	64.6%	427	60.7%	1,299	66.0%
Q5. Choosing a diet with a lot of staple foods [rice, wheat and related products] is not good for one's health.	Improve	762	28.5%	186	26.4%	576	29.3%
	Worsen	916	34.3%	227	32.2%	689	35.0%
	No Change	995	37.2%	291	41.3%	704	35.8%
Q6. Consuming a lot of animal products daily (fish, poultry, eggs and lean meat) is good for one's health.	Improve	708	26.5%	193	27.4%	515	26.2%
	Worsen	657	24.6%	180	25.6%	477	24.2%
	No Change	1,308	48.9%	331	47.0%	977	49.6%
Q7. Reducing the amount of fatty meat and animal fat in the diet is good for one's health.	Improve	477	17.8%	100	14.2%	377	19.1%
	Worsen	540	20.2%	158	22.4%	382	19.4%
	No Change	1,656	62.0%	446	63.4%	1,210	61.5%
Q8. Consuming milk and dairy products is good for one's health	Improve	193	7.2%	47	6.7%	146	7.4%
	Worsen	276	10.3%	64	9.1%	212	10.8%
	No Change	2,204	82.5%	593	84.2%	1,611	81.8%
Q9. Consuming beans and bean products is good for one's health	Improve	146	5.5%	24	3.4%	122	6.2%
	Worsen	262	9.8%	59	8.4%	203	10.3%
	No Change	2,265	84.7%	621	88.2%	1,644	83.5%

Note: E(FA) = expected food availability.

Table 2: Key Characteristics of Our Analytic Sample from the CHNS 2004 and 2006

	Total		Δ E(FA) > 0		Δ E(FA) < 0	
	Mean	SD	Mean	SD	Mean	SD
Number of Observations		2672		704		1968
Nutrient Intakes						
Initial calorie (kcal)	2307.48	738.64	2268.90	728.98	2321.27	741.77
Δ calorie (kcal)	-105.94	843.64	92.78	835.09	-177.04	835.49
Initial carbohydrate (g)	322.82	121.98	315.23	119.98	325.54	122.60
Δ carbohydrate (g)	-15.07	131.07	13.88	124.54	-25.43	131.82
Initial fat (g)	79.09	40.19	78.65	39.89	79.24	40.30
Δ fat (g)	-4.48	48.05	1.14	46.64	-6.49	48.39
Initial protein (g)	68.77	25.64	67.18	24.73	69.34	25.95
Δ protein (g)	-1.19	30.85	5.40	30.69	-3.55	30.57
Food Availability						
Δ E[ln(calorie per hh mem)]	-0.05	0.07	0.04	0.03	-0.08	0.05
Initial calorie per hh mem (kcal)	2260.21	665.95	2258.60	669.59	2260.80	664.82
Δ kcal per hh mem (kcal)	-106.55	763.72	88.54	747.71	-176.31	757.45
Other characteristics						
Δ ln(income per hh mem in yuan)	0.08	1.02	0.04	1.02	0.09	1.02
Δ ln(Food prices in yuan)						
cereal	0.08	0.19	0.09	0.17	0.07	0.19
bean	0.04	0.51	0.03	0.74	0.05	0.39
pork	-0.16	0.45	-0.15	0.36	-0.16	0.48
chicken	0.11	0.54	0.11	0.77	0.11	0.43
vegetables	0.28	0.81	0.37	0.96	0.25	0.75
eggs	0.21	0.77	0.00	0.51	0.29	0.83
oil	-0.21	0.50	-0.13	0.74	-0.24	0.37
Initial household size (person)	1.20	0.41	1.10	0.40	1.24	0.41
Prop female	51.1%		59.7%		48.0%	
Prop of age groups						
age14-30	10.5%		11.4%		10.3%	
age30-60	64.4%		64.2%		64.5%	
over 60	25.0%		24.4%		25.2%	
Prop of urban residents	46.7%	49.9%	24.6%		54.5%	

Note: Δ = change between 2004 and 2006, E(FA) = expected food availability, Prop = proportion, and hh mem = household member.

Table 3: Effect of Dietary Knowledge on Nutrient Intake

					Calorie		Carbo		Fat		Protein	
	Model #				(1)		(2)		(3)		(4)	
DKI	1	Sym			-0.004		0.000		-0.016	*	-0.006	
	2	Asym	POS		-0.022	***	-0.019	**	-0.034	**	-0.018	**
			NEG		0.003		0.008		-0.007		0.000	
			d		0.025	***	0.027	***	0.027		0.018	
Q1	5	Sym	CR-NC		-0.001		0.011		-0.060	**	0.015	
			IC-NC		-0.035	**	-0.017		-0.118	***	-0.028	
			CR-IC		0.033	*	0.028		0.058		0.043	**
	6	Asym	CR-NC	POS	-0.030		-0.003		-0.083		-0.050	
				NEG	0.007		0.015		-0.055		0.035	*
				Diff	0.037		0.018		0.027		0.084	**
			IC-NC	POS	-0.038		-0.015		-0.043		-0.011	
				NEG	-0.036	**	-0.020		-0.157	***	-0.038	*
				Diff	0.002		-0.005		-0.113	*	-0.027	
			CR-IC	POS	0.008		0.013		-0.039		-0.038	
				NEG	0.043	*	0.035		0.101	**	0.073	***
				Diff	0.035		0.022		0.141	*	0.111	**
Q2	7	Sym	CR-NC		-0.029		0.001		-0.099	**	-0.047	**
			IC-NC		0.008		0.041	**	-0.060	*	-0.020	
			CR-IC		-0.038		-0.039		-0.039		-0.027	
	8	Asym	CR-NC	POS	-0.079	**	-0.053		-0.138	**	-0.094	***
				NEG	-0.013		0.018		-0.082	*	-0.034	
				Diff	0.067	*	0.071	*	0.057		0.060	
			IC-NC	POS	0.041		0.086	***	-0.020		0.027	
				NEG	0.000		0.028		-0.071	*	-0.033	
				Diff	-0.041		-0.057		-0.051		-0.061	
			CR-IC	POS	-0.121	***	-0.138	***	-0.118		-0.122	***
				NEG	-0.013		-0.010		-0.011		0.000	
				Diff	0.108	**	0.128	***	0.107		0.121	**
Q3	9	Sym	CR-NC		0.020		0.019		-0.003		0.016	
			IC-NC		0.020		0.008		0.019		0.014	
			CR-IC		0.000		0.011		-0.022		0.002	
	10	Asym	CR-NC	POS	-0.016		0.007		-0.126		-0.038	
				NEG	0.029		0.020		0.036		0.029	
				Diff	0.045		0.013		0.162	*	0.067	
			IC-NC	POS	0.025		0.043		0.018		-0.003	
				NEG	0.021		-0.001		0.014		0.027	
				Diff	-0.005		-0.044		-0.003		0.030	
			CR-IC	POS	-0.041		-0.036		-0.144		-0.035	
				NEG	0.008		0.020		0.022		0.002	

				Diff	0.049		0.057		0.165		0.037	
Q4	11	Sym	CR-NC		0.015		0.012		0.025		0.020	
			IC-NC		-0.007		0.019		-0.061	*	-0.031	
			CR-IC		0.022		-0.006		0.086		0.050	*
	12	Asym	CR-NC	POS	-0.020		-0.021		0.023		-0.026	
				NEG	0.028		0.025		0.022		0.038	*
				Diff	0.048		0.047		-0.001		0.063	*
			IC-NC	POS	0.027		0.076	**	-0.036		0.008	
				NEG	-0.018		-0.001		-0.068		-0.043	*
				Diff	-0.045		-0.077	**	-0.032		-0.051	
			CR-IC	POS	-0.047		-0.097	**	0.059		-0.033	
				NEG	0.046		0.027		0.090		0.081	**
				Diff	0.093	**	0.124	***	0.031		0.114	**
Q5	13	Sym	CR-NC		-0.008		0.007		-0.028		-0.016	
			IC-NC		-0.006		-0.015		0.014		-0.016	
			CR-IC		-0.002		0.022		-0.042		0.000	
	14	Asym	CR-NC	POS	-0.003		0.014		-0.030		-0.006	
				NEG	-0.007		0.006		-0.023		-0.018	
				Diff	-0.003		-0.009		0.007		-0.012	
			IC-NC	POS	0.006		-0.006		0.034		-0.009	
				NEG	-0.010		-0.018		0.011		-0.019	
				Diff	-0.016		-0.012		-0.023		-0.010	
			CR-IC	POS	-0.010		0.021		-0.064		0.003	
				NEG	0.003		0.024		-0.034		0.001	
				Diff	0.012		0.003		0.030		-0.002	
Q6	15	Sym	CR-NC		0.015		0.026		-0.021		0.005	
			IC-NC		-0.007		-0.012		-0.006		-0.011	
			CR-IC		0.022		0.038	*	-0.015		0.016	
	16	Asym	CR-NC	POS	0.006		0.024		-0.038		-0.018	
				NEG	0.021		0.030	*	-0.016		0.017	
				Diff	0.015		0.006		0.022		0.035	
			IC-NC	POS	-0.002		-0.028		0.025		-0.031	
				NEG	-0.008		-0.007		-0.015		-0.003	
				Diff	-0.006		0.021		-0.039		0.028	
			CR-IC	POS	0.007		0.052		-0.063		0.013	
				NEG	0.028		0.037	*	-0.001		0.020	
				Diff	0.021		-0.015		0.061		0.008	
Q7	17	Sym	CR-NC		-0.015		0.000		-0.060	**	-0.032	*
			IC-NC		-0.040	***	-0.026		-0.078	***	-0.052	***
			CR-IC		0.025		0.026		0.018		0.021	
	18	Asym	CR-NC	POS	-0.060	**	-0.009		-0.169	***	-0.078	**
				NEG	-0.001		0.003		-0.024		-0.018	

				Diff	0.058	*	0.012		0.144	**	0.060	
			IC-NC	POS	-0.043		-0.009		-0.079		-0.080	***
				NEG	-0.037	**	-0.029		-0.082	**	-0.036	*
				Diff	0.005		-0.020		-0.004		0.044	
			CR-IC	POS	-0.017		0.001		-0.090		0.002	
				NEG	0.036		0.032		0.058		0.018	
				Diff	0.053		0.031		0.148	*	0.016	
Q8	19	Sym	CR-NC		-0.049	**	-0.054	**	-0.032		-0.054	**
			IC-NC		-0.009		0.000		-0.050		-0.005	
			CR-IC		-0.039		-0.054	*	0.018		-0.048	
	20	Asym	CR-NC	POS	-0.072	*	-0.099	**	-0.030		-0.127	***
				NEG	-0.039		-0.038		-0.027		-0.028	
				Diff	0.034		0.061		0.003		0.099	*
			IC-NC	POS	0.026		0.037		0.009		0.068	
				NEG	-0.018		-0.008		-0.069		-0.023	
				Diff	-0.043		-0.045		-0.078		-0.092	*
			CR-IC	POS	-0.098	*	-0.136	**	-0.040		-0.195	***
				NEG	-0.021		-0.030		0.042		-0.004	
				Diff	0.077		0.106		0.081		0.191	***
Q9	21	Sym	CR-NC		-0.032		0.015		-0.139	**	-0.025	
			IC-NC		-0.007		0.008		-0.092	**	-0.002	
			CR-IC		-0.025		0.007		-0.047		-0.022	
	22	Asym	CR-NC	POS	-0.080		-0.056		-0.104		-0.115	*
				NEG	-0.022		0.029		-0.143	**	-0.008	
				Diff	0.058		0.085		-0.039		0.107	
			IC-NC	POS	0.025		0.017		-0.031		0.058	
				NEG	-0.016		0.007		-0.113	**	-0.019	
				Diff	-0.041		-0.010		-0.082		-0.077	
			CR-IC	POS	-0.105		-0.073		-0.073		-0.173	**
				NEG	-0.006		0.022		-0.030		0.011	
				Diff	0.099		0.095		0.043		0.184	**

Note:
(1) Symm = Symmetric models, Asymm = asymmetric models, NEG = Estimates when household food availability (FA) decreases, POS = Estimates when household FA increases, and Diff = NEG – POS.
(2) DKI is the summary index of dietary knowledge that is based on all Q1-Q9.
(3) ***, **, and * indicate that the estimate is statistically significant at the 1%, 5%, and 10% level, respectively.