DIETARY DIVERSITY AND RURAL LABOR PRODUCTIVITY: EVIDENCE FROM PAKISTAN

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Abstract

The relationship between rural labor productivity and food diversity was analyzed from the household consumption survey data of Pakistan. The dietary diversity improves nutritional balance of the diet, which enhances productivity through possible improvement in health. The elasticity of wage earning to food diversity was 0.77, far higher than corresponding elasticity for food expenditure at 0.13. The wage elasticities to food group shares varied from 0.21 for dairy products to 0.54 for fruits and vegetables. Research aimed at lowering the relative prices of meats, pulses, and fruit and vegetable will have the greatest impact on rural workers’ productivity.

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INTRODUCTION

The Green Revolution of the 1970's and 1980's focused on cereals, and neglected other foods, such as vegetables, legumes and seafood, which traditionally were an integral part of the diet. While the average per capita consumption of cereals has reached near recommended levels in most Asian countries, a cereal-dominated and unbalanced diet became common and micronutrient deficiencies have surfaced prominently among the poor (Calloway; Bouis and Novenario-Reese; Walker and Ryan; Kurz and Johnson-Welch)[1].

Despite the recognized role of dietary diversity in balancing the diet, supplying micronutrients, improving health, and enhancing food security (Hoddinott and Yohannes; Ruel; Hatloy *et al.*; Hatloy, Torheim, and Oshaug; Hodgson, Hsu-Hage, and Wahlqvist), its contribution in overall economic development is rarely quantified. Generally dietary diversity is considered an outcome of urbanization (Kamiya; Goletti), rather than a tool of economic development. This paper assumes that dietary diversification enhances the supply of essential micronutrients leading to improved health, enhanced cognitive ability, and increased efficiency of work. These are eventually reflected in improved labor productivity, one of the measures of economic development.

The primary purpose of this study is to quantify the relationships between the productivity and dietary diversity of rural workers using the data from Pakistan. The efficiency-wage hypothesis, or the impact of nutritional intervention on labor productivity, has been widely tested in the literature (Liebenstien; Mazumdar; Stiglitz; Barlow; Bliss and Stern; Martorell and Arroyave; Strauss (1986); Deolalikar; Srinivasan; Behrman and

Deolalikar; Croppenstedt and Muller; Sahn and Alderman; Haddad and Bouis; Thomas and Strauss; Behrman; Bhargava; Satyanarayana *et al.*; Immink *et al.*). The early research was confined to relating productivity with calorie intake, which was extended to other nutrients such as iron (Haas and Brownlie). However, these studies considered the effect of individual nutrients, rather than overall food quality, on labor productivity.

On the other hand, a great deal of literature clearly demonstrates the positive relationship between various measures of health and productivity (e.g. Schultz 1999, 2001, 2002; Schultz and Tansel; Strauss and Thomas; Ruger, Jamison and Bloom; Currie and Madrain). Some studies have quantified the contribution of good health in economic growth via its effects on labor market participation, worker productivity, and further investment in human capital (Fogel 1994, 1997; Sohn; Bloom, Canning and Sevilla; Broca and Stamoulis; Wang and Taniguchi). These studies, however, also missed the link between balanced diet and health and productivity.

Many nutritional studies recognized dietary diversification as a key element for high quality (or balanced) diet leading to good health (Ruel) on various arguments like: (1) balancing the intake of essential nutrients/micronutrients (Randall, Nichaman and Contant; Krebs-Smith *et al.*; Hatloy, Torheim and Oshaug; Marshall *et al.*), (2) curing or reducing the risk of many diseases[2], and (3) improving the birth weight of child (Rao *et al.*). These studies in combination with above cited literature do establish theoretical grounds to argue for a positive relationship between dietary diversity and labor productivity, but do not provide any empirical evidence on such a relationship. This study attempted to fill this gap by first measuring the quality of food in terms of diversity, analyzing how this relates to the nutrient balance of the diet, and then relating dietary diversity to labor productivity. Such relationship has particular importance in developing world to provide an additional tool to development practitioners for increasing low labor productivity (Ruel).

THEORETICAL FRAMEWORK

In this study, we made following assumptions to establish the relationship between labor productivity and dietary diversity: (1) dietary diversity measures overall food quality so that it can be treated as an input in the wage earning function; and (2) a competitive labor market prevails in rural areas, which allows us to use wage as a proxy for labor productivity.[3] Here we first define the food diversity index, and then explain the structural relationship between wage earning and food diversity.

Food Diversity Index

Patil and Taillie have discussed various measures of diversity and their properties. The most common diversity indices used are some special cases of the form (Hannah and Kay):

$$DTF = \sum_{i-1}^{m} (S_i^{\alpha})^{1/(1-\alpha)} \qquad (1)$$

where *DTF* is the food diversity index, S_i is the share of the *i*th item in total food, and α is the diversity parameter, such that $\alpha \geq 0$ and $\alpha \neq 1$. For $\alpha = 2$, the index becomes the inverse of the *Herfindahl-Index* that is commonly used to measure industry concentration (Escalante and Barry; Hanson and Simons). As α approaches 1, the index becomes the Entropy-Index, which is calculated as $-\sum S_i \ln S_i$, where *ln* is the natural logarithm (Tauer).

The general index measures both the number of items and the evenness of item shares, with the parameter α determining the weight of number of items versus evenness. The higher the α value, the greater the emphasis on the evenness, while a parameter value of $\alpha = 0$ simply counts the number of items (Tauer and Seleka). The upper limit value of the index for any α value is the number of items, and the lowest limit is 1. The lower value occurs when all the shares go to one commodity, and the upper value occurs only if the shares are equal. The index decreases very little for the α values greater than two when large number of commodities are involved (Hill). In this study, the inverse of *Herfindahl-Index* was used, however, the results were also tested with alternative α values. The index was measured from the expenditure on individual food items.

Labor Productivity and Food Diversity

Wage earnings (W) was related to food diversity (*DTF*) along with its other causal factors such as per capita food expenses (*EXF*) and socioeconomic environment (*H*) in which workers operate, as follows:

$$W = f(DTF, EXF, H, \mu) \qquad (2)$$

where *W*, *DTF*, and *EXF* each are a column vector of nx1, *H* is an nxk matrix, and μ is assumed to be an identically and symmetrically distributed $(0,\sigma^2)$ error term. Diversity is assumed to improve the quality of food with positive impact on health, leading to enhance productivity of labor. Thus diversity is considered here as one of the inputs in a behaviorally determined measure of human capital of health (Schultz 2001).

The impact of food expenditures on labor productivity through health is an empirical question and depends upon the level of food expenditure and types of food purchased. If additional food expenditure positively affects the health, it may improve labor productivity. Such behavior is generally true in societies where essential food is scarce, but may not apply to affluent societies where additional expenditure on food (usually on excessive fats, drinks, etc.) may induce negative health impacts like obesity, which may in fact reduce labor productivity. In this study we intend to test these hypotheses in a society where economic access to food is limited. Therefore, we hypothesize that:

$$\frac{\partial W}{\partial DTF} \cdot \frac{DTF}{W} = \omega > 0, \frac{\partial W}{\partial EXF} \cdot \frac{EXF}{W} = \psi > 0 \quad (3)$$

An important empirical question for policy makers and development practitioners is the relative sizes of the wage elasticity for diversity (ω) and for food expenditure (ψ), as these determine the relative importance of food quality (i.e., diversity) and quantity in the improvement of labor productivity. Therefore, this study pays special attention on the relative magnitude of these two parameters.

MODEL SPECIFICATION AND ESTIMATION PROCEDURE

Model Specification

In model specification, a major challenge was posed by the possibility of simultaneity between labor productivity and food diversity. For example, a diversified improved food may enhance workers productivity and wages, and higher wage earning may enable them to buy a better quality food. Similarly, a bigger food basket associated with higher food expenditures may improve wage earnings, which in turn enable workers to purchase more food. Measurement errors in food expenditure could pose an additional estimation difficulty. In such situation, the error term μ in equation (2) is correlated with independent variable(s), and the application of Ordinary Least Square (OLS) yields biased although efficient estimates. To overcome these problems, we used the instrumental variable approach in our analysis. Therefore, we specified the model as follows:

$$\begin{aligned} W &= f(DTF, EXF, EDU, SEX, AGE, PRF, YRD) \\ DTF &= f(PRW, PRO, EDU, NFI, SES, YRD) \\ EXF &= f(PRW, PRO, EDU, NFI, SES, YRD) \end{aligned} \quad (4)$$

where W is the wage earning in rupees/month of the household head; DTF is already defined, EXF is the per capita expenditure on food in rupees/month; EDU is the number of years of schooling of the household head; SEX is the dummy variable having the value of one if the head is female, and zero otherwise; AGE is the age of the household head in years[4]; PRF is the dummy for the profession of the household head having the value of one if (s)he is engaged in certain profession group, and zero otherwise[5]; PRW is the price of wheat in rupees/kg; PRO is the average weighted price of all other food items in rupees/kg[6]; NFI is the total number of food items available in the village markets at the time of survey; SES is the dummy for the seasons having a value of one for a season, and zero other wise; YRD is the variable on year having a value of one for 1992-93 survey data, and zero otherwise.

The specification in (4) implies that W, DTF, and EXF are endogenous variables, while PRW, PRO, EDU, NFI, SES, and YRD are instrumental variables for DTF and EXF. Following Deolalikar, and Croppenstedt and Muller and others, the semi-log function for wage equation (model -1) was specified as follows:

$$\ln W = \beta_0 + \beta_D DTF + \beta_X EXF + \beta_E EDU + \beta_G SEX + \beta_O AGE + \sum_{p=1}^{2} \beta_P PRF + \beta_Y YRD \qquad \text{(5a)}$$

where all the variables are already defined, *ln* is the natural logarithm, $\beta's$ are the parameters to be estimated. After identifying instrumental variables on logical grounds, the linear forms for endogenous variables' (DTF and EXF) equations were specified as:

$$\begin{aligned} DTF &= \lambda_0 + \lambda_W PRW + \lambda_{OF} PRO + \lambda_E EDU + \lambda_C NFI + \sum_{s=1}^{3} \lambda_S SES + \lambda_Y YRD \\ EXF &= \lambda_0 + \lambda_W PRW + \lambda_{OF} PRO + \lambda_E EDU + \lambda_C NFI + \sum_{s=1}^{3} \lambda_S SES + \lambda_Y YRD \end{aligned} \qquad \text{(5b)}$$

The relationship between labor productivity (or wage earnings) and food shares of different food groups was also investigated (model 2). The purpose is to disaggregate the effect of food shares on wage earnings. For this, equation (5) was re-specified as:

$$\ln W = \beta_0 + \sum_{j=1}^{5} \beta_j FDS_j + \beta_X EXF + \beta_E EDU + \beta_G SEX + \beta_O AGE + \sum_{p=1}^{2} \beta_P PRF + \beta_Y YRD \quad (6a)$$

where FDS_j is the share of *j*th food group in total food expenditure, and all other variables are already defined. The food group shares were treated as endogenous variables.[7]

The following variables were assumed to be instruments, in the initial stage, to treat the endogeneity of the food group budget shares (*FDS*), if such endogeneity was found through the Durbin-Wu- Hausman test:

$$FDS_j = \lambda_0 + \sum_{F=1}^{5} \lambda_F PRICE_F + \sum_{C=1}^{4} \lambda_C NFI + \sum_{S=1}^{3} \lambda_S SES + \lambda_Y YRD \quad (6b)$$

where $PRICE_F$ are group-level weighted average prices. All variables are as defined before.

Estimation of Elasticities

The wage elasticities with respect to the *k*th explanatory variables (V_k) in equations (5a) and (6a) (i.e., excluded instruments) can be estimated by multiplying its coefficient in these equations with the respective mean value of the variable ($\overline{V}_k$).[8]

$$\xi_k = \frac{\partial \ln W}{\partial \ln V} \; or \; \frac{\partial W / W}{\partial V / V} = \overline{V}_k \left(\frac{\partial W / W}{\partial V_k}\right) = \overline{V}_k \beta_k \quad (7)$$

The elasticities of the *e*th endogenous (*END*) variables (i.e., food diversity, food expenditure, and food group expenditure shares) with respect to an instrument variable (*INST*) in equations (5b) and (6b) was estimated as:

$$\theta_e = \frac{\partial \ln END}{\partial \ln INST} \; or \; \frac{\partial END / END}{\partial INST / INST} = \frac{\partial END}{\partial INST} \cdot \frac{\overline{INST}}{\overline{\overline{END}}} = \lambda_e \cdot \frac{\overline{INST}}{\overline{\overline{END}}} \quad (8)$$

where $\overline{INST}$ and $\overline{END}$ are the mean values of the instrument and endogenous variables, respectively. The elasticity of dummy variables is equal to its respective coefficient.

The elasticity of wage with respect to the included instruments can be estimated as:

$$\eta_e = \frac{\partial \ln END}{\partial \ln INST} \cdot \frac{\partial \ln W}{\partial \ln END} = \sum \lambda_e \frac{\overline{INST}}{\overline{END_e}} \cdot \beta_e \overline{V}_e = \sum \lambda_e \beta_e \overline{INST} \qquad (9)$$

Estimation Procedure

The systems of equations in (5 and 6) were estimated using the Two Stage Least Square (2SLS) method. While using this method, the selection of appropriate instrumental variables that can sufficiently explain the variation in DTF and EXF yet uncorrelated with the error term of wage equation posed a big challenge. We first tested the exogeneity in DTF and EXF using the Durbin-Wu-Hausman test (Durbin; Wu and Hausman; Baum, Schaffer, and Stilman). Testing the exogeneity of each endogenous variable in fact is a test of the appropriateness of using OLS instead of 2SLS. We used a three-step procedure described by Davidson and MacKinnon as an alternative to the original specification.[9]

The Shea's partial R^2 was used to check the validity of the selected instrumental variables, and Sargan's specification to test the orthogonality of the wage equation with the error term[10]. Finally, by applying Cook and Weisberge test, the presence of heteroscedasticity in the wage equation was examined. However, for this test, we used the simplification proposed by Pesaran and Taylor, who suggested regressing the square of the error term on the square of the predicted value of dependent variable. The significance of the coefficient implies the presence of hetroskedasticity.[11]

DATA SOURCES

Household consumption survey data collected by the Federal Bureau of Statistics (FBS) of Pakistan were used to estimate the relationship between dietary diversity and wage earnings. The FBS collected these data in two consecutive surveys conducted during 1990-91 and 1992-93 on nearly 21 thousand households (different for each year) from 58 administrative units (districts) throughout Pakistan. While the sample was proportionately allocated to each district, the households were randomly selected from each district. These surveys provided detailed information on monthly consumption of individual food items and expenditure on each, along with family income and its sources, and other socioeconomic characteristics of the household and household head. Nearly 150 food items found consumed were divided into six groups, namely wheat, other cereals (13 items), pulses (12 items), dairy products (15 items), meats (20 items), fruits and vegetables (50 items), and miscellaneous (38 items). This study confines to rural labor. The households having a single earning member engaged in manual work were included in the analysis. In this way, a sample of 1652 household from 55 districts was drawn for this analysis.

RESULTS AND DISCUSSION

Descriptive Statistics

The average monthly food diversity index of the sample manual workers in rural areas of Pakistan, with diversity parameter (α) at 2, was estimated at 8.8, ranging from 1.4 to 20.8, and standard deviation 2.9. This is low compared to that in high-income countries. For example, using the similar consumption survey data, our estimates of food diversity index for Taipei city during 2001 was 21 while extremes were ranged from 7.9 to 30.2.

The food diversity of manual workers was grouped into low, medium and high, and related statistics are presented in Table 1. Food diversity was positively associated with number the items consumed in any food group, and such relationships were stronger in the case of fruits and vegetables.

Total food consumption and expenditure on food increased with diversity levels, although the differences in per capita food consumption between low and medium diversity groups were statistically insignificant. The positive relationship between diversity and level of food consumption, not very strong in this case, but is consistent with the conclusion of Hoddinott and Yohannes. The rise in total consumption and expenditure was mainly because of the increase in per capita intake of micronutrient rich foods, such as meats, pulses, fruits and vegetables and other cereals.

The most important relationship is between food diversity and the food quality measured as the intakes of micronutrients. More specifically the consumption of iron, vitamin A, vitamin C and niacin were significantly high at higher diversity levels, while energy consumption remained statistically unchanged and calcium availability marginally decreased. Besides these improvements in the intake of micronutrients observed in this study, we believe that food diversity also increases the consumption of other unrecorded micronutrients important to health, whose contributions are yet to be known.

Test Statistics

We first run the models as specified in equations (5) and (6). With these specifications, the hypothesis of homoskedasticity in wage equations was rejected in both models at the 1% level (Table 2). Therefore, these specifications would generate biased and inconsistent results. To resolve this issue, district dummies were incorporated as included instruments (i.e., in both the wage and endogenous variable equations). This resulted rejecting the homoskedasticity hypothesis at the 10% level in model 1 (results not reported) and completely resolved the problem in model 2. Inclusion of another variable, per capita value of family assets in model 1 greatly resolved the hetetroskedasticity problem, as we failed to reject the hypothesis of homoskedasticity at 15% in this model. However, this variable was not included in model 2, as it did not improve the results on heteroskedasticity test.

The inclusion of additional instrumental variables also greatly resolved the issue of non-orthogonality of the instrument variables with the error process. Without such inclusion, we rejected the hypothesis of the validity of over-identification restriction at the 1% level in both models. With these inclusions, we failed to reject the hypothesis of orthogonality of instrument variables in each model. Therefore, the instrument variables in our models are most probably exogenously determined.

With no hetroskedasticity in our system, we rejected the hypothesis of exogeneity of assumed endogenous variables (total food diversity, per capita food consumption, and various food shares). Therefore, these variables are most probably simultaneously determined by wage earnings and are non-orthogonal to the error process of the wage equation. This justifies the use of 2SLS, and gain in consistency in 2SLS is justified over the loss of efficiency when compared to the estimates of OLS.

The F-values were higher than 10 for all the first stage instrument equations, and Shea's R^2 in comparison of the partial-out standard R^2 remained high (or our own set criteria of 25% or more), suggesting that the excluded instruments are relevant to explain all the endogenous variables.

Total Food Diversity and Earning Capacity

The coefficient values for food diversity and food expenditure greatly improved in the 2SLS estimation relative to the OLS estimation (Table 3). The final 2SLS estimates suggest that a one unit increase in dietary diversity will increase the earning capacity of the workers by 8.7%. The estimated elasticity of wage earning with respect to food diversity is 0.77.

An increase in per capita food expenditure also enhances the earning capacity of rural workers, however the elasticity was only 0.14. This suggests that improvement in food through enhanced food diversity can play a far greater role in poverty eradication than merely increasing food expenditures without an increase in diversity.

The question whether the quantity or diversity is more important in efficiency wage hypothesis depends upon the level of socioeconomic development. In an economy where more manual labor is required and basic food is short in supply, the quantity of food may be an important determinant of the earning capacity of workers. In a relatively advanced economy where cognitive abilities and technical skills are also required even in manual work, the quality of food becomes more important.

Consistent to many other studies reviewed in Lockheed *et al.*, and Ali and Byerlee, education of rural workers is an important factor in enhancing their earning capacity. A 10% increase in education of the household head will increase the earning capacity of manual workers by 0.32%. The female sex negatively affects the earning capacity (gender discrimination in the job market explains this). Although wage is also positively associated to age of the worker, the coefficient is not significant. There is some variation in wage earning capacity across various professions.

The relationships specified in (5) were also estimated with alternative values of food diversity parameters (α) (results are not reported here). The elasticity of wage rate with food diversity gradually increased from 0.77 to 0.98 as the value of α was increased from 2 to 10 and then it stabilized. However, all other coefficients of the equations reported in Table 3 remained almost unchanged.

Food Shares and Earning Capacity

The parameter estimates of all endogenously treated food shares greatly improved quantitatively in 2SLS estimation relative to the OLS estimates. However, standard errors of the OLS estimates are lower than those of 2SLS (Table 4). The changes in the magnitude of other variables, especially per capita food expenditure, are also noticeable. The size of these parameters declined except for per capita food expenditure, sex and year dummy.

All parameter estimates of the food shares had expected signs, and were highly significant. This implies that increasing the share of any food items, keeping all other shares and variables constant, will improve workers earning capacity. However, the magnitude of these parameters varied across food groups. The estimated wage elasticities of food shares ranged from the lowest of 0.212 for dairy products and 0.320 for wheat to the highest of 0.545 for fruits and vegetables. This suggests that reallocation of food budget from the groups (such as dairy products and wheat) having low elasticities to the one bearing higher elasticities (like fruits and vegetables) can improve wage earnings.

The contribution of bigger food basket while keeping the relative share of different food items constant, i.e., the contribution of increase in food expenditure, was positive and statistically significant in model 2 as well. However, the magnitude of the coefficient was small, therefore, elasticity of wage earning for increased food expenditure was relatively small. A 10% increase in food expenditure, *ceteris paribus,* will increase the wage earning by 1.2%, similar to what was obtained in model 1. The results for other variables also remained unchanged in model 2 relative to model 1.

Factors affecting food diversity and food expenditure

Total food diversity and expenditure. Although, the first stage estimation of the 2SLS is a statistical requirement, since the selection of instruments was based upon logical reasoning, the estimates can provide a good clue on the factors affecting food diversity.

The adjusted R^2 of the estimated first stage equations for food diversity and per capita food expenditure are quite high and F-values are statistically significant suggesting that the instrument variables in these equations reasonably explain the variation in the endogenous variables (Table 5).

Increasing the number of items consumed is the most important factor affecting diversity. This variable also reflects the village level development in marketing by capturing the effect of quality road, presence of good food stores, etc. A 10% increase in the number of items will improve food diversity by 4.1%. Working through the wage equation, this implies 3.1% increase in earning capacity of manual workers. Another important policy factor in food diversity is the price of wheat. A 10% decrease in wheat prices will increase food diversity by about 0.57%. Working this through wage equation implies an improvement in the earning capacity of manual workers by about 0.44%.

Surprisingly, the values of assets does not significantly influence food diversity, neither does the education. Seasonal and yearly variations do not affect diversity very much (except during the October-December season when diversity reduces significantly).

On the other hand, value of assets is an important factor in determining the level of total food expenditure. Wheat price is insignificant in determining the total food expenditure. Education is also not significant. Unlike food diversity, food expenditure is a function of seasonal and yearly fluctuations.

Expenditure shares. The instrumental variables of model 2 reasonably explain the endogenous variables as depicted by relatively high R^2, and significant F-values. Again the important policy variables that explain the variation in food shares are food prices. The price of wheat affected different food shares in a way that it generated negative wage elasticity, implying that a decrease in wheat price will increase wage earnings. The stronger impact, however, came from the prices of meats and fruits and vegetables (Table 6). Therefore, technological innovations that aim to increase supply and decrease prices of these commodities will have strong spillover impact on the productivity of rural workers. Increasing the number of commodities consumed/available in the market, except dairy products, will also strongly influence the commodity shares, and therefore wage earnings.

CONCLUSION

Despite long standing recognition from nutritionists about the importance of dietary diversification in quality or balanced diet and human health, its role in overall economic development and poverty alleviation was never quantified. This study aims to fill this gap by establishing empirical relationship between dietary diversity and rural workers' productivity measured in terms of wage earnings.

The results suggest that doubling the overall food diversity, keeping total expenditure constant, will increase the wage earnings of rural manual workers at least by 77%, which is far more than the effect of merely doubling the expenditure on food (i.e.

14%). Therefore, quality of food measured in terms of food diversity is a better tool for poverty alleviation than increasing the size of food plate in the Pakistani environment.

Although increasing the shares of every food group, keeping other shares constant, would enhance the wage earnings of the rural manual workers, their individual contributions are less than what could be achieved through increasing total food diversity. Therefore, total food diversity, rather than emphasis on a single food group, will bring higher benefit to rural workers in terms of increasing their earnings.

As fruits and vegetables are good sources of food diversity, it is not surprising that improving their share in food has the highest impact on productive capacity of manual workers. Therefore, shifting the food budget share from wheat to vegetables will enhance earning capacity of rural workers.

To promote diversity, investments on technological innovations in a variety of crops and policies to enhance not only the supply of overall food but also the number of available options in the food markets are critical. Policies to improve the quality of rural food markets are key to enhance food diversity. Initially low cereal prices can help poor workers to save some money to buy high value crops. Unless the alternatives to cereals are available in the food market at low prices, such savings may not occur or may shift to non-food items. Thus, the low prices of micronutrient rich commodities, such as meats and fruits and vegetables, are critical to induce food diversification.

The conventional economic development policies focus on physical and human infrastructure improvement alone, while diversification policies need to combine these improvements with appropriate incentives for increased and cheap availability of micronutrient rich foods and crops, such as meats, vegetables, fruits, pulses, and minor crops. These incentives may even look uneconomical to start with, but well coordinated research and extension systems and policy incentives geared towards these crops can produce substantial spillover effects in the form of improved earning capacity of human labor. This study concludes that neglecting such enormous spillover effects of research and development policies would deprive a society from a very important source of economic growth. However, incentives to promote the production of micronutrient rich commodities should be broad based, rather than crop specific, in order to avoid introducing other rigidities in the production system (World Bank).

The main caveat of this study, however, is lack of an explicit relationship between workers productivity and food diversity through improved health parameters, such as body-weight and waist by height, and health outcomes, such as frequency of disease infection. We hope to get data on health parameters and health outcomes along with the data on food diversity to validate food diversity and productivity relationship through another angle.

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Table 1. Diversity related statistics of the sample households in Pakistan

Characteristic	Levels of dietary diversity			Overall (1652)
	Low (441)[a]	Medium (674)[a]	High (537)[a]	
Total diversity index of food	5.4[c]	8.5[b]	12.1[a]	8.8
Wage earnings per household (Rs.)	1194.0[c]	1357.7[b]	1495.1[a]	1358.6
Per capita daily nutrients intake				
Energy (Kcal)	2055.8[a]	2036.8[a]	2144.5[a]	2076.9
Protein (mg)	58.9[a]	55.9[b]	57.5[ab]	57.2
Calcium (mg)	942.6[a]	860.6[b]	853.9[c]	880.3
Iron (mg)	7.6[c]	8.6[b]	9.9[a]	8.8
Vitamin-A (μg)	882.3[c]	1313.1[b]	1776.1[a]	1348.6
Vitamin-C (mg)	26.5[c]	41.5[b]	55.2[a]	41.9
Vitamin-B_1 (mg)	0.4[b]	0.4[bc]	0.5[a]	0.4
Vitamin-B_2 (mg)	0.7[ab]	0.7[b]	0.8[ac]	0.7
Niacin (mg)	3.4[c]	3.9[b]	5.1[a]	4.1
% share in total food expenditure				
Wheat	25.8[a]	19.0[b]	14.1[b]	19.2
Other cereals	5.5[c]	6.7[b]	8.3[a]	6.9
Pulses	3.5[c]	4.1[ab]	4.3[a]	4.0
Milk products	21.1[a]	18.2[b]	15.5[b]	18.1
Meats	4.9[c]	7.1[b]	9.1[a]	7.2
Fruits and vegetables	10.0[c]	13.7[b]	17.1[a]	13.8
Miscellaneous	29.3[c]	31.2[bc]	31.6[a]	30.8
Per capita food expenditure (Rs.)	231.9[b]	244.4[b]	267.0[a]	248.4
Per capita daily consumption (gm)				
Wheat	411.5[a]	351.5[b]	317.3[c]	356.4
Other cereals	69.9[c]	86.6[b]	124.7[a]	94.5
Pulses	17.2[c]	24.1[b]	27.3[a]	23.3
Milk products	279.5[a]	236.7[b]	218.6[c]	242.2
Meats	12.2[c]	21.1[b]	28.0[a]	21.0
Fruits and vegetables	106.0[c]	165.3[b]	225.3[a]	169.0
Miscellaneous	91.7[b]	97.7[ab]	105.5[a]	98.7
Total	988.0[bc]	983.0[b]	1046.7[a]	1005.1

Different superscript in a row implies that the parameter values are significantly different across the diversity levels, and the parameter values do not differ in case superscript are the same.

[a] The ranges for low, medium, and high diversity are <7.0, 7.0-10.0, and >10, respectively. The figures in parenthesis are sample size for each diversity level.

Table 2. Various test statistics for the validity of 2SLS estimate

Type of test	Total diversity (Model 1)		Diversity at the food share level (Model 2	
	Without assets and districts	With asset and districts	Without districts	With districts
Homoskedasticity				
t-value	32.55***	1.52ns	-3.93***	-1.20ns
Overidentification restrictions				
Chi-square value	31.06***	47.91ns	24.28**	21.48ns
Exogeneity (t-value)				
Diversity	-7.62***	-11.54***	-	-
Per capita food	-10.50***	-2.01**	-	-
Food shares	-	-		
Wheat	-	-	-2.43**	-2.07**
Pulses	-	-	-12.10***	-11.45***
Dairy products	-	-	4.80***	2.24**
Meats	-	-	-7.98***	-6.76***
Fruits and vegetables	-	-	-6.26***	-6.34***
Relevance of Instruments variables				
Diversity				
F-value	114.97	25.81	-	-
Shea partial R^2 ratio	0.16/0.36=0.46	0.28/0.51=0.56	-	-
Per capita food				
F-value	17.57	10.94	-	-
Shea partial R^2 ratio	0.03/0.08=0.34	0.09/0.24=0.41	-	-
Cereal				
F-value	-	-	40.38	17.75
Shea partial R^2 ratio	-	-	0.06/0.24=0.25	0.11/0.44=0.25
Pulses				
F-value	-	-	68.29	17.34
Shea partial R^2 ratio	-	-	0.21/0.35=0.61	0.19/0.43=0.43
Dairy products				
F-value	-	-	69.84	16.93
Shea partial R^2 ratio	-	-	0.09/0.36=0.25	0.12/0.43=0.29
Meats				
F-value	-	-	147.96	37.46
Shea partial R^2 ratio	-	-	0.15/0.54=0.27	0.21/0.62=0.33
Fruit and vegetable				
F-value	-	-	93.13	25.65
Shea partial R^2 ratio	-	-	0.19/0.42=0.45	0.19/0.53=0.36

*** and ** implies statistical significance levels at 1 and 5 percent, respectively, and ns .implies that the coefficient is not significant at least at the 10% level.

Table 3. Effect of food diversity and per capita food expenditure on earning capacity in Pakistan[1]

Variable description	Variable Name	Mean values	OLS		2SLS[2]		Wage elasticity[3]
			Estimated coefficient	Standard error	Estimated Coefficient	Standard error	
Total food diversity index (see equation 5)	*DTF*	8.839	0.0205***	0.0041	0.0867***	0.0078	0.767
Per capita food expenditure (rupees/month)	*EXF*	248.396	0.0004***	0.0001	-0.0006***	0.0002	0.137
Age of the worker (years)	*AGE*	37.734	0.0006ns	0.0009	0.0001ns	0.0010	0.004
Education of the worker (years)	*EDU*	1.157	0.0320***	0.0041	0.0276***	0.0046	0.032
Sex of the worker (1=female, 0=male)	*SEX*	0.029	-0.2711***	0.0664	-0.2548***	0.0720	-0.255
Profession (1=brick layer/ carpenter and building labor, 0=otherwise)	PRF_1	0.433	0.0659***	0.0248	0.0658***	0.0267	0.066
Profession (1=fisherman/ cobbler/ black smith/plumber/ welder etc. except farm labor, 0=otherwise)	PRF_2	0.141	0.1509***	0.0336	0.1533***	0.0364	0.153
Year dummy (1=1992-93, 0=otherwise)	*YRD*	0.737	0.1418***	0.0245	0.1988***	0.0289	0.199

***, **, and * implies statistical significance levels at 1, 5, and 10 percent, respectively, and ns .implies that the coefficient is not significant at least at the 10% level.

[1]The estimated coefficients for district dummy variables are not reported in the table, as these were included just to control the regional differences and have little relevance in the discussion. We also omitted the values of the intercept from the table.

[2]Endogenous variables: *DTF, EXF*

[2] Instrument variables: *AST, EDU,* $PRICE_w$, $PRICE_{of}$, *NFI,* SES_1-SES_3, *YRD, RD*

[3] See equation (7) to estimate these elasticities.

[a] The elasticity of education reported here is only partial, as its effect through endogenous variables are not included.

Table 4. Effect of relative food group shares on earning capacity in Pakistan[1]

Variable description	Variable name	Mean values	OLS		2SLS [2]		Wage elasticity[3]
			Estimated Coefficient	Standard error	Estimated coefficient	Standard error	
Food group shares in total expenditure (%)							
Wheat	FDS_w	19.212	0.0004[ns]	0.0015	0.0166***	0.0050	0.320
Pulses	FDS_p	4.013	-0.0134***	0.0046	0.0877***	0.0112	0.352
Dairy products	FDS_d	11.098	0.0003[ns]	0.0012	0.0191***	0.0036	0.212
Meats	FDS_{mt}	7.205	0.0171***	0.0021	0.0478***	0.0048	0.345
Fruits and vegetables	FDS_{fv}	13.809	0.0005[ns]	0.0022	0.0394***	0.0053	0.545
Monthly per capita food expenditure (rupees)	EXF	248.39 6	0.0002**	0.0001	0.0005***	0.0001	0.124
Age of the worker (years)	*AGE*	37.734	0.0008[ns]	0.0009	0.0001***	0.0012	0.005
Education of the worker (year)	*EDU*	1.157	0.0309***	0.0041	0.0226***	0.0052	0.026
Sex of worker (1=female, 0=otherwise)	*SEX*	0.029	-0.2686***	0.0656	-0.2390***	0.0836	-0.239
Profession (1=brick layer/ carpenter and building labor, 0=otherwise)	PRF_1	0.0433	0.0866***	0.0246	0.0725***	0.0311	0.073
Profession (1=fisherman/ cobbler/ black smith/plumber/ welder etc. except farm labor, 0=otherwise)	PRF_2	0.141	0.1628***	0.0336	0.1484***	0.0426	0.148
Year dummy (1=1992-93, 0=otherwise)	*YRD*	0.737	0.1464***	0.0246	0.2104***	0.0326	0.210
Adjusted R^2			0.3453		0.2732		

***, **, and * implies statistical significance levels at 1, 5, and 10 percent, respectively, and [ns] .implies that the coefficient is not significant at least at the 10% level.

[1]The estimated coefficients for district dummy variables are not reported in the table, as these were included just to control the regional differences and have little relevance in the discussion. We also omitted the values of the intercept from the table.

[2]Endogenous variables: FDS_c, FDS_p, FDS_d, FDS_{mt}, FDS_{fv}

[2] Instrument variables: EDU, $PRICE_w$, $PRICE_{oc}$, $PRICE_p$, $PRICE_d$, $PRICE_{mt}$, $PRICE_{fv}$, SES_1-SES_3, YRD, RD

[3] See equation (7) to estimate these elasticities.

[a] The elasticity of education reported here is only partial, as its effect through endogenous variables are not included.

Table 5. Factors affecting food diversity and per capita food expenditure (results of first stage analysis)

Variable description	Variable Name	Mean values	Food diversity equation		Food expenditure equation		Elasticities of:[1]	
			Estimated coefficient	Standard error	Estimated coefficient	Standard error	Food diversity	Food expenses
Per capita value of assets owned (000 Rs)	*AST*	12.58	-0.0014[ns]	0.0018	1.4079***	0.1109	-0.0020	0.0713
Education of the worker (years)	*EDU*	1.16	-0.0245[ns]	0.0209	2.0144[ns]	1.2691	-0.0032	0.0094
Wheat price (Rs/kg)	$PRICE_w$	3.80	-0.1319	0.0837	-4.8983[ns]	5.0789	-0.0568	-0.0750
Other food items' price (Rs/kg)	$PRICE_{of}$	12.12	0.0194[ns]	0.0143	1.7873*	0.8713	0.0267	0.0872
Total number of food items	*NFI*	13.56	0.2647***	0.0096	0.8775[ns]	0.5833	0.4060	0.0479
Dummy for season (1=July-September, 0=otherwise)	SES_1	0.23	-0.0312[ns]	0.1527	17.3699**	9.2672	-0.0008	0.0163
Dummy for season (1=October-December, 0=otherwise)	SES_2	0.27	-0.3928***	0.1479	29.6217***	8.9746	-0.0119	0.0321
Dummy for season (1=January-March, 0=otherwise)	SES_3	0.26	-0.0064[ns]	0.1511	47.0745***	9.1686	-0.0002	0.0498
Year dummy (1=1992-93, 0=otherwise)	*YRD*	23.56	0.0152[ns]	0.1432	36.7868***	8.6891	0.0013	0.1092
Adjusted R^2			0.4863		0.2093			
F-Value			25.81	0.0001	10.94	0.0001		

***, **, and * implies statistical significance levels at 1, 5, and 10 percent, respectively.

[1] See equation (8) for the estimation of these elasticities.

Table 6. Factors affecting the relative food shares (results of the first stage analysis)

Variable description	Variable name	Mean values	Wheat		Pulses		Dairy products		Meats		Fruits and vegetable		Wage elasticity[1]
			Coefficient .	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient .	Standard error	Coefficient	Standard error	
Prices (Rs/kg):													
Wheat	$PRICE_w$	11.74	1.4001	0.3105	0.0412	0.0766	-0.4544	0.3525	0.1022	0.1623	-0.4155	0.1635	-0.0552
Pulses	$PRICE_p$	13.56	-0.0589	0.0638	0.1999	0.0157	-0.1380	0.0724	0.0858	0.0333	-0.0370	0.0336	0.2244
Dairy products	$PRICE_d$	12.11	0.1031	0.0330	0.0173	0.0081	-0.1759	0.0374	0.0521	0.0172	0.0208	0.0174	0.0364
Meats	$PRICE_{mt}$	27.81	-0.0333	0.0182	-0.0067	0.0045	-0.0632	0.0206	0.1344	0.0095	-0.0252	0.0096	-0.2570
Fruits and vegetables	$PRICE_{fv}$	8.70	0.0901	0.0803	-0.0709	0.0198	-0.1213	0.0911	-0.0322	0.0419	0.2247	0.0423	-0.1490
Number of food items in:													
Pulses	NFI_p	2.20	0.2171	0.1909	1.0396	0.0471	-0.1062	0.2167	-0.1186	0.0998	-0.5681	0.1005	0.1374
Dairy products	NFI_d	2.46	-2.0722	0.2307	-0.4682	0.0569	6.5345	0.2620	-0.2222	0.1206	-1.2499	0.1215	-0.0322
Meats	NFI_{mt}	1.39	-1.9696	0.2445	-0.3846	0.0603	-0.6653	0.2776	4.1955	0.1278	-0.8752	0.1287	0.1260
Fruits and vegetables	NFI_{fv}	8.40	-0.1219	0.0787	-0.0939	0.0194	-0.3198	0.0894	-0.1709	0.0411	1.1480	0.0414	0.1790
Dummy for season (1=Julyp-September, 0=otherwise)	SES_1	0.23	-1.1567	0.5674	0.0608	0.1400	0.9475	0.6443	0.6651	0.2966	-0.7249	0.2988	-0.0718
Dummy for season (1=October-December, 0=otherwise)	SES_2	0.27	-1.2451	0.5486	-0.2017	0.1354	1.9116	0.6229	-0.0036	0.2867	-1.1853	0.2888	-0.1077
Dummy for season (1=January-March, 0=otherwise)	SES_3	0.26	-3.0163	0.5552	0.0774	0.1370	2.1897	0.6304	1.3174	0.2902	-0.6011	0.2923	-0.1057
Year dummy (1=1992-93, 0=otherwise)	YRD	0.74	-1.6184	0.5623	-0.5103	0.1388	1.6061	0.6385	-1.7011	0.2939	-0.4558	0.2961	0.123
Adjusted R^2			0.4153		0.4093		0.4031		0.6072		0.5110		
F-value			17.75***		17.34***		16.93***		37.46***		25.65***		

***, **, and * implies statistical significance levels at 1, 5, and 10 percent, respectively, and ns .implies that the coefficient is not significant at least at the 10% level.

[1] These elasticities are estimated through equation (9).

Endnotes

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[1] The most important micronutrient deficiency is iron affecting about 3.5 billion people with anemia in the developing world (UNACC/SCN/IFPRI, 2000). Other widely deficient nutrient is vitamin A, affecting some 250 million preschool children with at least a mild vitamin A deficiency (UNACC/SCN/IFPRI, 2000), 0.7 million new cases are added to this every year (UNACC/SCN 1987), and 250-500 thousand vitamin A deficient children become blind every year (WHO, 2002).

Widespread prevalence of micronutrient deficiency is now regarded as one of the important developmental constraints as it is directly causing the slowdown of economic growth. For instance, 1.9% of GDP in Bangladesh, 1.27% in India, 1.2% in Malawi, and 0.85% in Pakistan is lost due to iron deficiency alone (Ross and Horton, 1998). For rural Pakistan, one standard deviation improvement in iron deficiency is associated with an increase in wages by 10-12% due to improvement in cognitive skill (Alderman *et al*.).

[2] For an inverse relation between dietary diversity/variety and diseases, see Tuyns *et al.* on esophageal cancer and Wahlquist, Lo and Myres on macro-vascular disease; Veer *et al*., and Cox, Whichelow and Prevost showed positive association between fruits and vegetables consumption and incidence of cancer and cardiovascular diseases.

[3] Te literature equating marginal productivity of the workers with wage has generally accepted this assumption in agriculture (Ali).

[4] Ideally, wages earnings are directly associated with the duration of professional experience. Since, no such information was available, age was taken as proxy for the professional experience.

[5] The professions of the manual workers were grouped into three categories as: (1) bricklayers, carpenters, and other construction workers; (2) cobblers, fishermen, blacksmiths, welders, and others; and (3) farm laborers, and farm laborers.

[6] All food items were divided into two groups: wheat and non-cereals. The group-level prices were estimated as weighted average price using the relative expenditure shares as weights.

[7] Only five shares could be included in the equation to avoid singularity. However, inclusion of a food group share as endogenous variable is subject to the results of Durbin-Wu-Hausman test.

[8] The elasticities for the variables also appearing in equation (5b) and (6b) are partial here, as the effects of these variables run through endogenous variables are not included.

[9] These steps are: i) regress the candidate endogenous variable on all exogenous variables, ii) use the residual from this regression as auxiliary variable in the main equation, iii) test the significance of the coefficient of the auxiliary variable. The significance of the coefficient implies that the hypothesis of exogeneity of the tested endogenous variable is rejected.

[10] This test checks the null hypothesis that instrumental variables are uncorrelated with the error term of the main model, assuming conditional homoscedasticity. The test statistics is calculated by regressing the 2SLS equation's residuals upon all instruments and estimating nR^2 and then comparing it with χ^2 distribution with the degree of freedom equal to the number of all instruments less the number of instruments included in the right hand side of the first stage equation.

[11] Pagan and Hall point out that this test will be valid for heteroskedasticity in the second stage estimation of the main equation, nowhere else in the system.