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Does food market modernisation lead to improved dietary diversity and diet quality for urban Vietnamese households?*

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This study investigates the possible mechanisms through which modern food markets may affect Vietnamese households' dietary diversity and diet quality using data from a survey of 1,700 urban households with seven-day food recall. We calculate Household Dietary Diversity Scores to measure dietary diversity, and use consumption frequencies of micronutrients (vitamin A and heme iron) and a macronutrient (protein) to create a household measure of diet quality. We estimate a Poisson regression model using a two-step control function approach to address the potential endogeneity of our key explanatory variable, modern market food expenditure shares. Higher modern market food expenditure share is positively and significantly associated with consumption frequency of heme iron, but there are no significant associations with consumption of vitamin A and protein. We further explore indirect linkages between food expenditure shares and dietary diversity, which in turn, may be linked to household diet quality. Results from a system of equations show that the food expenditure share variable has no significant relationship with dietary diversity, but dietary diversity is positively and significantly associated with diet quality. Our results indicate that alone, policies which encourage 'food market modernisation' are not enough to improve diet quality in urban Vietnam.

Key words: diet quality, food market modernisation, household dietary diversity, modern market food expenditure shares, Vietnam.

1. Introduction

Food systems in Asian developing countries are undergoing rapid transformation (Pingali 2007; Mergenthaler *et al.* 2009; Reardon and Timmer 2014; Qaim 2017). Retail structures are changing and modern food retail formats (e.g. hypermarkets, supermarkets, and mini-markets or convenience stores)

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are replacing traditional markets at a rapid pace (Reardon *et al.* 2003; Traill 2006; Reardon and Timmer 2012). Modernisation of food retail outlets or 'supermarketisation' has been considered as an important driver of the nutrition transition[1] that is taking place in some Asian emerging economies (Kelly *et al.* 2014; Reardon *et al.* 2014; Umberger *et al.* 2015; Baker and Friel 2016; Kelly 2016).

It is, however, not clear whether the net effects of 'supermarketisation' on nutrition transition, will be positive (i.e. diets become healthier) or negative (i.e. diets become less healthy). Furthermore, the rising concern of a 'double burden of malnutrition', with undernutrition (stunting and nutrient deficiencies) and overnutrition (overweight and obesity) with the increasing prevalence of overweight among urban consumers in Asia, warrants a better understanding of how, and to what extent, the penetration of modern food retailers influences urban consumers' diet quality (Ruel *et al.* 2017).

Literature on the impacts of food shopping at modern food retail outlets on diet quality in developing countries is still limited. Several studies in the literature show that usage of modern food markets is positively associated with the increased consumption of energy-dense, processed foods, which are generally considered to be 'unhealthy' (e.g. Asfaw 2008, 2011; Hawkes 2008; Kelly *et al.* 2014; Rischke *et al.* 2015; Toiba *et al.* 2015; Demmler *et al.* 2018). On the other hand, a Tunisia household study shows a slight improvement in diet quality among households who use supermarkets regularly (Tessier *et al.* 2008). Therefore, findings on the effects of shopping at modern outlets on household food consumption patterns and diet quality are mixed. One possible reason of such mixed findings may be the failure of identifying the contemporary confounding mechanisms through which these modern food markets are associated with households' dietary diversity and diet quality.[2] Understanding these mechanisms is important, especially in rapidly growing and increasingly 'westernised' urban areas where frequent consumption of high calorie and energy dense foods and beverages may be linked to negative health outcomes including overweight and obesity, cardiovascular disease, and burden of type 2 diabetes (e.g. Popkin *et al.* 2012; Popkin 2014; Kimenju *et al.* 2015; Toiba *et al.* 2015; Umberger *et al.* 2015; Conklin *et al.* 2016; Qaim 2017).

This study examines the association of modern market food expenditure share with household dietary diversity and diet quality in terms of nutrient

[1] Nutrition transition is a large shift in consumers' diet and physical activity. Two historic processes of change occur simultaneously with, or precede, the 'nutrition transition'. One is demographic transition-the shift from a pattern of high fertility and mortality to one of low fertility and mortality. The second is the epidemiological transition- the shift from a pattern of high prevalence of infectious disease-associated with malnutrition to one of high prevalence of chronic and degenerative disease associated with urban industrial lifestyles (Popkin 2002).

[2] Diversity is not synonymous with quality as greater dietary diversity can be associated with greater energy intake from a variety of food (Ruel *et al.* 2013; Leroy *et al.* 2015). On the other hand, diet quality, by definition refers to 'nutrient adequacy'- a diet that meets requirements for both energy and essential nutrient (Ruel 2003).

adequacy. Similar to the World Food Programme (WFP 2015), we focus our analyses on two micronutrients, vitamin A and heme iron, because of their widespread dietary deficiencies in developing countries such as Vietnam. Additionally, heme iron (found in meat and fish only) is considered because it is generally better absorbed by the human body (10% to 30%) compared with non-heme iron (found in cereals, fruits and vegetables, dairy products), which only 1% to 5% is absorbed by the body. Likewise, we concentrate on one macronutrient, protein, as it is a nutrient crucial for the prevention of wasting and stunting (WFP 2015).

Intuitively, we hypothesise that a household's modern market food expenditure share is directly associated with household dietary diversity and diet quality. We further hypothesise that modern market food expenditure share is also associated with household dietary diversity through indirect linkages, which in turn, may be linked to household diet quality. To understand the possible direct and indirect mechanisms through which the usage of modern food markets may associate with household diet quality, we collected novel data using a comprehensive survey of 1,700 urban households, conducted in Hanoi and Ho Chi Minh City in Vietnam.

Vietnam is a country in transition with remarkable achievements in socioeconomic development and ongoing transformation in food systems (World Bank 2018). Despite these achievements, the economy is confronted with the significant double burden of malnutrition, resulting from imbalances in diet and diet-related non-communicable diseases (Khan and Khoi 2008; Ha *et al.* 2011; Le Nguyen *et al.* 2013; Chaparro *et al.* 2014). While the stunting rate remains high at 29.3% and micronutrient deficiencies (e.g. vitamin A deficiency and iron deficiency) warrant attention, rates of overweight and obesity have been estimated in 4.8% of children and 6.6% of adults (Ministry of Health 2012; Le Nguyen *et al.* 2013). In order to address the double burden of malnutrition, the Vietnamese government has committed to ensuring Vietnamese consumers have access to safe and high quality food and healthy diets by the year 2020 (Ministry of Health 2012).

Modern markets in Vietnam (e.g. supermarkets, hypermarkets, and minimarkets) are generally considered by policymakers to be a source of high quality food products, particularly with respect to delivering services and food safety guarantees (Maruyama and Trung 2007a,b; Wertheim-Heck *et al.* 2014, 2015). Although traditional markets (e.g. wet markets) remain the dominant means of purchasing fresh foods such as fruits, vegetables and meat (Wertheim-Heck *et al.* 2014, 2015), more rapid growth in the modern food retail sector is expected due to urban consumers' preferences for high quality and diverse food products (e.g. convenience foods, western food brands), and a convenient and clean shopping environment (Smith and Vo 2017).

The Vietnamese government, therefore, has instigated polices to stimulate modern market expansion, particularly in inner city areas, where at least some of the development will be at the expense of traditional open-air food markets as these are 'upgraded' to multi-story shopping centres with modern

food markets (Dries *et al.* 2013; Wertheim-Heck *et al.* 2014, 2015; Wertheim-Heck and Spaargaren 2016; Smith and Vo 2017).

Intuitively, extensive use of these modern markets may have some diet-related health implications as experienced by other developing countries in Asia (e.g. Kelly *et al.* 2014 in Thailand and Toiba *et al.* 2015 in Indonesia). Although food market modernisation can have a positive impact on diets, for example, if consumption of nutrient-rich types of food products (e.g. dairy and imported fruits and vegetables) increases, the net impact on the Vietnamese diet is unclear. Possible negative dietary changes may include increasing consumption of processed foods at the expense nutrient-rich fresh foods. Given the prominence of the modern food retail environment changes, it is important to understand the net impact of the use of modern versus traditional food outlets on diet quality. This insight may assist policy makers to better understand the implications of policies on stimulating modern food retail expansion on diet quality and the double burden of nutrition in Vietnam.

2. Data and methods

2.1 Data

The analyses in the subsequent sections of this paper are based on data collected by the authors from December 2016 to April 2017 via a survey of 1,700 urban households located in Hanoi and Ho Chi Minh in Vietnam. Households were selected using a proportional sampling strategy considering ward-level populations in these two cities. To assure the representativeness of our sample, we also considered the income distribution since household income reflects purchasing power, and previous studies suggest income is closely related to food purchasing decisions and consumption behaviour (Bouis 1994; Turrell and Kavanagh 2006; Miller *et al.* 2016). The income distribution of our sample is similar to estimates of the populations in each city based on data from large third-party household surveys.[3] Trained enumerators conducted face-to-face interviews with the household member who was considered to be the most knowledgeable about household food purchasing decisions. To improve data quality, tablets, and immediate data entry using wireless networks were used during data collection.

The socioeconomic part of the survey questionnaire was designed to collect information on household and individual characteristics such as gender, age, years of education completed, religion, and physical activities of the household members etc. Household-level information was also collected with respect to ownership of assets, income, food and non-food expenditures, and shopping behaviour such as preferred outlets for purchasing different

[3] For further information, see into the online Appendix S1A (Figure S1A) and Appendix S1B (Figure S1B). Also see (Nielsen 2013).

types of food and access to outlets (distance and time taken by mode of transportation). Hypermarkets, supermarkets, and mini-markets[4] are defined as modern markets in this study. Traditional outlets include the following: formal public markets organised by provincial or district level authorities; informal street markets without a permanent built structure and without any management board; and neighbourhood family-owned shops selling a small range of processed food, dry goods, drinks, toys, daily needs etc. (Maruyama and Trung 2007a,b).

Our household food consumption data include detailed information on consumption and expenditures for 92 different food products for a 'typical' month. Specifically, the data includes information on the type of food retail outlet where each of the 92 food products was purchased. For each product, respondents provided information on the number of times they purchased the product and the average expenditure on the product for a 'typical' month (this is similar to the method used by Umberger *et al*. 2015). The 92 food product categories and related questions were designed after conducting twelve focus group discussions with between six to eight participants in each group. Focus group participants were the individuals primarily responsible for the food purchase and/or meal preparation for their household. We recruited participants with a range of household income levels (low, low-middle, upper-middle, and high-income), however, we grouped respondents with similar household income levels in the same session. The survey instrument was pre-tested extensively with approximately 60 households during development of the instrument as well as during enumerator training.

We also collected data on household food frequency and diet quality adapting the 2015 Food Consumption Score and Nutritional Quality Analysis (2015 FCS_N) questionnaire from the World Food Programme (World Food Programme 2015). Thus, using the 2015 FCS_N questionnaire, we assessed household consumption frequencies for 15 food groups over seven days, including particular foods rich in micronutrients and macronutrients. This data were used to calculate a household score to determine whether or not the intake of food groups rich in essential nutrients these nutrients is adequate (WFP 2015).

The descriptive statistics in Table 1 provide detailed information of all variables used in this study. After the data cleaning and checking the outliers, our final sample consists of 1,695 households.

[4] The term hypermarket in Vietnam is defined as a very large modern store which occupies over 12,000 m^2 of total area, with more than 10 cash registers and selling a large variety of food and non-food consumer goods (Cadilhon *et al*. 2006). Supermarkets are medium to large-sized stores which are over 500 m^2 in size, with 3-9 cash registers and stock at least 4,000 different food and non-food consumer goods. Mini-markets or convenience stores are small, less than 100 m^2 in surface with 1-2 cash registers and selling food and non-food consumer goods (Cadilhon *et al*. 2006). Examples of hypermarkets and supermarkets in Vietnam include Aeon, Metro, Big C, Fivi Mart, Unimart, AC Mart, and Citi supermarket. Examples of mini-market or convenience store in Vietnam include Seven eleven, Vinmart, Shop & Go, and Circle K.

Table 1 Descriptive statistics for all variables included in the estimated models

Variable names	Description	Mean	SD	Min	Max
Dependent variables					
Vitamin A	Consumption frequencies from seven-day recall	6.90	0.63	0	7
Heme Iron	Consumption frequencies from seven-day recall	6.32	1.32	0	7
Protein	Consumption frequencies from seven-day recall	6.94	0.45	1	7
HDDS	Household dietary diversity score using seven-day recall	9.90	1.16	4	11
Explanatory variables					
ModernMarket	Average monthly expenditure share of modern food markets, continuous	0.13	0.16	0	1
Other covariates					
AgeMale	Age of male household head	46.09	11.79	20	92
AgeFemale	Age of female household head	42.37	11.43	19	92
EduMale	Education completed (in years) by the male household head	11.19	3.30	0	23
EduFemale	Education completed (in years) by the female household head	10.89	3.19	0	19
Buddhist	(=1 if the household head is a Buddhist,0 otherwise)	0.36	0.48	0	1
Christian	(=1 if the household head is a Christian,0 otherwise)	0.06	0.25	0	1
Income	Household monthly income				
Low income	Less than 4.49 mil. VND/month				
Lower-middle income	4.5 to 7.49 mil. VND/month	0.28	0.44	0	1
Upper-middle income	7.5 to 14.9 mil. VND/month	0.43	0.49	0	1
High-income	15 mil. or more VND/month	0.23	0.42	0	1
Household size	Size of the household	4.11	1.08	2	8
Children	Number of children less than 15 years of age in the household	1.27	0.86	0	4
Microwave	(=1 if the household owns a microwave, 0 otherwise)	0.41	0.49	0	1
Ho Chi Minh City	(=1 if household lives in Ho Chi Minh City, 0 otherwise)	0.58	0.49	0	1
Instrumental variables					
OtherModernMarket	Average food expenditure shares at modern outlets of all other surveyed households in the same ward	0.002	0.003	0	0.05
ShoppingList	(= 1 if the household uses a shopping list when shopping for food, 0 otherwise)	0.166	0.37	0	1
Number of households	1,695				

Note: Authors' calculation. SD represents standard deviation and Min and Max represent minimum and maximum values of the sample statistics. VND/month is Vietnamese Dong per month. 1 USD = 22,318 VND on December 30, 2016. Reference income is low-income in VND/month.

2.2 Measurement of outcome variables

We discuss the outcome variables of household dietary diversity and diet quality that are used in this study, and the calculation process followed to create the variables.

2.2.1 Household dietary diversity

Household Dietary Diversity Score (HDDS) is a proxy indicator of dietary diversity, used to examine the direct and indirect linkages between the use of modern food markets and household diet diversity. Using Equation (1) and following Kennedy *et al*. (2011), we calculate the HDDS for each household (h) living in city (j) using information regarding household h's consumption of 12 food groups ($1...k$).

$$\text{HDDS}_{h,j} = \sum_{k=1}^{12} \text{Foodgroup}_{k,h,j} \tag{1}$$

Thus, in Equation (1), the variable $\text{HDDS}_{h,j}$ represents the dietary diversity score of household h living in city j. Food $\text{group}_{k,h,j}$ is a binary variable indicating whether household h living in city j consumed food group k in the past seven days. Food groups in the FCS_N questionnaire (World Food Programme 2015) are categorised as follows: cereals; roots and tubers; pulses; vegetables; fruits; meat and poultry; eggs; fish; milk and milk products; sugars; oils and fats; and miscellaneous. Summary statistics for the HDDS variable are provided in Table 1. The mean for HDDS is 9.9, indicating that, on average, urban Vietnamese households have relatively diverse diets.

2.2.2 Household diet quality

In our analyses, we use three measures of diet quality to assess households' micronutrient (Vitamin A and Heme Iron) and macronutrient (Protein) adequacy. Equations (2–4) show how the diet quality variables: Vitamin $\text{A}_{h,j}$, Heme $\text{Iron}_{h,j}$ and $\text{Protein}_{h,j}$ are calculated by adapting the 2015 FCS_N methods (WFP 2015):

$$\text{Vitamin A}_{h,j} = \sum_{k=1}^{6} V_k \tag{2}$$

$$\text{Heme Iron}_{h,j} = \sum_{k=1}^{3} I_k \tag{3}$$

$$\text{Protein}_{h,j} = \sum_{k=1}^{6} P_k \tag{4}$$

Specifically, we first use the household food recall data, and sum the consumption frequencies (over seven days) for three food sub-groups, V_k, I_k and P_k, which each include specific foods rich in vitamin A, heme iron, and protein, respectively. Foods high in vitamin A that are included in V_k are dairy, organ meats, eggs, orange vegetables, green vegetables, and orange fruits. Foods high in heme iron, which are in the I_k subgroup, include: flesh meat,

organ meat and fish. Foods that are high in protein in the P_k subgroup include: pulses, dairy; flesh meat; organ meat; fish; and eggs.

As the World Food Programme (WFP 2015) outlines, FCS_N analyses attempt to provide a link between household food access and nutritional outcomes. Understanding the dynamics of this relationship can be helpful for the policy makers interested in designing nutrition-sensitive development programs and policies (WFP 2015).

It is evident from Table 1 that urban Vietnamese households are consuming food rich in vitamin A and protein almost seven (6.9) days a week and heme iron just over six (6.3) days a week on average. To gain a deeper understanding of households' micro-nutrient and macro-nutrient differences among income groups from seven-day food recall, Figure 1 represents the nutrient consumption of foods for four income groups: low; lower-middle; upper-middle; and high for Hanoi and Ho Chi Minh City, respectively. This figure shows that in both Hanoi and in Ho Chi Minh City, and for all income categories, consumption of foods rich in heme iron is lower than consumption of vitamin A and protein. In fact, almost one-third of the households in the sample data are facing risk of nutrient deficiencies with respect to heme iron. Iron deficiency, is the most common cause of anaemia, which remains high in Vietnam, with 36.5% of the population iron deficient nationally (Ministry of Health 2012). Considering our food consumption and nutritional analyses in the sample data on heme iron closely matches the national statistics, the following analyses and results are aimed at providing insights into factors affecting food consumption behaviour that may contribute to deficiencies.

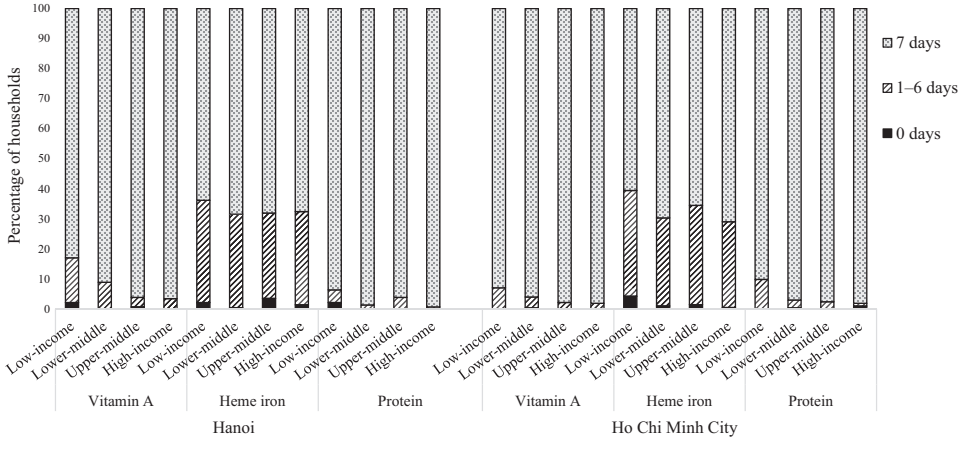

Figure 1 Nutrients consumption differences among income groups in Hanoi and Ho Chi Minh City.

Notes: Gross income categories for Low-income range from 1.5 million to 4.49 million Vietnamese Dong per month; for Lower-middle is 4.5 million to 7.49 million; Upper-middle is 7.5 million to 14.9 million and High-income is 15 million or more Vietnamese Dong per month.

2.3 Variables explaining household dietary diversity and diet quality

2.3.1 Modern market food expenditure shares

The main explanatory variable in this study is the household share of total food expenditures made in modern food retail outlets, which include supermarkets, mini-markets, and/or convenience stores in a typical average month. This is referred as ModernMarket, which is a continuous variable in our analyses. It is similar to the explanatory variable used in the related study by Umberger *et al.* (2015).

Thus, ModernMarket is calculated following Umberger *et al.* (2015) using responses to three relevant questions. First, 'During the past month, how many times did your household purchase [particular food product X]?' Second, 'For each purchase, what is the normal value (in Vietnamese Dong) of [product X] bought for household consumption?' Third, 'Where do you purchase most of the [product X]?'. Using the responses to these questions, we, first calculate monthly total household food expenditures by calculating the product value of the first and second questions for each of the 92 food products in our data set and then summing the 92 values. Next, we use responses to the third question to calculate each household's total monthly food expenditure at modern markets. Finally, we divide the household's total monthly food expenditure at modern markets by the household's total monthly food expenditure to get the household value for ModernMarket, which is the share of food expenditures at modern markets for each household in a typical month. The summary statistics of the sample data show that approximately 13% of urban Vietnamese households' monthly food expenditures are made at modern retail outlets (Table 1).

2.3.2 Other covariates

We also incorporate other covariates in our empirical strategy which represent socio-demographic characteristics of the households and household members that previous studies have suggested may also influence household diet quality.

We include the ages of the male (AgeMale) and female (AgeFemale) heads of household to explore the possibility that individuals become more concerned about the healthfulness of their diet as they get older, as shown in other studies (e.g. Frazao and Allshouse 2003; Toiba *et al.* 2015). We also include covariates EduMale and EduFemale, which represent the years of education completed by the male and female household heads, respectively. More educated adults may purchase healthier foods for their family (Schroeter *et al.* 2012), therefore, positively affecting diet quality. As shown in Table 1, the average age of male and female household head are 46 years and 42 years, respectively. On average, both male and female heads of household completed approximately 11 years of schooling.

We include two dummy variables: Buddhist (equal to 1 if the household head is a Buddhist, 0 otherwise); and Christian (equal to 1 if the household head is a Christian, 0 otherwise) to examine if the main type of religion households

practice influences their food consumption patterns (e.g. vegetarian vs. non-vegetarian) and diet quality. Previous studies in other Asian countries consider religion in their analyses. For example, Hossain *et al.* (2012) and Umberger *et al.* (2015) show in Bangladesh and Indonesia, respectively, that religion (i.e. Muslim) has a significant impact on the weight outcomes of the household members. In our sample, approximately 36% of households report that they are Buddhist and 6% report they are Christian/Catholic (Table 1).

The variable Children represents the total number of children that are less than 15 years of age living in the household. Umberger *et al.* (2015) show a potential link between the use of supermarkets and the probability of a child being overweight or obese in high-income households, which might be as a result of increased consumption of food high in energy, such as sweetened milk, juice, and processed products.

We also include the variables Income, Household size, and Microwave. Income represents a household's gross monthly income. Asfaw (2008) shows that expansion of supermarkets can have a negative impact on the diet quality of the poor since they are more likely to buy cheap, filling, and tasty processed food items than the rich. Furthermore, Umberger *et al.* (2015) show in their Indonesian study that children from low-income urban households have significantly higher body mass index (BMI) compared with those from middle-income and high-income households. Household size is the family size, which may affect the overall diet quality of the household. For example, large household size is widely regarded as a risk factor for malnutrition in developing countries (Pelto *et al.* 1991). Microwave, is a binary variable equal to 1 if the household owns a microwave and 0 otherwise. Households who own a microwave may have more options of preparing different food items that might affect their food consumption patterns (Asfaw 2011). Approximately 41% of the urban households own a microwave as reported in Table 1.

Finally, Ho Chi Minh City is a dummy variable included to control for unobservable city-level social norms and cultural traditions (Umberger *et al.* 2015). Approximately 58% of the households are from Ho Chi Minh City in our study shown Table 1.

2.4 Empirical estimation

Outcome variables for dietary diversity and diet quality in this study are count data and take only non-negative values. Therefore, we use the Poisson model, which accommodates the discrete nature of the data (Cameron and Trivedi 2010), to estimate the following:

$$\boldsymbol{D}_{h,j} = \exp(\beta_0 + \beta_1\ \text{ModernMarket}_{h,j} + \beta_2 \boldsymbol{X}'_{h,j}) + \varepsilon_{h,j} \tag{5}$$

$\boldsymbol{D}_{h,j}$ is the diet outcome measure for dietary diversity and diet quality for household h in city j. We use HDDS to measure dietary diversity. Three diet

quality measures, Vitamin A, Protein, and Heme Iron, are employed to capture the consumption frequencies of vitamin A, protein and heme iron, respectively. The right hand side variable, $\text{ModernMarket}_{h,j}$ measures household h's share of total food expenditures made at modern markets. $\boldsymbol{X}_{h,j}$ is a vector of covariates which include socio-demographic characteristics of both households (h) and individuals, and $\varepsilon_{h,j}$ is a random error term.

The equidispersion property of equal mean and variance in the Poisson model is commonly violated in applied work due to overdispersion (Dean 1992). Therefore, we test for overdispersion in our model and the outcome indicates no significant presence of overdispersion,[5] suggesting our use of Poisson model is appropriate.

The explanatory variable of interest $\text{ModernMarket}_{h,j}$ is potentially endogenous as there may exist some unobservable factors omitted in the model that affect both the outcome variables and share of expenditures at modern markets. For example, households may desire to purchase food with certain quality certifications, which may result in more frequent use of modern markets (Umberger *et al*. 2015). In this case, a simple Poisson regression estimation is likely to produce a biased and inconsistent result. To minimize endogeneity, we apply a two-step control function (CF) approach to the Poisson model with appropriate Instrumental Variables (IV) in the first analysis. Models with count data and endogenous explanatory variables can most easily be estimated using the CF approach since it requires fewer assumptions than maximum likelihood and it is computationally simpler (Wooldridge 2015). The endogenous regressor $\text{ModernMarket}_{h,j}$ in Equation (5) is first estimated as a function of instruments, and then, the second step involves including the error from the first step as an additional regressor in the main model.

Finding valid IVs is difficult, and they could potentially give estimations inferior to OLS if used inappropriately. We use a variable OtherModernMarket as an instrument, which represents average food expenditure share at modern outlets of all other surveyed households in the same ward. We predict that the instrument may have a high correlation with the modern market food expenditure share of the individual household (i.e. $\text{ModernMarket}_{h,j}$) as it captures both the general shopping pattern(s) of the community and possible neighbourhood effects in food purchasing behaviour. For instance, women are usually responsible for shopping for foods and preparing meals for their families in Vietnam (Van Dinh *et al*. 2013). It is possible that these women may share information on food price, food quality, and food safety issues with their neighbours in the same community or ward. At the same time, it may not have any effect on the dietary diversity or diet quality of the individual households other than through possible changes in the food purchasing behaviour of the latter.[6]

[5] The test for overdispersion is presented in Table 2 with the empirical results. The residual lpuhat is not significant in our analyses at 5% level which indicates that our use of Poisson model is appropriate.

[6] Pearson correlation coefficients between the instrumental variable OtherModernMarket and dietary diversity and diet quality measures are very low (<0.04).

Table 2 Direct estimates of household dietary diversity and diet quality (Two-step control function approach)

	Dietary diversity	Diet quality		
	HDDS	Vitamin A	Heme Iron	Protein
ModernMarket	−0.0781	−0.0626	0.2140***	0.0228
AgeMale	0.0001	0.0006**	0.0004	0.0002
AgeFemale	−0.0003	−0.0008***	−0.0008	−0.0004*
EduMale	−0.0021***	0.0004	−0.0065***	−0.0009*
EduFemale	0.0006	0.00430***	0.00562***	0.00125**
Buddhist	−0.0139***	−0.0044*	−0.0213**	−0.0119***
Christian	0.0112*	−0.0038	0.0348***	−0.0015
Income				
Lower-middle income	0.0349***	0.0216*	0.0356*	0.0012
Upper-middle income	0.0463***	0.0264**	0.0190	−0.0024
High-income	0.0504***	0.0290***	0.0342	−0.0018
Household size	0.0072***	0.0035*	−0.0027	0.0031**
Children	0.0052**	0.0111***	0.0070	0.0018*
Microwave	0.0356***	0.0022	0.0173**	0.0062***
Ho Chi Minh City	0.0185***	0.0123***	−0.0057	0.0033***
lpuhat (Residual)	−0.0102	0.0731*	−0.0570	0.0067
Constant	2.197***	1.810***	1.832***	1.918***
First stage regression				
OtherModernMarket	9.642***			
F-test	106.02***			
Mean VIF	3.68			
Deviance goodness of fit (Prob > ch2)	678.94 (1.0)	452.32 (1.0)	2048.54 (1.0)	201.60 (1.0)
Pearson goodness of fit (Prob > ch2)	650.20 (1.0)	289.65 (1.0)	1397.12 (1.0)	147.80 (1.0)
Number of households	1,695			

Note: Asterisks ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Full results with the standard errors are reported in Table S2A in Appendix S2 online. VND/month is Vietnamese Dong per month. 1 USD = 22,318 VND on December 30, 2016. Reference income is low-income in VND/month. Instrumental variable: OtherModernMarket represents average modern market food expenditure share of other surveyed households in the same ward.

Our second objective is to examine if there are any indirect linkages between food expenditure shares at modern markets and household diet quality through dietary diversity. To examine whether the association is negative or positive, we estimate a system of equations through which modern market food expenditure share correlates to households' diet quality. Our systems of equations are as follows:

$$\text{ModernMarket}_{h,j} = \alpha_0 + \boldsymbol{\alpha}_1 \boldsymbol{Z}_{h,j} + \boldsymbol{\alpha}_2 \boldsymbol{X}_{h,j} + e_{1h,j} \tag{6}$$

$$\text{HDDS}_{h,j} = \beta_0 + \beta_1 \text{ ModernMarket}_{h,j} + \boldsymbol{\beta}_2 \boldsymbol{X}_{h,j} + e_{2h,j} \tag{7}$$

$$\boldsymbol{D}_{h,j} = \gamma_0 + \gamma_1 \text{ HDDS}_{h,j} + \gamma_2 \text{ModernMarket}_{h,j} + \boldsymbol{\gamma}_3 \boldsymbol{X}_{h,j} + e_{3h,j} \tag{8}$$

Here, $\text{ModernMarket}_{h,j}$ measures household h's share of food expenditures made at modern markets; $\boldsymbol{Z}_{h,j}$ is a vector of instrumental variables for choosing modern markets for food shopping in city j; $\text{HDDS}_{h,j}$ represents household dietary diversity score of the same household in city j; and $\boldsymbol{D}_{h,j}$ indicates the three diet quality measures discussed above. The term $\boldsymbol{X}_{h,j}$ represents the vector of individual and household characteristics, while $e_{1h,j}$ to $e_{3h,j}$ are random error terms which are assumed to be independent and identically distributed in the model. We also secure model identification by rank and order conditions.

To investigate the indirect linkages, we apply the three-stage least squares method (3SLS) to estimate a system of structural equations where some equations have endogenous variables. In many cases, these endogenous variables are dependent variables of other equations in the system. Therefore, the error term is correlated with the endogenous variables which violates the assumptions of OLS (Greene 2012). 3SLS obtains instrumental variable estimates, taking into account the covariance across equation disturbances (Davidson and MacKinnon 1995). In our systems of Equations (6–8), the variables ModernMarket and HDDS are used on both the left and right sides and therefore they potentially suffer from endogeneity. Therefore, we apply this method to produce consistent estimates and Generalized Least Squares (GLS) to account for the correlation structure in the disturbances across the equations.

To address possible endogeneity, we use the variable OtherModernMarket as an instrument for the possibly endogenous explanatory variable, ModernMarket. For the other endogenous variable, HDDS we use another IV, ShoppingList (with a value of 1 if the household uses a shopping list when shopping for food). A study by Crawford *et al.* (2007) shows that a shopping list can help the household plan meals for the households and is often used when the household is trying new recipes, which may involve new types of foods. Therefore, it is possible that having a shopping list may increase household dietary diversity. To ensure that shopping list is not correlated to household diet quality, we check Pearson correlation coefficient test and find very low correlations between the variable ShoppingList and measures of diet quality.[7]

3. Results and discussion

3.1 Direct estimates of household diet quality

Table 2 reports the results of the estimation of the direct relationship between ModernMarket and measures of HDDS, and diet quality, that is, the consumption frequencies of food rich in Vitamin A, Heme Iron, and Protein.

[7] The respective Pearson correlation coefficients between ShoppingList and Protein and Heme Iron are <0.05 and that between ShoppingList and consumption frequencies of Vitamin A is −0.007.

We find no statistically significant relationship between ModernMarket and HDDS. Further, the direct estimates of household diet quality in Table 2 show no significant association between ModernMarket and consumption frequencies of foods rich in Vitamin A and Protein. However, we find a positive and significant association between ModernMarket and consumption frequencies of Heme Iron.

The first-stage coefficient on the OtherModernMarket variable indicates a positive and statistically significant association with ModernMarket (at 1% level of significance). The first stage *F*-statistic is 106.02 which satisfies the conventional 'rule of thumb' for *F*-statistics (Staiger and Stock 1997).

The second stage regression fits a Poisson model that includes the first-step residual (variable lpuhat shown in Table 2). The z-statistic for the coefficient of the residual lpuhat in Table 2 provides the basis for a robust Wald test of the null hypothesis: $H_0 : \rho = 0$ of exogeneity (Cameron and Trivedi 2010). Our results show that the z statistic has a non-significant *P*-value against the alternative hypothesis: $H_1 : \rho \neq 0$, thereby, failing to reject the null hypothesis. The Deviance and Pearson goodness of fit statistics indicate the model is appropriate for the analysis.

Among the other covariates, the significant coefficient on the variable EduMale shows a negative association with HDDS and diet quality measures such as Heme, Iron and Protein (Table 2). However, the associations between EduFemale and measures of diet quality (Vitamin A, Heme Iron and Protein) are positive and statistically significant (1% level). Perhaps, higher educated female household heads are more knowledgeable about the health benefits of nutrient-rich food; and therefore, female household heads encourage family members to consume more nutritious types of food.

We find a negative and statistically significant association between the variable Buddhist and dietary diversity and diet quality, with Heme Iron and Protein strongly significant at the 5% and 1% level, respectively. This is as expected as Vietnamese Buddhists are generally vegetarians; and meat consumption, which is a good source of heme iron and protein, is generally low among them (Nam *et al.* 2010). On the other hand, we find a positive and statistically significant relationship between the variables Heme Iron and Christian. These results suggest that urban Vietnamese household religious practices affect their diet quality.

The coefficients on the income dummy variables show positive and statistically significant associations with higher levels of household income and household dietary diversity (Panel (1) of Table 2). However, income effects for households in upper-middle (7.5 million to 14.9 million VND/month) and high (15 million or higher VND/month) income ranges show stronger levels of significance in explaining consumption frequencies of Vitamin A compared with lower-middle income. Not surprisingly, household income appears to play an important role in explaining diet quality of urban Vietnamese households. Further detailed analysis of the data revealed that the urban households with higher socioeconomic status are more likely to

consume nutrient rich foods that are good sources of nutrients such as Vitamin A, such as tropical fruits, fish, and dairy products.

Somewhat surprisingly, Household size has a positive and significant correlation with the variables HDDS, Vitamin A and Protein (Table 2). This could be because larger households may consume a greater variety of food due to heterogeneous demand for food by the members. The variable Children is positively associated with HDDS and nutrient adequacies (Vitamin A and Protein). This is an interesting result and may suggest that households are consciously selecting foods that are higher in these nutrients to ensure that their children have higher quality diets. Further research is needed to look at the intra-household food consumption behaviour of the children versus the adults in these households and also compare the diet quality of adults in household with children to adults in households without children, but with other similar socio-economic characteristics.

Finally, we find that Ho Chi Minh City households, compared with Hanoi households, have a significantly higher overall diet diversity and diet quality, particularly with respect to adequacy of vitamin A and protein. This could be because the eating habits and availability of food items vary greatly due to cultural, ethnic, geographical, and economic development differences between the two cities (Van Dinh *et al*. 2013). For example, Hanoi, which is in the northern part of Vietnam, has operated under socialism since the 1940s (Ralston *et al*. 1999), and modern market growth has been relatively slower in Hanoi (Wertheim-Heck *et al*. 2015). On the other hand, Ho Chi Minh City, which is located to the southern part of Vietnam, has been influenced by the U.S. and other Western cultures for several decades (Engholm 1995). Van Dinh *et al*. (2013) reported that the traditional diet and eating habits of households in the Northern part of Vietnam differed from the southern households in Ho Chi Minh, due in part to food availability as a result of differences in climatic conditions, as well as cultural differences and eating habits. Therefore, it is not surprising that we found regional differences in this study.

3.2 Indirect estimates of household diet quality through household dietary diversity

Results of the estimation (using the system of Equations (6–8)) of indirect linkages between modern market food expenditure shares and household diet quality through household dietary diversity are summarised in Table 3.[8] The results suggest that ModernMarket may have a significant association with household diet quality indirectly through HDDS. More specifically, we find a positive and significant (1% level) association between ModernMarket and

[8] Full results are presented in Table S3A for micronutrients (vitamin A and heme iron) and in Table S3B for macronutrient (protein) in Appendix S2 online.

Table 3 Indirect estimates of household diet quality through household dietary diversity (Results from 3SLS)

	(1)		(2)		(3)	
	Vitamin A	HDDS	Heme Iron	HDDS	Protein	HDDS
Modern Market	−0.8250*	−0.7090	2.7090***	−0.7090	0.4850***	−0.7090
HDDS	−0.5160		1.6850**		0.4260**	
Hansen J statistic (*P*-value)	0.1550 (0.694)					
Individual attributes	Yes	Yes	Yes	Yes	Yes	Yes
Household attributes	Yes	Yes	Yes	Yes	Yes	Yes
City dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of households	1,695					
Chi-square	124.23***	365.38***	43.12***	365.38***	47.03***	365.38***

Note: Asterisks ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Full results with the standard errors are reported in Appendix S2 online (See Table S3A and Table S3B).

both Heme Iron and Protein, and a negative and weak association between ModernMarket and Vitamin A.

Conversely, for all three measures of diet quality, the impact of ModernMarket on HDDS is not statistically significant. Yet, when we use HDDS as an explanatory variable in our analyses to explain Vitamin A, Heme Iron, and Protein, an increase in HDDS is statistically significant (5% level) and positive with respect to estimates of the consumption frequencies of Heme Iron (micronutrient) and Protein (macronutrient). These results indicate that increased household dietary diversity significantly contributes to higher consumption of nutrient-rich foods in urban Vietnamese households.

The coefficients on the instrumental variables OtherModernMarket and ShoppingList are positive and statistically significant in explaining the endogenous variables ModernMarket and HDDS, respectively, thus, they appear to satisfy the relevance condition. The first stage *F*-statistics report that the instruments are valid as the rule of thumb of exceeding the value 10 is satisfied (Staiger and Stock 1997). In all three cases, based on the over identification test using the Sargen and Hansen J statistic, we fail to reject the null hypotheses (at the 5% level) and can conclude that the over-identifying restriction is valid. These results jointly lend credence to the overall set of instruments used in the 3SLS estimation.

3.3 Discussion

In general, there is no conclusive evidence of a statistically significant and direct relationship between modern market food expenditure shares and measures of household dietary diversity and diet quality. Rather, we found

that modern market food expenditure shares may have a significant association with diet quality through indirect linkages. More specifically, modern market expenditure share is positively associated with consumption of foods rich in heme iron and protein, which could occur through purchases that result in increased consumption of certain foods rich in these nutrients, such as meat, fish, and dairy products. Households may prefer to purchase these perishable food items from modern markets rather than wet markets because as Wertheim-Heck *et al.* (2015) discussed, modern markets are perceived by some Vietnamese consumers to be safer. However, Wertheim-Heck *et al.* (2015) also reported that shoppers at modern markets have a specific socio-demographic profile such as higher income and/or younger.

On the other hand, modern markets may have a negative impact on household diet quality in terms of offering food rich in vitamin A such as leafy green vegetables, orange and yellow vegetables and fruits. This may be because in Vietnam, traditional wet markets as well as street vendors largely dominate the market for fresh fruits and vegetables. For example, supermarkets in Hanoi account for only 2% of total vegetable consumption (Wertheim-Heck *et al.* 2014, 2015).

Further, as expected, household dietary diversity plays an important role in diet quality, through increasing consumption of micronutrients (e.g. heme iron) and macronutrients (e.g. protein). This is not surprising as diet quality is likely to improve if the household consumes a more diversified diet, rich in fresh and relatively unprocessed food.

These findings imply that policies, which encourage food market modernisation as a way of stimulating economic development in Vietnam, may need to be re-evaluated if household diet quality improvement is also a policy goal. A comprehensive set of factors can affect diet quality. For example, more work is needed to understand drivers of heterogenous consumer shopping and food purchase behaviour (e.g. perceptions and concerns regarding food safety and quality, nutrition knowledge, and socio-demographics) in Vietnam, particularly as they relate to the use of different food retail outlet formats; and the association between these factors and diet quality. Further, Vietnamese consumers' food demand patterns are changing. While per capita consumption of nutrient-dense meat, fish and seafood, eggs, and dairy products is increasing in Vietnam, demand is also growing for relatively less nutritious processed foods (Hoang 2018). Thus, it is important to understand the various food products (fresh and processed) that are offered in different food retail outlets and consumers' purchasing behaviour and preferences with respect to food outlets and food products.

Alternatively, policies that directly promote and encourage consumption of fresh, unprocessed and diverse healthy foods may be more efficient mechanisms for improving the diet quality of the urban Vietnamese population. Further, increasing education and rising awareness of nutrition may also have a positive impact on the diet quality of Vietnamese households, which in turn, may contribute to reducing the double burden of malnutrition. Thus, the Vietnamese

government may consider promoting complementary policies focused on improving the general knowledge and awareness of nutrition.

4. Conclusions

This study explores the relationship between the share of household food expenditures at modern food retail outlets and diet quality in terms of diet diversity and nutrient adequacy with respect to vitamin A, heme iron and protein. To the best of our knowledge, this is the first study that explicitly examines the relationship between modern market food expenditure share, household dietary diversity and diet quality in order to shed light on the implications of food market modernisation on Vietnamese diets.

This current study has several limitations. First, the study is cross-sectional in nature and therefore, findings of this study cannot infer causal relationships. Also, this study is based on household data from only two cities in Vietnam: Hanoi and Ho Chi Minh City; thus our study may not be representative of the whole country. Future research in this direction should include households from more urban and peri-urban areas. Moreover, the conceptual links among modern food retail outlet usage, dietary diversity, and diet quality will need to be established without loss of generality, which is beyond the scope of the current study which focuses on a specific transition economy.

Additionally, the data on food consumption behaviour, dietary diversity, and diet quality in this study are at the household level. Collecting individual-level diet quality data may be expensive and time consuming. However, inequalities in the intra-household distribution of food and calories are common in developing countries, and there is growing concern that estimates based on household-level data may not accurately identify the nutritional status of individual household members. Thus, it is important to examine the effect of modern market usage on the diet quality of individuals, including children, adolescents, and adults. Future studies may also consider using food diaries to measure the food consumption behaviour of individuals in households considering various age groups and gender to obtain improved estimates of diet quality.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1A. Household income classification comparison between the Vietnam Urban Food Consumption and Expenditure Study with third party survey (Hanoi).

Figure S1B. Household income classification comparison between the Vietnam Urban Food Consumption and Expenditure Study with third party survey (Ho Chi Minh City).

Table S2A. Direct estimates of household dietary diversity and diet quality (Two-step CF approach).

Table S3A. Indirect estimates of household diet quality (Micronutrients) through household dietary diversity using 3 SLS (Full results).

Table S3B. Indirect estimates of household diet quality (Macronutrient) through household dietary diversity using 3 SLS (Full results).