The Influence of Household Refrigerator Ownership on Diets in Vietnam

Brent R. Heard1\*, Huong Trinh Thi2,3, Dharani Dhar Burra2, Martin C. Heller1, Shelie A. Miller1, Thanh Thi Duong2, Michel Simioni4, Andrew D. Jones5

1Center for Sustainable Systems, School for Environment and Sustainability, University of Michigan, Ann Arbor, MI, U.S.A.

2Alliance Bioversity International and CIAT, Asia Hub, Hanoi, Vietnam

3Department of Mathematics and Statistics, Thuongmai University, Hanoi, Vietnam

4MOISA, INRAE, University of Montpellier, Montpellier, France

5School of Public Health, University of Michigan, Ann Arbor, MI, U.S.A.

Corresponding Author Contact Information:

\*Corresponding Author: [brheard@umich.edu](mailto:brheard@umich.edu)

Brent Heard

Center for Sustainable Systems

School for Environment and Sustainability

University of Michigan

Dana Building, 440 Church Street

Ann Arbor MI 48109

Phone: 412-478-3121

**Abstract**

Refrigerator ownership accompanies socio-economic development, with the potential to change human diets. Household refrigerator ownership in Vietnam has increased from 13% to 59% between 2004-2014. This study estimates changes in food consumption and diet linkages with household refrigerator ownership in Vietnam, controlling for socioeconomic variables. We use a two-step instrumental variable regression model on two panels of the Vietnam Household Living Standards Survey covering 2004-2014. Our study finds refrigerator ownership to be statistically significantly connected with decreases in per-capita calorie intake over both periods, and a 29.4% decrease in high-nutrient foods from 2004-2008. Refrigerator ownership leads to a decrease in calories from starchy staple foods, by 744 Kcal in the first panel and 250 Kcal in the second panel, as well as decreases in nuts and seeds consumption in both panels. However, we find refrigerator ownership increases calories from dairy in both periods.

Keywords: refrigeration, diet, sustainability, nutritional transition, Vietnam

1. **Introduction**

Vietnam has experienced tremendous economic growth over the past thirty years as a result of the government’s *Đổi Mới* policy promoting market liberalization. GDP growth has averaged 6.42% between the beginning of this program in 1986 and 2017, with annual per capita GDP growth averaging 5.04% (The World Bank, 2018). This growth has been attained in part through infrastructure development throughout the country. For example, household electrification has increased from less than 50% in 1993 to including nearly all households in 2014 (World Wildlife Fund, 2016).

As a country develops, dietary shifts towards lower amounts of starchy staple foods and greater quantities of protein-rich and higher-fat foods have been demonstrated (Thang and Popkin, 2004). While this linkage is well-established, the specific mechanisms enabling these shifts are understudied, including the presence of refrigeration. This study assesses the relationship between household refrigerator ownership and the consumption of food types in Vietnam, filling part of this research gap.

Refrigeration plays a transformative role in food system development, and is interconnected with changes in what foods are consumed and can be supplied (Heard and Miller, 2016a). The presence of refrigeration is connected with diets containing more perishable food items (Garnett, 2007), with a connection to increased meat consumption explicitly noted in China’s development (Garnett & Wilkes, 2014). Perishable foods have the potential to improve health outcomes in developing countries (International Organization for the Development of Refrigeration, 2009), but the availability of refrigeration in conjunction with income increases may also promote diets which increase obesity and related health burdens (Popkin, 2001). The relationship between refrigeration, diet, and development has been addressed in the academic literature either largely qualitatively (Garnett, 2011, 2007; Parfitt et al., 2010) or modeled more-abstractly, carrying an assumption of dietary convergence reflecting diets in developed Western countries (Heard and Miller, 2019).

Refrigerator ownership is tied to wealth, with sufficiently high household wealth being a necessary precursor for purchasing a refrigerator. Wealth increases have been empirically connected with decreased starchy staple food consumption and increases in fruit, vegetable, meat, dairy, and refined grain consumption; with the degree of these shifts dependent on the relative cost of these food types (Godfray et al., 2018). Due to the technological and logistical requirements of supplying perishable foods, shifts towards their consumption is in part enabled by refrigeration as a technology, and in part enabled by wealth used to purchase these products and a refrigerator. The extent to which diet shifts with development are attributable to refrigeration, wealth, and/or the interaction between these factors is relatively unassessed in the academic literature (Heard and Miller, 2016a).

The unbroken refrigerated supply chain, or “cold chain,” provides the capacity to robustly supply perishable foods, and its presence is a characteristic of a developed, industrialized food system (Parfitt et al., 2010). Cold chain services have developed in Vietnam in recent years due to an increase in international investment and an increase in the presence of supermarkets, with sales from modern grocery retailers growing from 30.9 trillion VND in 2011 to 69.2 trillion VND in 2015 (Euromonitor, 2017). The cold chain also plays a key role in agricultural development and in the transition towards Vietnam becoming an agricultural product exporter (Arita and Dyck, 2014). Despite these changes, cold chain development in Vietnam still faces several challenges including the need for improved training at the professional and farmer levels, a lack of supporting information technology, and high costs of installation and operation (Gligor et al., 2018). The introduction of refrigerators into the household connects the cold chain to the consumer; with this analysis assessing the influence of household refrigerator ownership on diet.

The expected influence of having a refrigerator on the diet can be summarized in two hypotheses. First, household refrigerator ownership is hypothesized to have a positive and statistically significant relationship with the consumption of the more-perishable food types assessed: flesh foods (meat and fish), eggs, vegetables, fruits, and dairy. Second, refrigeration is hypothesized to have a negative and statistically significant decrease in consumption of the less-perishable foods studied: starchy staple foods, nuts and seeds, and pulses.

Previous hypotheses are investigated through the empirical analysis of causal linkages between refrigerator ownership and household nutrition. First, the chosen estimation strategy must take into account that refrigerator ownership is likely not the only variable influencing a household’s consumption of different food types. Socio-economic variables including income, household location, education level, and household size (among others) can be expected to affect food consumption. These variables are included in the estimated regression model as control variables. Second, the availability of panel data on Vietnamese household consumption allows for an explicit treatment of unobserved individual heterogeneity by adding individual fixed effects to the estimated regression model (Stock and Watson, 2015). Indeed, unobserved individual heterogeneity can be a source of endogeneity of the explanatory variable of interest, owning a refrigerator. The latter variable can be correlated with individual, non-time-varying factors that are not observed and that also influence diet. Individual fixed effects introduction makes it possible to control for this source of endogeneity of owning refrigerator. Third, the issue other potential sources of endogeneity of owning refrigerator, due to reverse causality between nutritional outcome and owning refrigerator or some unobserved time-varying factors impacting on these two variables, is addressed using an instrumental variable approach, namely control function approach (Wooldridge, 2015).

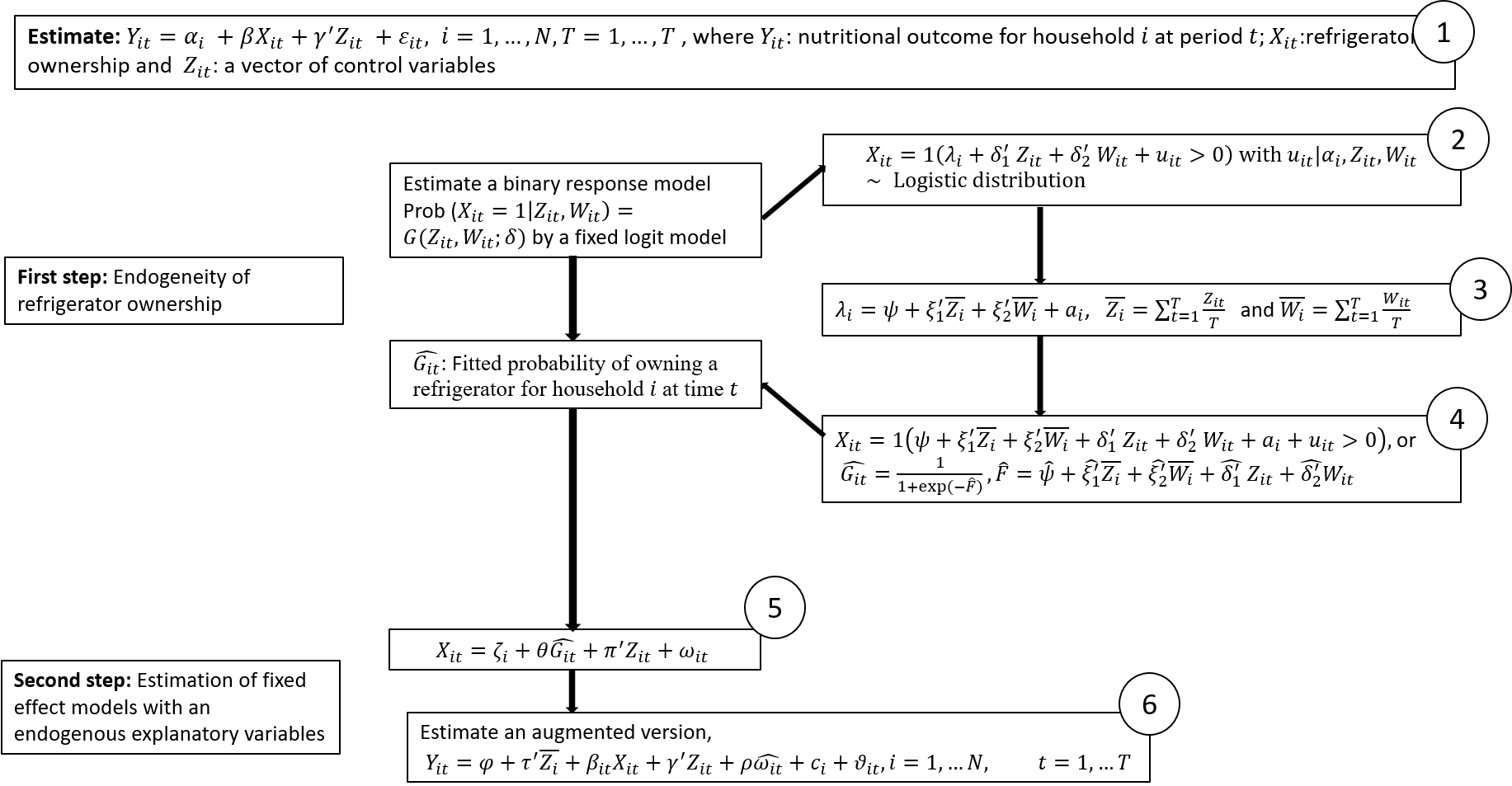
The proposed estimation strategy is implemented using data from Vietnamese Household Living Standard Survey, or VHLSS, over the 2004-2014 period. Consumption data are converted into energy intakes and normalized using per capita calorie intakes, thus allowing comparison between households. Nutritional outcomes under consideration include a diversity measure, total per capita calorie intake, per capita calorie intakes for major food items, and the ratio between the shares of calories coming from food items with high nutrient intake and food items with low nutrient intake. Thus, empirical analysis provides a snapshot of the causal effect of owning refrigerator on nutritional diet seen from different angles.

The paper is organized as follows. First, our estimation strategy is detailed, followed by a description of the VHLSS data, and then a description of our results and findings.

**Estimation strategy**

The influence of refrigerator ownership for Vietnamese households is investigated through regression of nutritional outcome for household at period , or , on refrigerator ownership, or , and a vector of control variables, or :

Household fixed effect, or , controls for potential unobserved time-invariant household heterogeneity. is the classical random term capturing the effect of unobserved time-variant variables.Estimating the influence of household refrigerator ownership on diet requires addressing issues of endogeneity of household ownership. The specific estimation strategy undertaken is depicted in **Figure 1**, and described as follows.



**Figure 1:** Visual depiction of the two-step estimation strategy employed to estimate the influence of household refrigerator ownership on dietary outcomes

The treatment of endogeneity of refrigerator ownership in Eq. (1) needs a special attention as the endogenous explanatory variable is binary: owning or not a refrigerator. Eq. (1) is usually called a dummy endogenous variable model (Heckman, 1978). As discussed in Wooldridge (2010), instrumental variables techniques must be adapted to deal with dummy endogenous explanatory variable issue. Let denote a vector of instrumental variables. The estimation strategy consists then of a two-step IV method:

1. First step: Estimate a binary response model Prob ( by maximum likelihood (for instance, a fixed-effect logit model).
2. Second step: Estimate Eq. (1) by IV regression using instruments and where denotes fitted probability of owning a refrigerator for household at time obtained in first step.

Implementation of this two-step estimation procedure using panel data raises various issues:

In the first step, different estimation strategies have been proposed to deal with the estimation of fixed-effect logit model. A possible strategy is maximum likelihood estimation with a dummy variable for each household. It is well known that estimation of parameters of usual fixed effects models with a small number of observations per fixed effect suffers from the incidental parameters problem (Neyman and Scott, 1948). Estimates of fixed effects values have no intrinsic interest, but their presence may prevent to estimate consistently the parameters of interest, here β in Eq. (1). Even increasing the number of time periods does not necessary solve the incidental parameters bias because fixed effects estimators are asymptotically biased even if grows at the same rate as (Hahn and Newey, 2004). Conditional logit estimator has been proposed as an alternative to the previous estimation strategy (see Andersen, 1970; Chamberlain, 1980). The main drawback of conditional logit estimator is that it does not provide estimates of the fixed effects we need to compute fitted probabilities.

The alternative estimation strategy we follow is inspired by correlated random effects panel data models recently surveyed in Wooldridge (2019). Consider the fixed-effect logit model

As proposed by Mundlak (1976), potential correlation between unobserved household heterogeneity, as captured by fixed effects , and regressors in model (2) can be written as

where and denote time-averaged values of  and , i.e. and and, conditionally to is purely random and distributed with zero mean. By including the vector of time-averaged explanatory variables, i.e. and , time-invariant unobserved heterogeneity can be controlled as with fixed effects, but without encountering the incidental parameters problem that affects fixed effects model estimation. Indeed, Eq. (2) can be written as

and estimated using classical random effect panel data estimator. As a byproduct, computation of fitted probabilities is not marred by the need to estimate fixed effects, i.e

and

where , , denote estimated values of from Eq. (4).

In the second step, we turn now to classical estimation of fixed effects models with an endogenous explanatory variable. Recently, Wooldridge (2015) proposes to deal with this estimation issue using a control function approach. The estimation strategy we have chosen combines control function approach with correlated random effect one. As explained above, this last approach allows to control for time-invariant unobserved heterogeneity as with fixed effects, but without encountering the incidental parameters problem that affects fixed effect model estimation. Second, this approach can be easily combined with a control function approach, which addresses the potential endogeneity of refrigerator ownership. The control function approach is inherently an instrumental variables method. Its implementation assumes the availability of variables that do not appear in the equation to be estimated (i.e. excluded instrumental variables), and that explain the variation of the endogenous explanatory variable. The exogenous variation induced by excluded instrumental variables provide separate variation in the residuals obtained from a reduced form, which serve as control functions. By adding appropriate control functions, which are estimated in a first stage, the endogenous explanatory variable becomes appropriately exogenous in a second-stage equation. Accordingly, the control function approach enables testing the endogeneity of the explanatory variable by using a simple Hausman (1978) test. This test first can be corrected from having estimation errors coming from first-stage estimation of control functions using bootstrap techniques, and then can be easily made robust to heteroskedasticity and serial correlation in a panel data setting.

Our estimation strategy proceeds thus in two steps:

1. Estimate a linear probability model where is regressed on and or

Compute the estimated residuals, or and where denotes predicted value of

1. Estimate an augmented version of Eq. (1), i.e.

where time-averaged explanatory variables and the random term come from Mundlak's modeling of fixed effect , as above, and measures the correlation between the residuals of Eqs. (1) and (5), or, put differently, with purely random with zero mean. Testing endogeneity of is now equivalent to testing nullity of using a robust t-statistics. [[1]](#footnote-2)

1. **Data**

***3.1. The Vietnam Household Living Standards Survey (VHLSS)***

This study uses the Vietnam Household Living Standards Survey (VHLSS) conducted by the General Statistics Office of Vietnam (GSO) every two years since 2002.  This multi-purpose survey has been conducted in approximately 9,000 Vietnamese households. Our analysis uses the six most recent VHLSS waves: 2004 to 2014. VHLSS is a rotating panel design with 50% rotation of households. In addition, The VHLSS 2004-2006-2008 master sample design has a-two-stage from enumeration areas (EAs) of the 1999 Population and Housing Census of Vietnam while the master sample of the VHLSS since 2010 was based on the 2009 Population and Housing Census of Vietnam. Due to these sample design, it enables us to make two panel datasets from 2004 to 2014: between the years 2004, 2006 and 2008 and between the years 2010, 2012 and 2014 (detail information is in Appendix B).

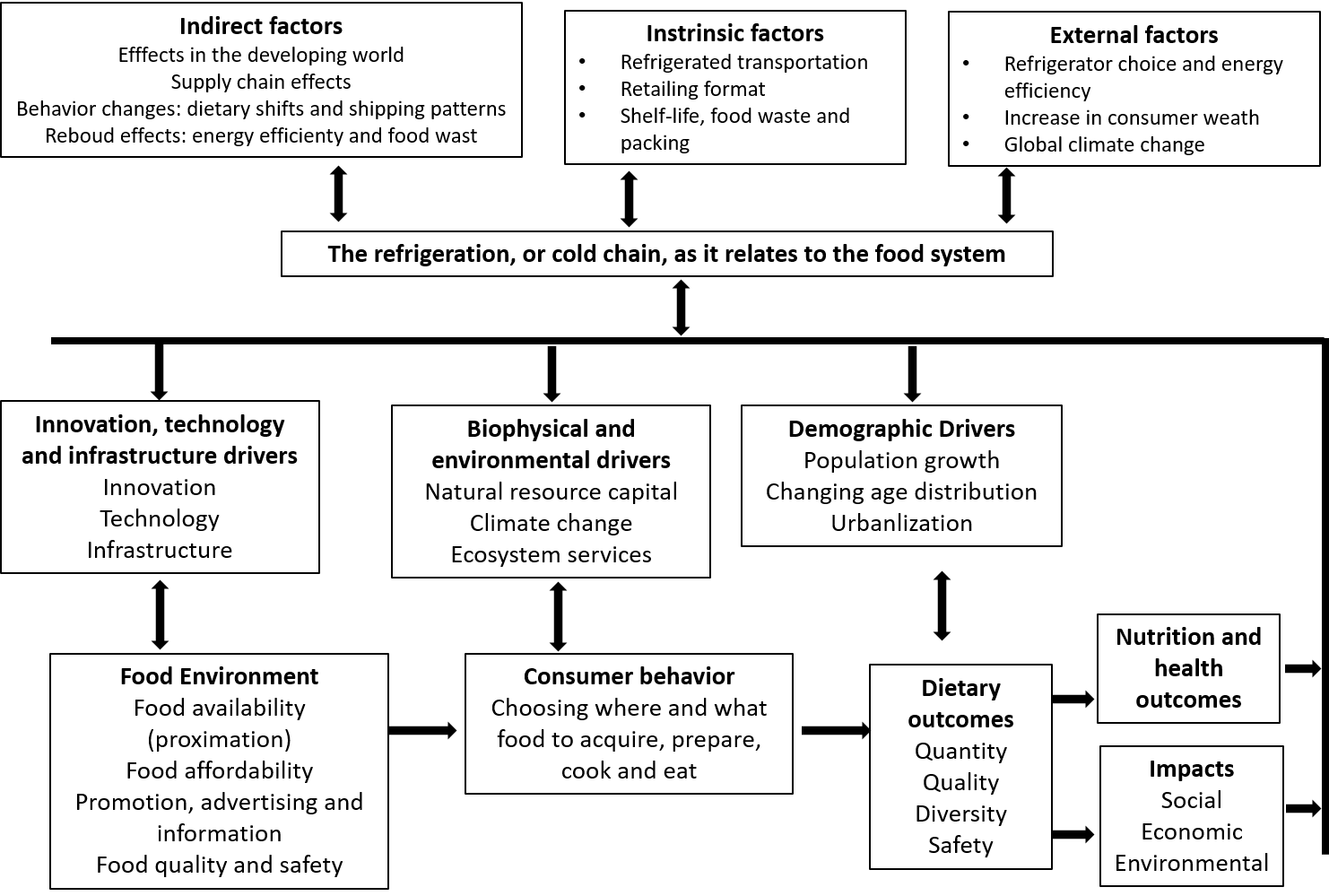
***3.2. Nutrition outcome***

The VHLSS survey collects recall responses on household food consumption. This study uses various nutrition outcome indicators. First, a diet diversity score (DDS) is calculated based on a count of nine food group consumption at household level. The nine food groups are starchy staple food, nuts and seeds, pulses, flesh foods, eggs, vegetables, fruit, dairy and others.[[2]](#footnote-3) This score is recommended for validated indicators of dietary diversity (Food and Agriculture Organization of the United Nations, 2016; World Health Organization, 2008). A higher DDS reflects a diet consisting of a greater variety of foods. Dietary diversity measures positively correlate with nutrient adequacy for individuals in both developing and developed countries (Ruel, 2003). However, the relationship between dietary diversity and food system development remains a research gap. A full table of the food types aggregated into the categories is available in Table B-1, Appendix B.

Second, household calorie intake expressed in kcal per day and per adult equivalent for each food groups in DDS are calculated from total per capita calorie intake (PCCI). Household food consumption quantity (in Kg) is normalized into daily intake values and converted into household calories by using a calorie conversion table constructed by Vietnam National Institute of Nutrition (National Institute of Nutrition, 2013). Then, per capita calorie intake is computed as adult equivalent calorie intakes as employed by Aguiar and Hurst (2013) and Trinh et al. (2018). Per capita calorie of food types are disaggreated from per capita calorie intake. The authors refer the reader to (Zezza et al., 2017) for a useful discussion of the relative advantages and disadvantages of household expenditure surveys for measuring food consumption. While the dietary recall period employed by the VHLSS survey exceeds that typically recommended by nutritionists, it is the most-granular household dietary data available which can be coupled with measures of household refrigeration in Vietnam.

Third, an aggregate ratio is also used to measure diet adequacy. Food groups are combined into only two categories: low nutrient intake (starchy food and other items) and high nutrient intake (all other food groups). For each household, share of calorie intake coming from low nutrient (resp. high nutrient) food items, denoted by (resp. ) is computed. Nutritional outcome is the log ratio of the two shares, i.e. . Since , then and the log ratio can be interpreted as log odds ratio.

All these variables are used to study the causal linkages between household owning a refrigerator and diet, under general framework of the complex food system, as in Figure 2.



**Figure 2**. Conceptual framework of hypothesized causal linkages between household refrigerator ownership on the quality and diversity of diets in Vietnam. Authors adapt from FAO’s HLPE (2017) and Heard and Miller, 2016a.

***3.3. Refrigerator Ownership in Vietnam***

The VHLSS survey records ownership of nearly 40 durable goods for households, including refrigerator ownership. The refrigerator ownership in Vietnam is coded “Yes” if household owns a refrigerator and “No” if households does not own any refrigerator. Refrigerator ownership in Vietnam has increased recently, given electrification, a necessary pre-condition for refrigeration (Heard and Miller, 2016), and is robustly present in Vietnam (Table C-1, Appendix C.).

***3.4. Instrument variables***

Three instrumental variable are considered: households use national-grid electricity as the main lighting. The power system of Vietnam is under the control of Vietnamese government and the government has a responsibility to build and spread national-grid electricity. Two criteria must be met by instrumental variables. First, they must be relevant, i.e. correlated with the endogenous explanatory variable, owning refrigerator. The chosen variables are thus appropriate instruments for refrigerator ownership as they require reliable household electricity to be used, in the same way as a refrigerator. Second, the chosen instrumental variables must be considred as exogenous. It is therefore conceivable that If household is using national grid electricity for lighting, this means that this household is living in a community with access to national grid electricity. The household has chosen this access for basic use of electricity, that is lighting. Maybe, other uses of electricity such air conditioned are more elaborate choices whose determinants (observed or not) are similar to those justifying refrigerator use. And maybe, these determinants (observed or not) have also an impact on nutrition. Only lighting could be viewed as a necessary need, disconnected to more elaborated use of electricity.

***3.5. Other variables***

Following many papers in the literature on diets using VHLSS, other socio-economic household variables are considered. To measure income, we use (monthly) per capita expenditure (PCE), which has been widely used as an appropriate proxy (Baulch and Masset, 2003; Minot et al., 2006; Trinh Thi et al., 2018). Per capita expenditure serves as a useful income proxy as it avoids the issues of underreported income (Deaton, 1997) and income volatility (Bhalotra and Attfield, 1998). An overall income measure is studied in this analysis as it affects a household’s ability to purchase both food and durable goods such as a refrigerator. This study normalizes PCE to 2014 thousand VND[[3]](#footnote-4).

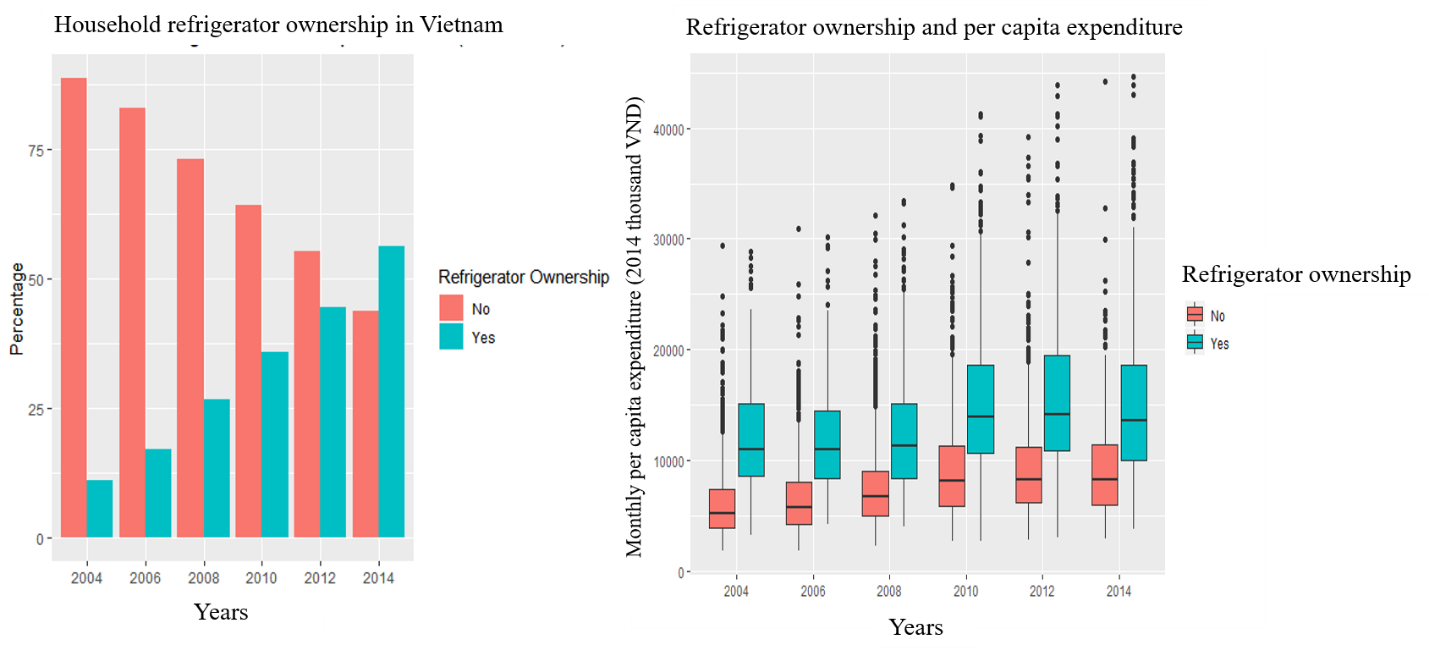
The VHLSS data also collect information about the sources of food consumption: including purchased goods, home-produced food, and food received in-kind. The proportion of food consumed from purchase is the proportion of food consumed that originated from purchased source over the total amount of consumed food.

Control variables include: URBAN: dummy variable equals 1 if the household is located in an urban area, equals 0 if not; AREA: the region where the household is located, including Red River Delta, Midlands Northern Mountains, Northern Central Coast, Central Highlands, South East, Mekong River Delta. 2) Household size (HSIZE): less or equal to two members, three members, four members, five members, equal or more than six members; 3) the proportion of children under 15 years old in family; 4) KINH: ethnicity equals 1 if the head of the household belongs to the major ethnic group of the country (Kinh for Vietnam), equal to 0 otherwise; EDUCH: the highest education level, including three levels: below and equal primary school, secondary school, university; GENDER: Male or female; WA: if the household is located in a house with access to clean water or not. Table D-1 summarizes the main characteristics of all the variables from 2004-2014 which includes two panel data (Appendix D).

1. **Results**

***4.1 Increasing Refrigerator Ownership in Vietnam***

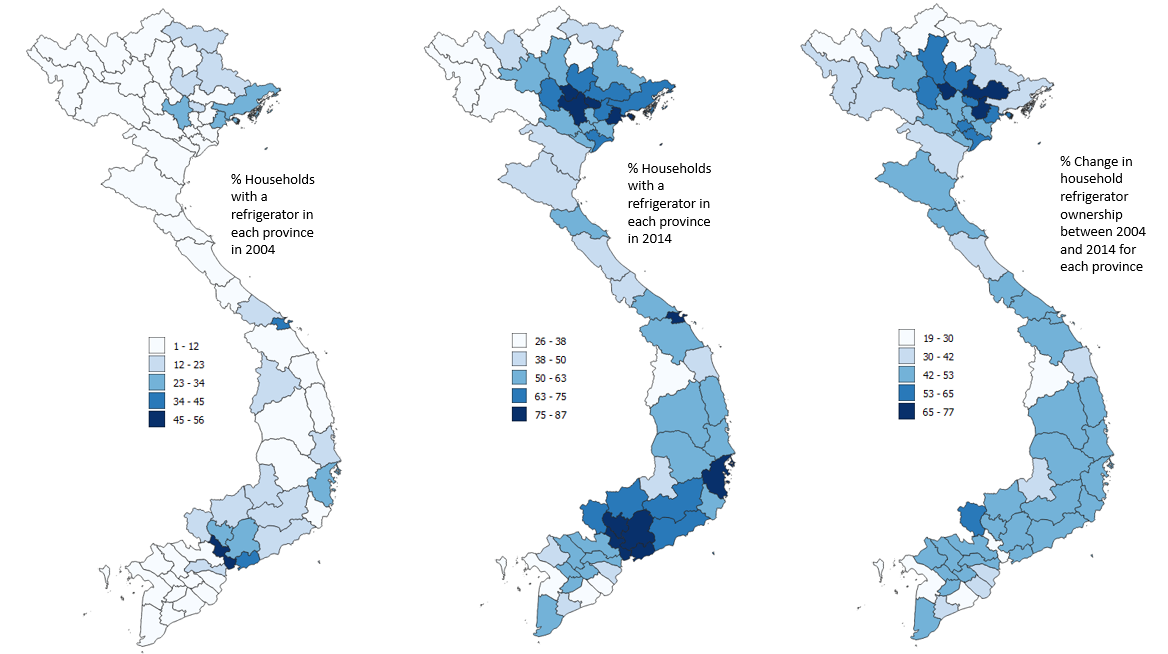
Trends of Vietnamese refrigerator ownership and its relationship to average per capita expenditure over the study period are displayed in **Figure 3**.



**Figure 3:** Vietnamese refrigerator ownership and average per capita expenditure (PCE) over 2004-2014 as recorded by the Vietnam Household Living Standards Survey. The right plot boxes encompass the 25th and 75th percentile values of PCE per year, with the black lines extending to the extreme high and low values recorded. The horizontal black lines in the boxes indicate the median PCE value for each group per year.

Household refrigeration has increased notably during the time period observed, with 2014 being the first year when more surveyed households owned refrigerators than did not. Average household PCE is higher among refrigerator-owning households than those households that do not own a refrigerator. However, PCE increases 84% among both categories of households over the study period of 2004-2014.

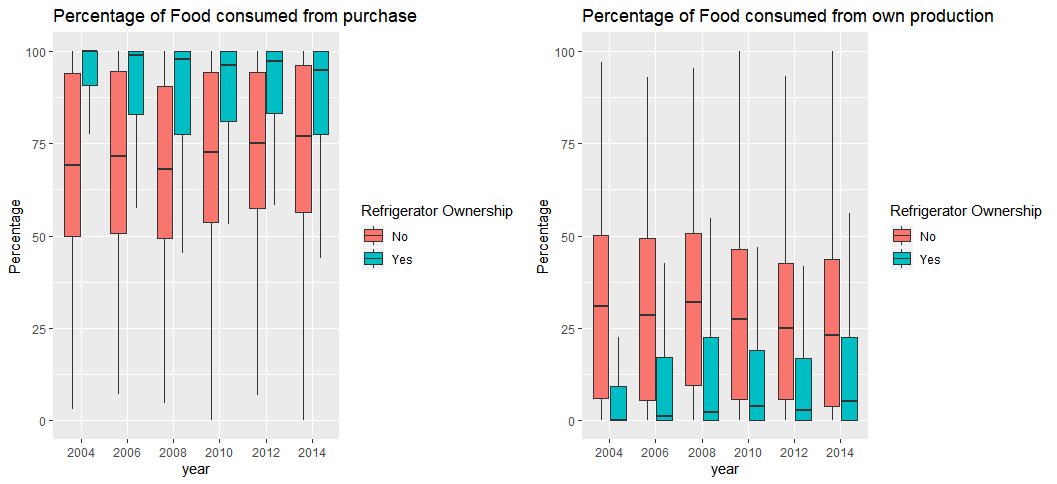
Refrigerator ownership over the study period by province is displayed in **Figure 4**. The largest growth (65-77%) in household refrigerator ownership between 2004-2014 is seen in the provinces surrounding Vietnam capital city, Hanoi, with moderate growth experienced elsewhere in the country.



**Figure 4:** Percentage of households reporting ownership of a refrigerator in the Vietnam Household Living Standards Survey. Data from the 2004 survey wave is displayed in the left-most map, 2014 data in the middle, and the percentage change between these survey waves on the right

Data on household refrigerator ownership in developing nations is sparse. However, for comparison, Vietnamese refrigerator ownership percentages in both 2010 and 2014 were lower than those recorded for China in both rural and urban regions (97% urban and 45% rural ownership in China compared with 60% and 28% for Vietnam in 2010; 92% urban and 78% rural Chinese ownership in 2014 compared with 80% and 51% for Vietnam) (National Bureau of Statistics of China, 2019). Additionally, using data from (USDA Economic Research Service, n.d.), Vietnamese household refrigerator ownership is recorded as larger than that for India in 2002, 2006, and 2008, and below that for Indonesia for 2002 and 2006, but exceeding Indonesian ownership rates in 2008.

Households which do not own a refrigerator consume a higher share food from their own production than households who do own a refrigerator, as illustrated in **Figure 5.**

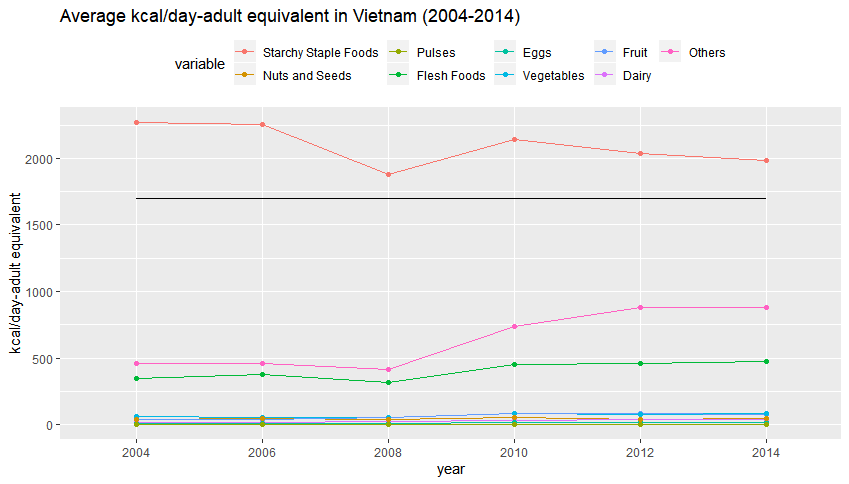


**Figure 5:** Boxplots of proportions of food consumed from a household’s own production (left) or purchased external to the home (right). Proportions are of the food when characterized into monetary values, and displayed for households with or without refrigerators.

This trend coincides with a similar division by income: the average household in the highest income quintile purchases 92% of their food over the years observed, compared with 58% for households in the lowest quintile. An average lowest quintile household produces 42% of their food consumed over the observed years, compared with 7% for an average household in the highest income quintile.

***4.2 Vietnamese Dietary Change from 2004 to 2014***

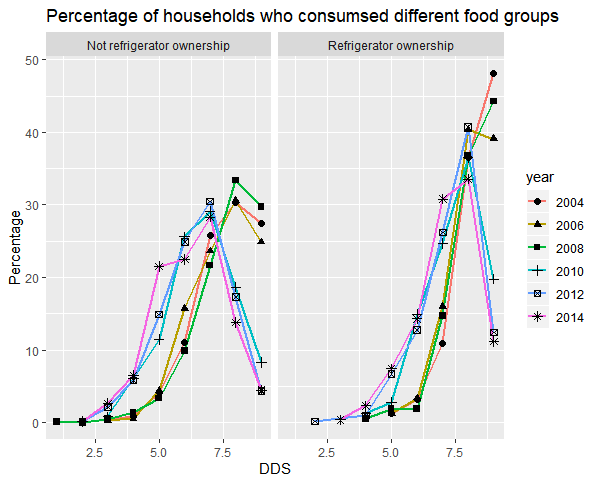
Changes in food consumption by Vietnamese households over the study period are displayed in **Figure 6.** Starchy staple food consumption decreases 16% over the time period observed, while flesh food consumption rises 38%. Calories from “other” sources rise 98% between 2004-2014, capturing changes in calories from non-major food sources including sugars, alcohol, lard, cooking oil, among others. These food groups have the largest average consumption in kcal, with averages for the other foods examined (nuts and seeds, pulses, eggs, vegetables, fruit, and dairy) remaining below 125 kcal/day over the observation period. Volumn average consumption by food groups and by year are in Table D-2 (Appendix D).



**Figure 6:** Average household kcal/day per adult equivalent of food types examined as measured by the VHLSS between 2004 and 2014. A black line is defined at 1700 kcal/Per Adult Equivalent to better-display the changes in consumption of Starchy Staple Foods in conjunction with other food categories. Results are obtained from two rotating panel in this period.

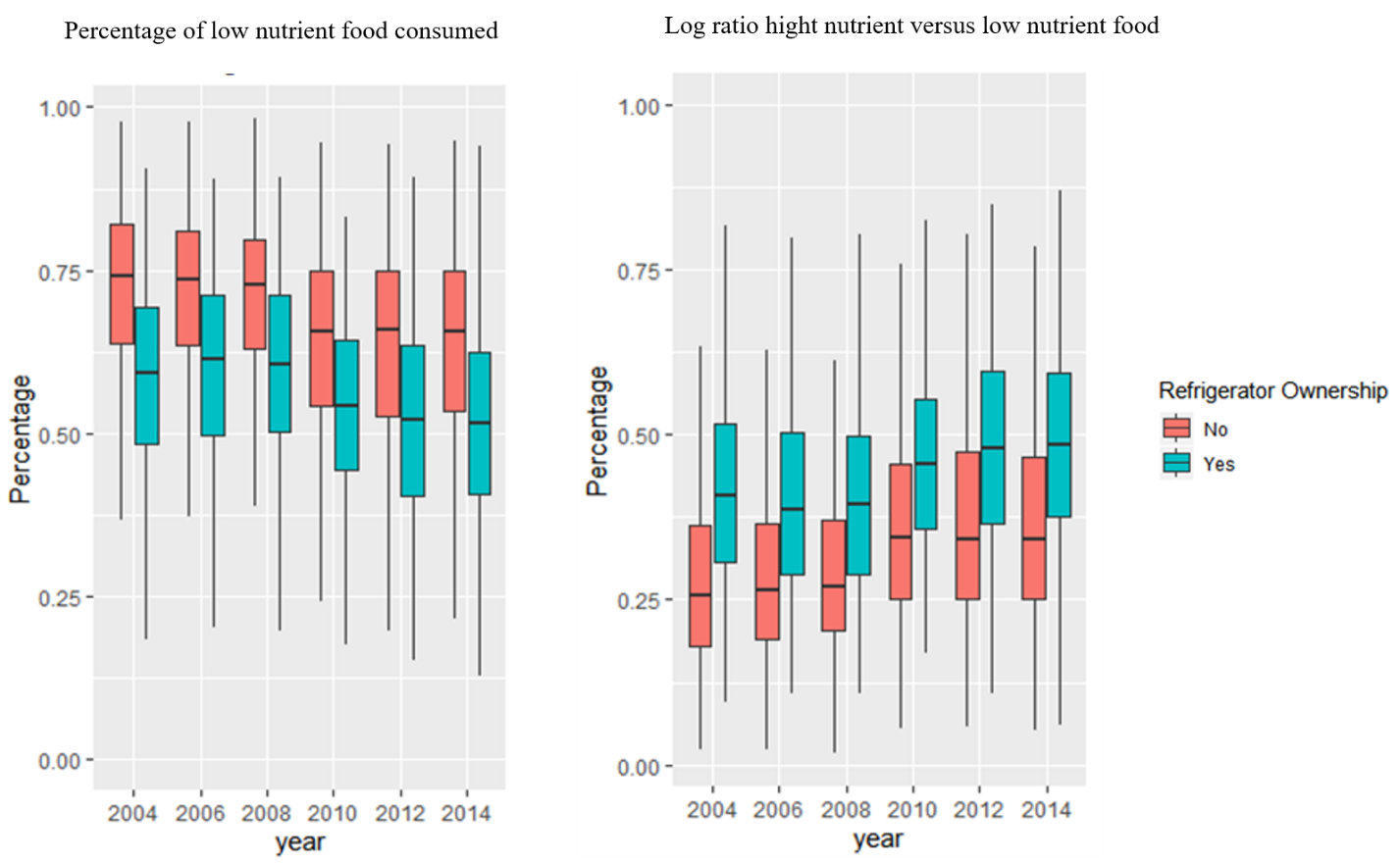
***4.3 The Influence of Household Refrigerator Ownership on Diet***

Dietary Diversity scores and its relationship to refrigerator ownership across time is presented in **Figure 7**. There is a higher proportion of food group consumed for refrigerator-owning households across all observation periods, as compared to households that do not own refrigerators, as can be seen in shifted lines in Figure 6 from left figure to right figure. In addition, among households owning refrigerator, there is a higher proportion of households consuming food from 5-to-8 groups groups in the period 2010-2014 than the period 2004-2008. However, there is an inverse trend for all households who consume up to 8 or 9 food groups. The difference may come from sample design[[4]](#footnote-5) and may include increases in the consumption of the “other” food group over the observation period, as well as the influence of VHLSS food categories remaining fixed over the years, despite new foods being increasingly introduced in Vietnam through import or general increases in availability.



**Figure 7**: Proportion of households consume different number of food group (Dietary Diversity Scores (DDS), out of a maximum of 9) by year and refrigerator ownership status in VHLSS data (2004-2014).

Percentage of consumption of low nutrient food items among households owning a refrigerator, has been consistently smaller across time, in comparison to those not owning a refrigerator (**Figure 8**; left panel). However, low nutrient food still predominant sources for households in Vietnam: 70-75% for households not owning a refrigerator and 50-55% for households owning a refrigerator. The log ratio of share of hight nutrient over share of low nutrient food consumed, i.e , shows an opposite effect, households owning a refrigerator showed a higher log ratio value than those that do not (**Figure 8**; right panel). Interestingly, the log ratio has gradually increased from 2004 to 2014, which shows the increaes of calories sourced high nutrient overtime and potententially substitutes caloried sourced high nutrient over calories source low nutrient. However, the blue boxplots (i.e corresponding households owning a refrigerator) stay below zero value for all years, except for 2014,



**Figure 8**: The left plot displays the percentage of food consumption from low nutrient food types (the starchy staple foods category), and the right plot displays the log ratio of share of hight nutrient over share of low nutrient food consumsed, sorted by refrigerator ownership status in VHLSS (2004-2014).

* 1. ***Effect of refrigerator ownership on diet***

The estimation strategy presented in section 2 is implemental using the two distinct panel data sets to assess the causal link between nutritional outcomes and refrigerator ownership.. Thus, Table 1 shows estimation results of fixed logit model using Mundlak (1976) correlated random error approach, focusing on instrumental variables (all estimated coefficients are displayed in Table E-1). Theinstrumental variable, namely households use national grid electricity for main lighting , showed a significantly positive relationship with household refrigerator ownership in both panels (p-value <0.05 in the panel 2004-2008 and p-value <0.0001 in the panel 2010-2014). In addition, the likelihood ratio test (LRT) confirms that the parameters associated to the three instruments cannot be assumed to be simultaneously equal to zero. Therefore, classical rank condition for instrumental varaibles is satisfied. Then, we conclude that the three instrument variables are the right choice for both panels 2004-2008 and 2010-2014.

**Table 1:** Estimation results of fixed effects logit model

|  |  |  |
| --- | --- | --- |
|  | Panel 2004-2006-2008 | Panel 2010 - 2012 - 2014 |
|  | Coef | Coef |
| Households use national grid electricity for main lighting | 1.67. (0.87) | 4.8 \*\*\*(1.31) |
| The likelihood ratio test (LRT) of the nullity of the coefficients associated with instrument | = 2x(-1208.4– (-1210.8)) = 4.8 with p-value < 0.0001 | = 2x(-1765.1 – (-1781.3)) = 32.4  with p-value < 0.0001 |

Note: ., \*,\*\*, and \*\*\*mean significant at 5%, and 1%, 0.1%, 0.01%, respectively. Robust standard errors are in parenthesis.

We then calculated the fitted probability of owning a refrigerator for household, denoted , and estimated the linear probability model expressing refrigerator ownership as a function of and a vector of control variables. The estimated coefficient associated to estimated probability on the panel 2004-2008 is 0.54 (0.05), with a p-value < 0.0001, and the estimated coefficient on the later panel is 0.8 (0.06), with a p-value < 0.0001 (full estimation results are displayed in TableE-2). The residuals of this linear probability model is denoted .

Finally, we estimated the augmented version of Eq. (1), i.e. Eq. (6), for the different nutrition outcomes, results of which are presented in Table 2 and Table 3. Table 2 shows the impact of refrigerator ownership on per capita calorie intake (PCCI on the ratio between high nutrientfood groups share and low nutrient food groups share, and diet diversity score (DDS). Table 3 shows the impact of owning refrigerator and other socio-economics on per capita calorie intake provided by different food groups. As shown in the estimation strategy section, there is a potential endogeneity of refrigerator ownership on nutrition outcomes and this issue is taken into account when inclusion of the residuals of the liner probability model, i.e coefficients. The coefficient of are significant in most of regressions in Table 2 and Table 3, then ,the estimated values of the effect of refrigerator ownership on nutrition outcome do not suffer from any bias sue to endogeneity of refrigerator owning.

If a household owns a refrigerator, per capita calorie intake decreases significantly by 1051.65Kcal per day per adult-equivalent in the first panel while only by 386.93 Kcal in the second panel. For the log ratio of shares, the coefficient is negative and significantly different from zero in 2004-2008 period. Therefore, owning a refrigerator implies a decrease of the ratio high nutrients by 82% over low nutrients in the first panel. This would indicate that a household owning a refrigerator has substituted food groups with low nutrient intake (increase in the denominator) to food groups with high nutrient intake (decrease in numerator). There is no effect of owning refrigerator in the second panel. Finally, there is a positive effect of owning refrigerator on diet diversity score in the first panel while owning refrigerator leads to decrease slightly in diet diversity score from 2010 to 2014. On combing all three indicators, household owning a refrigerator before 2010 has decreased dramatically total per capita calorie intake focusing on food groups with high nutrient intake while, in the next period, household has decreased per capita calorie intake, also decreasing slightly at the same time diversity in their food consumption.

We then go on to further disaggregate calorie from difference food group (see Table 3). Refrigerator ownership leads to a significant decrease of Kcal obtained from starchy staple food by 648.04 Kcal in the 1st panel, and by 127.42 Kcal in the second panel. The decrease in per capita calorie intake, shown in Table 2, mainly comes from the decrease in starchy staple food – a low nutrient source of calories. The analysis also revealed a decrease in nuts and seeds and vegetables, attributable to owning a refrigerator in both periods. Interestingly, a household owning a refrigerator has increase their calorie sourced dairy (by 23 Kcal) and sourced flesh foods (by 151 Kcal) in the 2004-2008 period. In the later panel, owning a refrigerator also leads to increase kcal sourced dairy (by 36 Kcal) and eggs (by 3 Kcal) but not flesh foods.

**Table 2:** Second step estimation results for PCCI, log(high nutrient/low nutrient) and DDS

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Per capita calorie intake | | log(highnutrient/lownutrient) | | DDS | |
|  |  | Panel 2004-2008 | Panel 2010 - 2014 | Panel 2004-2008 | Panel 2010-2014 | Panel 2004-2008 | Panel 2010-2014 |
|  | **(Intercept)** | 2565.07 \*\*\* | 2813.27 \*\*\* | -2.47 \*\*\* | -1.9 \*\*\* | 1.97 \*\*\* | 1.74 \*\*\* |
|  | **Owning Refrigerator** | -1051.65 \*\*\* | -386.93 \* | -0.82 \*\*\* | -0.08 | 1.18 \*\*\* | -0.31 \* |
|  | **The residuals of the linear probability model,** | 827.61 \*\*\* | 332.58 . | 0.86 \*\*\* | 0.13 | -1.35 \*\*\* | 0.24 . |
|  | Per capita expenditure (2014 thousand VND) | 0.02 \*\*\* | 0.03 \*\*\* | 0 \*\*\* | 0 \*\*\* | 0 \*\*\* | 0 \*\*\* |
|  | **Proportion of food consumed from purchases** | -90.84 | -75.89 | 1.41 \*\*\* | 0.92 \*\*\* | -0.37 \* | -0.03 |
|  | **Proportion of children under 15** | 316.62 \* | 469.43 \* | -0.25 \* | -0.11 | -0.17 | -0.45 \*\*\* |
|  | **Household in urban site** | 149.29 \*\*\* | 188.76 \*\*\* | 0.19 \*\*\* | 0.08 \*\*\* | -0.15 \*\* | -0.11 \*\*\* |
|  | **Clean water for cooking indicator** | -22.55 | -50.01 | -0.02 | 0.12 \*\*\* | -0.07 \*\* | 0.01 |
| **Household size (ref: less than 3 members)** | **three members** | 339.37 \*\*\* | 330.81 \*\*\* | 0 | -0.08 \* | -0.27 \*\*\* | -0.06 |
| **four members** | 443.7 \*\*\* | 422.34 \*\*\* | 0.01 | -0.08 \* | -0.48 \*\*\* | -0.13 \*\* |
| **five members** | 439.86 \*\*\* | 413.74 \*\*\* | 0.02 | -0.12 \*\* | -0.6 \*\*\* | -0.22 \*\*\* |
| **more than five members** | 364.49 \*\*\* | 351.52 \*\*\* | -0.03 | -0.17 \*\*\* | -0.71 \*\*\* | -0.24 \*\*\* |
|  | **Kinh (majority)** | -72.06 \* | 43.86 | 0.18 \*\*\* | 0.12 \*\*\* | -0.31 \*\*\* | -0.22 \*\*\* |
|  | **Female** | -11.02 | -6.58 | 0.08 \*\*\* | 0.09 \*\*\* | -0.07 \* | -0.06 \* |
| **Education levels (ref: below primary)** | **Secondary/High school** | 26.69 | 40.22 | 0.07 \*\*\* | 0.03 | -0.13 \*\*\* | -0.01 |
| **University** | -127.47 | 44.61 | 0.04 | 0.01 | -0.39 \*\* | 0.02 |

Note: ., \*,\*\*, and \*\*\*mean significant at 5%, and 1%, 0.1%, 0.01%, respectively. Standard errors are in parenthesis. These results control for time average of all continuous variables

**Table 3:** Second step estimation results for each food groups

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Panel 2004-2008** | | | | | | | |
|  |  | Starchy Staple Foods | Dairy | Eggs | Flesh foods | Fruit | Nuts and Seeds | Pulses | Vegetables |
|  | **(Intercept)** | 2502.07 \*\*\* | -6.13 | 1.07 | -8.55 | 4.52 | 38.89 \*\*\* | 0.44 | 37.3 \*\*\* |
|  | **Owning Refrigerator** | -648.04 \*\*\* | 42.66 \*\*\* | -7.13 \* | -335.02 \*\*\* | -53.5 \*\*\* | -71.28 \*\*\* | -3.07 \* | -51.95 \*\*\* |
|  | **The residuals of the linear probability model**, | 479.59 \*\* | -32.41 \* | 7.3 \*\* | 313.06 \*\*\* | 55.21 \*\*\* | 70.2 \*\*\* | 3.47 \* | 48.8 \*\*\* |
|  | Per capita expenditure (2014 thousand VND) | 0 | 0 \* | 0 \*\*\* | 0.01 \*\*\* | 0 \*\*\* | 0 \*\*\* | 0 \*\* | 0 \*\*\* |
|  | **Proportion of food consumed from purchases** | -848.26 \*\*\* | -3.67 | 3.83 \* | 217.15 \*\*\* | -10.61 | 11.7 | 0.45 | 13.1 . |
|  | **Proportion of children under 15** | 329.01 \*\* | 28.75 \*\*\* | 2.5 | 94.54 \*\* | -22.88 \* | 4.21 | 1.67 . | 16.88 \* |
|  | **Household in urban site** | -5.07 | -1.24 | 1.52 \*\* | 40.62 \*\*\* | 1.12 | 7.25 \* | 0.33 | 5.24 \* |
|  | **Clean water for cooking indicator** | 8.73 | 0.65 | -0.09 | -11.55 \* | 4.09 \* | -3.97 \* | -0.11 | 2.79 \* |
| **Household size (ref: less than 3 members)** | **three members** | 248.34 \*\*\* | -2.47 | -0.04 | 41.9 \*\*\* | -6.01 . | 0.68 | 0.97 \*\* | 0.84 |
| **four members** | 332.5 \*\*\* | -4.94 . | -0.15 | 57.64 \*\*\* | -8.38 \*\* | 5.13 | 0.7 \* | -1.64 |
| **five members** | 349.77 \*\*\* | -5.88 . | -0.86 | 49.55 \*\*\* | -9.49 \*\* | 5.29 | 0.75 \* | -5.88 . |
| **more than five members** | 328.88 \*\*\* | -5.97 | -1.57 . | 40.11 \*\* | -10 \* | 1.57 | 0.83 \* | -13.41 \*\*\* |
|  | **Kinh (majority)** | -138.23 \*\*\* | 0.47 | -0.43 | -19.02 \* | -0.62 | 3 | -0.26 | -3.35 |
|  | **Female** | -40.92 . | 3.8 \* | -0.03 | 0.87 | 0.12 | 5 \* | 0.04 | 2.07 |
| **Education levels (ref: below primary)** | **Secondary/High school** | 0.84 | -2.85 . | 1.57 \*\*\* | 21.91 \*\*\* | -0.28 | 16.66 \*\*\* | -0.03 | 5.16 \*\*\* |
| **University** | -29.47 | -1.54 | -0.74 | 6.31 | -4.41 | 13.81 \* | 0.08 | 3.89 |
|  | **Adj. R-Squared** | 0.26 | 0.11 | 0.08 | 0.22 | 0.08 | 0.08 | 0.01 | 0.06 |
|  |  | **Panel 2010-2014** | | | | | | | |
|  |  | Starchy Staple Foods | Dairy | Eggs | Flesh foods | Fruit | Nuts and Seeds | Pulses | Vegetables |
|  | **(Intercept)** | 2744.18 \*\*\* | -30.76 \*\*\* | 12.59 \*\*\* | 221.03 \*\*\* | 20.13 . | 62.55 \*\*\* | 1.68 \* | 98.02 \*\*\* |
|  | **Owning Refrigerator** | -127.42 | 36.77 \*\*\* | -0.32 | -17.81 | -7.92 | -11.8 | 1.49 | -0.61 |
|  |  | 53.07 | -33.74 \*\* | 0.44 | 50.08 | 5.77 | 12.91 | -1.37 | -1.94 |
|  | Per capita expenditure (2014 thousand VND) | 0 \*\*\* | 0 \*\*\* | 0 \*\*\* | 0.01 \*\*\* | 0 | 0 \*\*\* | 0 \*\*\* | 0 |
|  | **Proportion of food consumed from purchases** | -804.5 \*\*\* | 12.69 | -2.65 | 64.96 \* | 7.37 | -0.51 | -1.04 | -4.31 |
|  | **Proportion of children under 15** | 404.09 \*\*\* | 94.21 \*\*\* | 9.83 \*\*\* | 88.52 \* | 23.2 | -3.51 | 2.71 \* | 14.73 |
|  | **Household in urban site** | -129.44 \*\*\* | -1.47 | -0.25 | 1.99 | 1.78 | -1.11 | 0.31 | -3.92 . |
|  | **Clean water for cooking indicator** | 282.64 \*\*\* | -0.11 | -0.67 | 16.58 | -19.61 \*\*\* | -2.05 | -0.24 | -15.95 \*\*\* |
| **Household size (ref: less than 3 members)** | **three members** | 332.8 \*\*\* | -4.26 | -2.48 \*\* | 7.72 | -25.14 \*\*\* | 3.34 | 0.08 | -28.06 \*\*\* |
| **four members** | 359.51 \*\*\* | -0.32 | -3.92 \*\*\* | -10.43 | -31.8 \*\*\* | 2.53 | -0.25 | -36.33 \*\*\* |
| **five members** | 362.91 \*\*\* | 1.98 | -5.12 \*\*\* | -19.32 | -32.9 \*\*\* | -0.64 | -0.23 | -47.58 \*\*\* |
| **more than five members** | -39.87 | 3.7 | 1.84 \*\* | -6.27 | 9.55 \* | -0.08 | -0.68 \* | 5.43 . |
|  | **Kinh (majority)** | -66.89 \*\* | 11.02 \*\*\* | 1.52 \*\* | -2.16 | 7.89 \* | 5.21 \* | -0.41 | 1.06 |
|  | **Female** | -0.37 | -7.67 \*\* | 2.66 \*\*\* | 24.39 \*\* | -9.59 \* | 17.7 \*\*\* | 0.14 | 3.99 |
| **Education levels (ref: below primary)** | **Secondary/High school** | -27.73 | -1.58 | 1.62 | 22.52 | -9.68 | 16.14 \*\*\* | -0.09 | 1.29 |
| **University** | 0.24 | 0.13 | 0.08 | 0.24 | 0.09 | 0.06 | 0.01 | 0.07 |
|  | **Adj. R-Squared** | 2744.18 \*\*\* | -30.76 \*\*\* | 12.59 \*\*\* | 221.03 \*\*\* | 20.13 . | 62.55 \*\*\* | 1.68 \* | 98.02 \*\*\* |

1. **Concluding remarks**

At a basic level, the purpose of a refrigerator is to increase the capacity to store perishable foods. Household refrigerator ownership significantly decreases per capita calorie decreases by 744 Kcal per day per adult-equivalent in the first VHLSS panel, and by 250 Kcal in the second panel, at a statistically suggestive level. Refrigerator ownership is implied to have resulted in the household substituting low-nutrient food items with higher-nutrient ones, but only significantly in the 2004-2008 period. This study finds that when controlling for socio-economic variables, refrigerator ownership causes statistically significantly decreases in the consumption starchy staple foods, nuts and seeds from 2004 to 2014 and the consumption of flesh foods and vegetables in 2004-2008 period. Importantly, household owning refrigerator increased significantly calorie sourced dairy product, by 23 Kcal/day/person during 2004-2008 period and by 36 Kcal/day/person during 2010-2014. These results have limitation to capture the potential substitution among food groups, while keeping constant per capita calorie intake since households very typically consume food from more than one food group. These limitation can be addressed by recent composition data analysis (CoDa) in the literature (see Mert et al. (2018), Trinh et al. (2019) and Solans et al. (2019)).

Refrigerator ownership in Vietnam increases over the time period studied, as does mean per capita expenditure and other developmental indicators. Wealth is connected to both the ability to own a refrigerator and with dietary shifts, and a refrigerator is a technological pre-condition to support diets which have higher quantities of perishable foods. While the casual linkages between refrigerator ownership and diet shifts have been identified when controlling for income, refrigerator ownership is unlikely to occur wholly independently of wealth increases. As such, refrigerator ownership influences diet, but is concurrently a necessary enabler for the influence of wealth.

Refrigerator ownership and income growth are occurring within the context of grocery retail development in Vietnam. The growth in supermarket retailing in Asia has been associated with refrigerator ownership in addition to income growth, urbanization, and other elements of development (Shepherd, 2005). Retail development typically results in more centralized food provision, realized in its fullest form as groceries of all types sold in a supermarket or hypermarket. This process of “de-fragmentation” in retail is characterized as occurring first for dry goods, then later for fresher foods (Reardon et al., 2003). Vietnamese retail sales through “modern” grocery retailers grew by 11% in 2017, though the quantity of these stores are still vastly outnumbered by traditional retailers (Vo and Francic, 2017) and with 77%–99% of food expenditures by urban consumers still occurring at traditional outlets (The Centre for Global Food and Resources, 2018a). Supermarket shopping in Vietnam is stratified by income, with lower-income consumers found to be purchasing less from supermarkets, and more from a diversity of outlets (both formal and informal), considering factors including accessibility, the ability to purchase on credit, and prices (Figuié and Moustier, 2009). Supermarket purchasing has been found to be highly income-elastic, with income playing a stronger role in influencing fruit and vegetables purchases at a supermarket than price or supermarket penetration in Vietnam (Mergenthaler et al., 2009). Findings from this study showing smaller and often non-significant changes in fruit and vegetable consumption suggest a continuation of purchasing produce from more-traditional, local vendors. Lower prices, the proximity of these venues, as well as traditional shopping habits have been noted as maintaining this practice (Maruyama and Trung, 2007).

In health outcomes, a trend towards higher body mass index values for children connected with increased household food expenditures at supermarkets may be emerging (The Centre for Global Food and Resources, 2018b), which in the context of Vietnam may lead to a situation where parts of the population are overweight, with other portions of the population undernourished (Khan and Ha, 2008).

Meat accounts for the largest share of monthly food expenditures among Vietnamese households, with pork accounting for an average of 32% to 40% of meat expenditures (The Centre for Global Food and Resources, 2018c). Vietnam has also experienced a growth in beef consumption in recent years. While still 5.2 times smaller than pork supply, there has been an almost 180% increase in beef supply between 2001-2011, making beef the largest greenhouse gas emissions-contributor in the Vietnamese meat supply (Heller et al., 2019). This increase in beef consumption has been characterized as part of the “meatification” of the Vietnamese food system (Hansen, 2018): encompassing the intensification of production systems, addition of more meat to traditional meals, changes in consumption patterns for food, as well as the role of meat as a socio-economic status symbol.

The availability of refrigerators has implications for nutrition and sustainability outcomes. Concurrent and pressing challenges from malnutrition and health burdens, climate change and environmental pressures, in addition to socio-economic and cultural inequities motivate a broader consideration of diet in the context of sustainability. The interdependencies between these considerations motivate the concept of a sustainable diet (Johnston et al., 2014). Analyses of these interconnected relationships in Vietnam is an essential task for future research. Integrated metrics assessing these dimensions of dietary transitions provides an opportunity to assess the multi-faceted elements of sustainable diets (Jones et al., 2016).

There are particular research gaps related to refrigeration’s effects on nutrition and food system development (Heard and Miller, 2016a). Topics explored in this analysis but still in need of further study include both the influence of refrigeration and wealth in isolation, the extent to which they present effects which can be casually-identified, as well as their interactions and interdependencies. Additionally, the cultural practices of food storage, and whether certain foods such as eggs, fruits, and vegetables are stores in refrigerators in some food contexts will influence the role that household refrigerator ownership has in determining dietary outcomes. Research addressing the relationship between refrigeration and infrastructure such as the electricity grid and transportation networks is also needed. Finally, culture and tradition must not be overlooked when assessing diet shifts, development, and the use of technology. This study finds that the practice of shopping for fruits and vegetables on a regular basis from informal vendors (Maruyama and Trung, 2007; The Centre for Global Food and Resources, 2018a) may explain the lack of a statistically significant casual linkages between refrigeration and fruits and vegetables. This study’s findings provide some insights into refrigerator ownership’s connection with diet, but this topic remains in need of continuing research.

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**Appendix A. A rotating panel data from VHLSS**

This study relies on Vietnam Household Living Standard Surveys or VHLSS. The VHLSS master sample design has a-two-stage from enumeration areas (EAs) of the 1999 Population and Housing Census of Vietnam (VHLSS before 2010) and the 2009 Population and Housing Census of Vietnam (VHLSS since 2010). Province and urban-rural site are strata. Primary sample unit (PSU) are communes, including around 3,000 selected communes/words from the Population and Housing Census. The secondary sampling unit is EAs. Three EAs were selected per commune and then only one of EA was used for each year of the VHLSS survey. VHLSS includes two different sample sizes: (1) sample for income survey and (2) sample for the income-expenditure survey. This study is based on the sample for income-expenditure survey, including more than 9,000 households, to collect information for further assessment and analysis of living standards at the national, regional and provincial levels. There are two steps:

**Step 1: Select EAs**

The VHLSS can be viewed as a rotating panel with 50% rotation of households. For example, EAs of the VHLSS 2008 will be re-selected 50% EAs of the VHLSS 2006 (in which half of EAs were surveyed in the 2004 and another half of the EAs were only surveyed in 2006) and the other 50% EAs will be newly selected from the master sample – which was not selected in the 2006 and 2004. The above design leads to make use of a panel data from a sub-sample of VHLSS and up to three waves. There is a questionnaire of VHLSS 2008, such as “Did this household participate in the VHLSS 2006” and there is a questionnaire about identification code for both household and individual members in the VHLSS 2006. Figure XX shows the selection method of EAs. Using VHLSS from 2004 to 2014, this study includes two panels: a panel using VHLSS 2004-2006-2008 and a panel using VHLSS 2010-2012-2014. The choice of years in each panel is in line with the corresponding master sampling from the Population and Housing Census of each panel.

VHLSS 2008

EAs were only in 2006

New

VHLSS 2006

EAs were in 2004

New

EAs were in 2004 and will be selected in 2008

EAs were in both 2006 and 2004

VHLSS 2004

EAs will be selected in 2006 and 2008

**Figure A-1:** Selection method of EAs

**Step 2: Select households**

Households will be selected differently based on EAs type. Assume we are in VHLSS 2008, for EA which is re-selected from the 2006 VHLSS, 15 households will be selected in which three households were already surveyed with the income-expenditure survey for 2006 VHLSS. For the new EA, 20 households will be selected in which 5 households (3 official and 2 spare households) for the income-expenditure survey. This similar selection method will be applied for all years of the VHLSS.

There is also a commune questionnaire survey applied for all rural communes which have selected EAs for the household survey interview.

**Appendix B: Calculating nutritional outcome**

Total food acquired by households is converted from expenditure values into grams with a food composition tablefrom the (National Institute of Nutrition, 2013). Between 2004-2008 the dietary recall period is the last 12 months, and between 2010-2014 the recall period is the last 30 days. Cereals and roots and tubers have been aggregated into a single category as “starchy staple foods,” the categories for vitamin A-rich dark green leafy vegetables and “other vegetables” have been aggregated into a single vegetable (Food and Agriculture Organization of the United Nations, 2016; World Health Organization, 2008). kcal per adult equivalent per day in the household is then computed for all observations. kcal values per food type are displayed in **Table B-1** as follows:

**Table B-1: Conversion table and food groups**

| **Groups** | **Food items** | **Calories per 100 grams** | **Groups** | **Food items** | **Calories per 100 grams** |
| --- | --- | --- | --- | --- | --- |
| ***Starchy Staple Foods*** | Plain rice | 344.5 | ***Flesh Foods*** | Pork | 260 |
| Sticky rice | 347 | Beef | 142.5 |
| Maize | 354 | Buffalo meat | 122 |
| Cassava | 146 | Chicken meat | 199 |
| Potato of various kinds | 106 | Duck and other poultry meat | 275 |
| Wheat grains, bread, wheat powder | 314 | Other types of meat | - |
| Floor noodle, instant rice noodle, porridge | 349 | Processed meat | - |
| Fresh rice noodle, dried rice noodle | 143 | Fresh shrimp, fish | 83 |
| Vermicelli | 110 | Dried and processed shrimps, fish | 361 |
| Nuts and seeds | Peanuts, sesame | 570.5 | Other aquatic products and seafoods | - |
| ***Pulses*** | Beans of various kinds | 73 | Fish sauce | 60 |
| Tofu | 95 | Fruit | Orange | 37 |
| Vegetable | Fresh peas of various kinds | 59 | Banana | 81.5 |
| Morning glory vegetables | 25 | Mango | 69 |
| Kohlrabi | 36 | Other fruits | - |
| Cabbage | 29 | Dairy | Condensed milk, milk powder | 396 |
| Tomato | 20 | Ice cream, yogurth | - |
| Other vegetables | - | Fresh milk | 61 |
| ***Eggs*** | Eggs of chicken, ducks, geese | 104 | Others | Sugars, molasses | 390 |
| Others | Lard, cooking oil | 827 | Confectionery | 412 |
| Lard | 827 | Alcohool of various kinds | 47 |
| Cooking oil | 900 | Beer of various kinds | 11 |
| Outdoor meals and drinks | - | Bottled, canned, boxed beverages | 47 |
| Other foods and drinks | - | Coffee powder | 353 |
| Notes: (1) Unit = kcal per 100 g. (2) Source:(National Institute of Nutrition, 2013).  (2) Food categories without calories are approximated from price of one calorie of all food items (Fao and World Bank, 2018) | | | | | |

**Appendix C: Vietnamese Household Electricitation**

 The number of households with electricity for lighting (how electricity is inquired about in the VHLSS questionnaire) is consistently high throughout our study period: with 93.4% of households reporting electricity at the household in 2004 and 98.3% reporting so in 2014. In general, household electrification statistics are high for most household groups between 2004-2014, with 91.6% of rural households 84.8% of lowest-income quintiles reporting electricity in 2004, growing to 97.6% and 93.6% respectively in 2014.

Table C-1: The share of households using electricity for lighting and Infrastructure (having electricity) of communes by region, Programme No 135 (i.e Socio-economic Development of the Most Vulnerable Communes in Ethnic Minority and Mountainous Areas in Vietnam).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year of VHLSS | National (households) | Rural areas  (households) | The poorest  Quintiles  (households) | Infrastructure (having electricity) of communes by region, Programme No 135 and main ethnic group | Sources |
| 2014 | 98.3% | 97.6% | 93.6% | 99.4% | GSO (2016) |
| 2012 | 97.6% | 96.6% | 92.1% | 99.1% | GSO (2014) |
| 2010 | 97.2% | 96.2% | 91.6% | 98.9% | GSO (2014) |
| 2008 | 97.6% | 96.8% | 93% | 99.1% | GSO (2014) |
| 2006 | 96% | 94.9% | 90.7% | 99.0% | GSO (2014) |
| 2004 | 93.4% | 91.6% | 84.8% | 98.1% | GSO (2014) |

**Appendix D: Vietnam Household Living Standards Survey (VHLSS) Data Summary**

All data in **Table D-1** is number of observations except those for Per Capita Expenditure, which indicates means and (in parenthesis) standard deviations.

**Table D-1: VHLSS Summary Statistics (2004-2014)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 |
| Observations |  | 1389 | 1389 | 1389 | 1369 | 1369 | 1369 |
| Per capita expenditure (2014 thousand VND) |  | 6868 (4200 ) | 7555 (4286) | 8940 (5058 ) | 11436 (6323) | 12231 (6789 ) | 12617 (6874 ) |
| Proportion of food consumed from purchases |  | 0.7 ( 0.3 ) | 0.7 ( 0.2 ) | 0.7 ( 0.2 ) | 0.8 ( 0.2 ) | 0.8 ( 0.2 ) | 0.8 ( 0.2 ) |
| Proportion of children under 15 |  | 0.3 ( 0.2 ) | 0.2 ( 0.2 ) | 0.2 ( 0.2 ) | 0.2 ( 0.2 ) | 0.2 ( 0.2 ) | 0.2 ( 0.2 ) |
| Number of air conditions |  | 0 ( 0.1 ) | 0 ( 0.1 ) | 0 ( 0.1 ) | 0 ( 0.2 ) | 0.1 ( 0.3 ) | 0.1 ( 0.3 ) |
| Number of electric fans |  | 1.4 ( 1.2 ) | 1.6 ( 1.3 ) | 1.7 ( 1.2 ) | 1.3 ( 1.2 ) | 1.7 ( 1.3 ) | 1.8 ( 1.3 ) |
| Number of washing machine |  | 0 ( 0.2 ) | 0.1 ( 0.2 ) | 0.1 ( 0.3 ) | 0.1 ( 0.3 ) | 0.2 ( 0.4 ) | 0.2 ( 0.4 ) |
| Number of motos |  | 0.5 ( 0.7 ) | 0.7 ( 0.7 ) | 0.8 ( 0.8 ) | 1 ( 0.8 ) | 1.2 ( 0.8 ) | 1.3 ( 0.9 ) |
| Households use national grid electricity for main lighting | Yes | 93.1 | 96.5 | 98.3 | 95.8 | 96.6 | 97.7 |
| Refrigerator ownership (%) | No | 88.8 | 82.9 | 73.1 | 64.2 | 55.4 | 43.8 |
| Yes | 11.2 | 17.1 | 26.9 | 35.8 | 44.6 | 56.2 |
| Household location (%) | Rural | 81.4 | 80.5 | 79.7 | 75.3 | 74.9 | 74.4 |
| Urban | 18.6 | 19.5 | 20.3 | 24.7 | 25.1 | 25.6 |
| Household size (%) | ≥2 | 8.9 | 10.2 | 12.9 | 13.3 | 15 | 16.9 |
| 3 | 14.8 | 15 | 18.1 | 17 | 17.7 | 19.6 |
| 4 | 32.5 | 32 | 31 | 35.3 | 32.5 | 30.4 |
| 5 | 22.6 | 22 | 19.4 | 19.2 | 19.4 | 17.7 |
| 6 | 21.3 | 20.7 | 18.6 | 15.2 | 15.3 | 15.4 |
| Ethnic of the head of hosueholds (%) | Minorities | 15.6 | 15.4 | 15.3 | 19.9 | 19.9 | 19.6 |
| Kinh | 84.4 | 84.6 | 84.7 | 80.1 | 80.1 | 80.4 |
| Gender of the head of household (%) | Male | 75.8 | 75.2 | 74.9 | 79.7 | 78.6 | 78.2 |
| Female | 24.2 | 24.8 | 25.1 | 20.3 | 21.4 | 21.8 |
| Education levels of the head of households (%) | Below primary | 53.9 | 51.6 | 50.7 | 51.1 | 50.7 | 50.2 |
| Secondary/High school | 43.6 | 45.4 | 45.9 | 44.6 | 45 | 45.3 |
| University | 2.6 | 3 | 3.5 | 4.3 | 4.3 | 4.5 |
| Area of country (%) | Red River Delta | 20.4 | 20.4 | 20.4 | 22.8 | 22.8 | 22.8 |
| Midlands Northern Mountains | 19.8 | 19.8 | 19.8 | 21 | 21 | 21 |
| Northern Central Coast | 22.5 | 22.5 | 22.5 | 21.7 | 21.7 | 21.7 |
| Central Highlands | 6 | 6 | 6 | 6.5 | 6.5 | 6.5 |
| South East | 11.2 | 11.2 | 11.2 | 8.8 | 8.8 | 8.8 |
| Mekong River Delta | 20.2 | 20.2 | 20.2 | 19.3 | 19.3 | 19.3 |
| Clean water for cooking indicator (%) | No | 30.8 | 38.9 | 34.3 | 40.2 | 36.9 | 33.7 |
| Yes | 69.2 | 61.1 | 65.7 | 59.8 | 63.1 | 66.3 |

**Table D-2: Average Consumption of Food Types by Year (2004-2014).** All values are in kcal/day/adult-equivalent.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Average Per-Capita kcal Consumption** | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 |
| Starchy Staple Foods | 2261.8 | 2205.03 | 1875.8 | 2042.04 | 1964.2 | 1903 |
| Nuts and Seeds | 42.09 | 42.52 | 36.38 | 46.19 | 36.76 | 40.8 |
| Pulses | 2.13 | 2.02 | 1.78 | 2.19 | 1.46 | 1.57 |
| Flesh Foods | 349 | 381.11 | 323.13 | 443.81 | 449.95 | 482.2 |
| Eggs | 8.61 | 8.81 | 9.18 | 18.82 | 13.37 | 14.73 |
| Vegetables | 87.37 | 87.33 | 84.20 | 120.8 | 112.14 | 112.3 |
| Fruit | 19.70 | 20.24 | 27.67 | 59.86 | 50.32 | 56.3 |
| Dairy | 17.91 | 21.10 | 23.14 | 38.17 | 37.24 | 42.6 |
| Other | 506.3 | 507.8 | 439.28 | 850.43 | 939.7 | 1003.5 |
| Total Calories | 3294.9 | 3275.9 | 2820.5 | 3622.3 | 3605.1 | 3657 |

**Appendix E: Full results from IV regression.**

**Table E-1:** Estimation of fixed effects logit model using CRE approach of Mundlak (1976)

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Panel 2004-2006-2008 | Panel 2010 - 2012 - 2014 |
|  |  | Coef | Coef |
|  | (Intercept) | -14.04 \*\*\*(1.17) | -14.43 \*\*\*(1.44) |
|  | Households use national grid electricity for main lighting | 1.67 .(0.87) | 4.8 \*\*\*(1.31) |
|  | Per capita expenditure (2014 thousand VND) | 0 \*\*\*(0) | 0 \*\*\*(0) |
|  | Proportion of food consumed from purchases | 2.36 \*\*(0.84) | 1.16 \*(0.56) |
|  | Proportion of children under 15 | -2.4 \*\*(0.77) | -0.84 (0.66) |
|  | Household in urban site | 0.67 \*\*(0.25) | 0.69 \*\*(0.22) |
|  | Clean water for cooking indicator | 0 (0.17) | 0.52 \*\*(0.17) |
| Household size (ref: less than 3 members) | three members | 0.59 .(0.34) | 0.69 \*\*(0.25) |
| four members | 1 \*\*(0.32) | 1.1 \*\*\*(0.25) |
| five members | 1.68 \*\*\*(0.35) | 1.75 \*\*\*(0.27) |
| more than five members | 2.13 \*\*\*(0.36) | 2.18 \*\*\*(0.3) |
|  | Kinh (majority) | 0.95 \*(0.41) | 0.22 (0.27) |
|  | Female | 0.3 (0.21) | -0.16 (0.21) |
| Education levels (ref: below primary) | Secondary/High school | 0.58 \*\*(0.19) | 1.03 \*\*\*(0.16) |
| University | 1.52 \*\*(0.48) | 1.39 \*\*(0.46) |
|  | sigma | 2.93 \*\*\*(0.22) | 3.19 \*\*\*(0.19) |

Note: ., \*,\*\*, and \*\*\*mean significant at 5%, and 1%, 0.1%, 0.01%, respectively. Standard errors are in parenthes. These results control for time average of all continuous variables.

**Table E-2:** A table presenting the result of the regression of refrigerator owning on estimated probability of owning a refrigerator (first stage of second step of estimation strategy

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Panel 2004-2006-2008 | Panel 2010 - 2012 - 2014 |
|  | (Intercept) | 0.77 \*\*\*(0.03) | 1.02 \*\*\*(0.05) |
|  | **Estimated probability of owning a refrigerator,** | **0.54 \*\*\*(0.05)** | **0.8 \*\*\*(0.06)** |
|  | Per capita expenditure (2014 thousand VND) | 0 \*\*(0) | 0 (0) |
|  | Proportion of food consumed from purchases | 0.07 (0.06) | 0.02 (0.07) |
|  | Proportion of children under 15 | -0.08 (0.06) | -0.03 (0.08) |
|  | Household in urban site | 0.03 .(0.02) | -0.02 (0.02) |
|  | Clean water for cooking indicator | 0 (0.01) | 0.05 \*\*(0.01) |
| Household size (ref: less than 3 members) | three members | 0.04 .(0.02) | 0.01 (0.02) |
| four members | 0.07 \*\*\*(0.02) | 0.04 (0.02) |
| five members | 0.09 \*\*\*(0.02) | 0.05 \*(0.03) |
| more than five members | 0.12 \*\*\*(0.02) | 0.04 (0.03) |
|  | Kinh (majority) | 0.01 (0.02) | 0.03 (0.02) |
|  | Female | 0.02 .(0.01) | 0 (0.02) |
| Education levels (ref: below primary) | Secondary/High school | 0.03 \*(0.01) | 0.02 (0.02) |
| University | 0.05 (0.03) | 0.03 (0.03) |
|  | Adj. R-Squared | 0.34 | 0.37 |

Note: ., \*,\*\*, and \*\*\*mean significant at 5%, and 1%, 0.1%, 0.01%, respectively. Standard errors are in parenthes. These results control for time average of all continuous variables.

1. Estimation strategy was implemented using plm and pglm packages in R. [↑](#footnote-ref-2)
2. A full table of the food items aggregated into the food groups is given in Table B-1, Appendix B [↑](#footnote-ref-3)
3. Inflation rate is in this website <http://data.worldbank.org/indicator/PA.NUS.FCRF?page=1> [↑](#footnote-ref-4)
4. This difference may come from the sample design: the recall period as 12 months in VHLSS before 2010 and as 30 days in VHLSS since 2010. [↑](#footnote-ref-5)