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Philippine Institute for Development Studies
Surian sa mga Pag-aaral Pangkaunlaran ng Pilipinas

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Weather Events and Welfare in the Philippine Households

Connie Bayudan-Dacuycuy¹

Using fixed effects estimators to remove unobserved heterogeneity and instrumental variable technique to address the endogeneity of income, this paper analyzes the effect of weather events on welfare in the Philippines. The paper finds that, one, treating income as an exogenous variable underestimates the effect of income on the household's resource allocation. Two, there are more expenditure shares for which income is endogenous using the tropical cyclone data than using the heat index deviation data as instruments. This likely indicates that the households' unobservable characteristics like risk aversion is heightened for more destructive weather events. Three, households choose cheaper foods but just as nutritious when they are frequently hit by tropical cyclones. Reallocation of income within food items is also observed: from carbohydrate-rich foods to protein-rich foods and to fruits and vegetables. Four, the presence of children affects most of the food items and it has the biggest effect on non-alcoholic beverages such as juice and coffee while the presence of the elderly affects only a few expenditure items such as education and medical care. This reflects the still evolving needs of children and the relatively stable consumption patterns of the elderly. Based on the results, specific recommendations are forwarded. In broader terms, the study points to the desirability of greater forms of investment in resilience against weather events and climate change. At the household level, poverty is a binding constraint to good investment in resilience against weather events and the government has to continue its efforts towards poverty reduction. To this end, the government should ensure that the Department of Social Welfare and Development internal and external convergence strategy is successfully implemented.

Keywords: Weather events, Welfare, Fixed effects

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1.0 INTRODUCTION

Economic life in developing economies is susceptible to weather fluctuations and has become more so in the light of severe weather events. This is particularly true for the Philippines whose households are engaged either directly or indirectly in the agriculture, forestry and resource sector, a sector that is believed to be strongly affected by climate change.

If all households have costless access to financial markets and adequate insurance is in place, such as those provided by the formal labor markets, then the effects of weather fluctuations would not be a big issue as far as smoothing consumption is concerned. This is not the case for some segments of society in a country where there is still a big gap between rural and urban areas in terms of economic opportunities. The concerns about the rising threats of weather variability to current income and consumption patterns of households or individuals have been raised in Foresight (2011). This makes the analysis of the welfare impacts of weather variability a potentially valuable input to the efforts of the Philippine government to meet its MDG target of poverty reduction. To maintain the same welfare level, households reallocate their income to various expenditure items. Understanding how households reallocate income is an important component in formulating policies to abate the effects of weather variability and possibly extreme weather events. It can identify industries that can qualify for input subsidies, for example.

While the welfare impact of weather fluctuations has been analyzed in other developing economies, there are very few studies that systematically analyze such issue in the Philippines. One exception is Yang and Choi (2007) whose focus is on whether remittance functions as insurance within the context of migration. This paper will attempt to analyze the effects of weather variability on household welfare and is closely related to Thomas, Christiansen, Do and Trung (2002) and Skoufias, Katayama and Essama-Nssah (2012). Like Wolpin (1982), our research argues that fluctuations in weather affect expenditure shares through its effects on income.

Results show that treating income as an exogenous variable underestimates the effect of income on the household's resource allocation. In addition, there are more expenditure shares for which income is endogenous when the tropical cyclone data are used as instruments than when heat index deviation data are utilized. This indicates that the effects of the unobservable characteristics differ depending on the weather events.

Results indicate that budget moves from carbohydrate-rich foods to fish and protein-rich foods. In addition, the presence of the elderly and the presence of under-school age children have different effects on the household expenditures. The presence of under-school age children affects the expenditures of most food items while the presence of the elderly affects the expenditures on medical services. While the results are based on a simple utility maximization framework, it may be plausible to speculate that weather conditions may interact with habit persistence in consumption. For example, the prevalence of insignificant effects of the presence of the elderly in the household may reflect consumption patterns that

evolved overtime to favour expenses on medical items and services. Households with young children have different consumption patterns that possibly reflect still evolving habits and preferences. Several avenues for future research are also identified.

This paper is organized as follows: Section 2 reviews the related literature while section 3 discusses the research methods and strategies. Section 4 discusses the data sources and section 5 discusses the variables used. Section 6 discusses the results using heat index deviation data as proxies for weather event, section 7 discusses the results using tropical cyclone data as alternative proxies for weather events and section 8 summarizes and concludes.

2.0 REVIEW OF RELATED LITERATURE

Substantial studies have been done to analyze the economic impact of natural disasters/severe weather events owing to the consensus that this is an important issue not only today but also in the future. The literature employs different ways to operationalize severe weather events but the most common involves the variability in temperature and precipitation since these are inputs to the production in agriculture, the sector believed to be the most affected by these changes (Deschenes and Greenstone 2007). While differing in coverage and estimation procedures, studies concerning agriculture indicate that weather events have adverse effects on the sector. For example, Burgess et al (2011) find that hot weather is associated with lower agricultural yields, lower agricultural wages and higher agricultural prices in India. Schlenker, Hanemann and Fisher (2006) estimate the potential impacts of global warming on farmland and find moderate gains up to large losses, with losses that can become quite large under scenarios of sustained heavy use of fossil fuels. Deschenes and Greenstone (2007) find that even though the overall effect on agricultural profits in the US is small, there is heterogeneity across counties with some counties more adversely affected than others. In a slightly different perspective, Levine and Yang (2014) find that in Indonesia, deviations from mean local rainfall are positively associated with district-level rice output and suggest that researchers are justified in interpreting higher rainfall as a positive contemporaneous shock to local economic conditions in Indonesia.

Weather also affects migration. Feng, Oppenheimer and Schlenker (2014), for example, present evidence that weather affects migration through its influence on agricultural productivity using an instrumental variables approach. In a related approach, Yang and Choi (2007) use rainfall shocks as instruments to analyze the effect of remittances on household incomes and find that consumption of households without migrants responds strongly to income shocks.

At the macro level, the literature is indecisive about the effects of weather events/natural disasters on growth. Among those who observe significant effects, Dell, Jones and Olken (2009) find the effects to be heterogenous within counties and within states in the US while Loayza et al (2009) find the effects to be heterogenous across sectors. Jaramillo (2007) observes that the sign and magnitude of the relationship depends on the type of disaster and Skidmore and Toya (2002) find that climatic disasters are associated with higher long run economic growth while geologic disasters are negatively associated with growth. In a related study, Toya and Skidmore (2007) and Noy (2009) argue that institutions play a role

in reducing weather-related damages. While Caselli and Malhotra (2004) fail to find any significant effect of weather events on growth, Noy and Vu (2010) show that disasters that destroy more properties and capital boost the economy in the short-run.

Owing to the presumed exogeneity of weather variations, the effects of natural disasters/severe weather events experienced earlier in life have been the subject of many studies. This line of research is inspired by works that show the adverse impacts of health and nutrition stress during gestation on adult's life outcomes (Almond 1996; Bozzoli et al. 2009; Alderman, Hoozeven and Rossi 2009, Glewwe et al. 1995). Parallel to this inquiry, several studies relate weather events to health and education outcomes. Deschenes, Greenstone and Guryan (2009) and Murray et al (2000), for example, document the negative health consequence of extreme high and low temperatures on babies in utero. Thai and Falaris (2014) investigate the effect of rainfall shocks during gestation on schooling outcomes and find that adverse rainfall shocks (lower annual rainfall relative to the average) in the third year of life negatively affect both the children's schooling (proxied by years of school entry delay and progress) and health (proxied by height-for-age). These adverse effects are bigger for families that are unable to smooth consumption. Similarly, Maccini and Yang (2009) find that the long-run well-being of Indonesian women is sensitive to the environmental conditions they experienced early in life. In particular, women with higher early-life rainfall are taller, and have better health, better school grades and higher asset ownership index. One pathway the authors identify is the positive effect of higher rainfall on agricultural output.

The effects of weather variability/natural disasters are also found to be higher in rural areas. While production in developed countries is less dependent on weather contingencies and the power of weather to result in excess mortality is limited (Deschenes and Greenstone 2008), evidence show that this is not the case for developing economies where huge population still depends in agriculture and on weather-contingent agricultural incomes. Along this reasoning, Burgess et al (2011) investigate the effects of weather on deaths and find that hot days increase mortality in rural but not in urban populations and suggest that weather in India kills via the interruptions it imposes on agricultural production and employment.

The effect of weather variability/natural disasters can have contemporaneous, lagged or persistent effects as well. For example, some studies find evidence on the immediate effect of rainfall in fetal birth weight (Deschenes, Greenstone and Guryan 2009; Murray et al 2000). Others find that higher early-life rainfall can have impacts on future socioeconomic outcomes (Thai and Falaris, 2014; Yamauchi 2012; Maccini and Yang 2009). While weather variability/natural disasters have immediate effects on prices, disasters have effects in the labor market manifested in wage reduction several years after (Jayachandra 2009; Mueller and Quisumbing 2010). Understanding the timing of the effect would therefore help in planning for the short- and medium-term programs to stave off the adverse effect of severe weather events. For example, subsidy to staple goods is a plausible intervention only in the short-run. Policies related to human capital accumulation/training and infrastructure should address the persistent effects of a natural disasters/severe weather events on household welfare.

Natural disasters or weather shocks also have welfare impacts. Thomas, Christiansen, Do and Trung (2002), for example, find that natural disasters have negative effects on

household welfare. In particular, Thomas, Christiansen, Do and Trung (2002), use disaggregated measures of natural disasters to create disaster and hazard maps which they linked to household surveys in Vietnam. They find substantial short-run losses from natural disaster but these losses can be mitigated by infrastructures like irrigation. They also find long-run negative effects from droughts, flash floods, and hurricanes. Skoufias, Katayama and Essama-Nssah (2012) also find that rainfall after the onset of monsoon season has negative effects on household welfare. Thomas, Christiansen, Do and Trung (2002) find that the effects of weather shocks are different between households in different areas. In particular, households in areas exposed to low rainfall following monsoon are negatively affected and that these households are able to protect their food expenditures at the expense of their non-food expenditures. No such effect is found in households with family farm businesses.

While the welfare impact of weather fluctuations has been analyzed in other developing economies, there are very few studies that systematically analyze such issue in the Philippines. One exception is Yang and Choi (2007) whose focus is on whether remittance functions as insurance within the context of migration.

3.0 FRAMEWORK AND BASIC EMPIRICAL STRATEGY

The research framework to be used would be the standard household utility maximization problem $\max U(x_i)$ subject to $p_i x_i = Y$ where x_i and p_i are the consumption and the price of good i and Y is income. Maximization of this problem leads to demand functions $x_i = x_i(p_i, Y; z)$ where z is a vector of household characteristics. One approach in the literature is to simultaneously estimate these within the context of demand systems (Deaton, 1980), which essentially estimate the price and expenditure elasticities of each consumption good. Another strand veers away from the demand systems and focuses more on the non-price determinants of demand (see for example, Skoufias, Katayama and Essama-Nssah 2012; Quisumbing and Maluccio 2003; Handa 1996). Although these two strands differ in approach, the standard x_i in the empirical application is the expenditure share or a variant of it (per capita or in logs). Consumption-based measure of welfare is based on the Samuelson's (1974) *money metric utility*, which measures levels of living by the money required to sustain them. The starting point is the standard utility maximization problem above where households choose goods to maximize utility subject to a budget constraint. Consumer preferences over goods are thought of as a system of indifference curves that can be labeled by taking a set of reference prices and calculating the amount of money needed to reach a utility level². The exact calculation of money metric utility requires information on preferences, which can be approximated from the cost function. By the known Shepard's Lemma, the derivative of this cost function with respect to prices is the quantity consumed. Building up on this, the literature has used household consumption as an indicator of household welfare (see for example, Deaton 1997; Skoufias and Coady 2007).

For the purpose of this paper, we follow the second strand. Hence, the basic model is:

² Detailed discussion of labelling indifference curves can be found in Deaton and Zaidi (2002).

$$w_i = \alpha_i + \delta_i Y_i + \phi_i z_i + \varepsilon_i \quad (\text{Equation 1})$$

where w_i is the log of expenditure share of good i , α_i is an intercept, ε_i is the error term, and Y and z are as defined before. Using OLS to estimate equation 1 raises some econometric concerns, the most common of which is the issue of endogeneity or when the standard OLS assumption $\text{cov}(Y, \varepsilon) = 0$ is violated. This can happen when there are systematic unobservable characteristics among households that vary with the households' income as well. For example, attitude towards shocks that affect spending/consumption patterns are most likely the same attitudes that affect the propensity of households to look for more income sources. Reverse causation can also be an issue since income can be a function of expenditures. For example, households wishing to send their children to school will seek more opportunities or increase work hours to earn higher income.

Behaviourally, households tend to exhibit patterns of optimal response that may or may not vary over time but may be different relative to other households. For instance, households in temperate regions are more knowledgeable of technologies suitable for adapting to local weather conditions. To account for this unobserved heterogeneity, the ideal strategy is to use the fixed effects estimator on panel data and to use weather-related shocks as instruments for income. The estimating equations become:

$$Y_{it} = \varphi_i + \gamma \text{weather}_{it} + e_{it} \quad (\text{Equation 2})$$

$$w_{it} = \alpha_i + \delta \hat{Y}_{it} + \phi z_{it} + \varepsilon_{it} \quad (\text{Equation 3})$$

where *weather* is a proxy for weather events, φ_i and α_i are intercepts, e_{it} and ε_{it} are error terms, and \hat{Y}_{it} is the predicted income from the first-stage regression.

A key issue in this type of methodology is to establish the validity of weather-related fluctuations as instruments to income. If the instruments are not valid, OLS is a more efficient estimator than the IV. In this context, we explore the plausibility of the weather variables as appropriate instruments. In terms of relevance, the impact of weather may be transmitted through known mechanisms that drive income changes. For example, agricultural households' budgetary allocations may change due to shortfalls induced by prolonged dryness as a result of experiencing above normal temperatures. In this scenario, dry conditions affect agricultural productivity, income and eventually budgetary allocations. This potentially implies that the elasticity of expenditure shares in response to changes in income may be higher or lower, depending on the nature of variations in weather conditions. The literature also supports the use of weather variables as instruments. Yang and Choi (2007), for example, argue that households in the Philippines are either directly or indirectly engaged

in agriculture and are therefore susceptible to weather-related shocks. Further tests on the validity of the instruments are discussed in greater detail in section 6.1.

All estimates are clustered at the provincial level to address the bias introduced by spatial correlation.

4.0 DATA SOURCES

4.1 FIES panel data

The income and expenditure data are from the 2003, 2006, and 2009 Family Income and Expenditure Survey (FIES) collected by the Philippine Statistics Authority (PSA). The FIES is a nationwide survey conducted every three years by the PSA as a rider to the Labour Force Survey and collects detailed expenditure and income. Individual information such as age, sex, marital status, and employment data pertain to the household head, however. Some information such as the spouse's age and employment status are also collected

The 2003, 2006, and 2009 FIES can be merged to form a panel dataset since there is a master sample based on the Census of Population and Housing. A portion of the master sample is retained that the PSA resurveys for some period. These samples are replaced by another set of samples to be tracked again after another period. PSA databank has four replicates and each of these replicates possesses the properties of the master sample. For the purpose of this research, the PSA has provided the second rotation of replicate four of the datasets.

Merging of the FIES datasets is done by creating a household identification number through the concatenation of various geographical variables such as region, province, municipality, *barangay*³, enumeration area, sample housing unit serial number, and household control number. There are 6311 samples that are common to the three datasets. The samples are further limited to households that satisfy two criteria: the sex of the household head should be the same throughout the period and the age of the household head should be consistent as well. For example, the age difference of the household head between 2003 and 2006 should either be two or three years. These criteria are set to ensure that the samples are the same households tracked down from 2003 to 2009. There are 2223 households left (total of 6669 households for 3 years) when these additional restrictions have been imposed.

To make the results comparable across time and space, all incomes and expenditures are expressed in 2003 National Capital Region (NCR) prices. The provincial price data are sourced from the National Statistical Coordination Board.

The FIES follow a multi-stage sampling design to make the sample representative of the population. However, the panel data constructed for the current research do not make use of the sampling weights since the weights differ across the survey data. Therefore, we make

³ This is the basic political unit in the Philippines, equivalent to a village.

no claim that the results from the constructed panel data can be generalized for the population.

4.2 PAGASA weather data

Weather data are collected by the Philippine Atmospheric and Geophysical Astronomical Services Administration (PAGASA) weather stations spread across the Philippines. We initially focus on three weather variables, namely, temperature represented by wetbulb readings (in degrees Celsius), relative humidity (in percent), and average rainfall (in millimetres). All parameters have been measured, compiled, and disseminated through a public use file containing 59 weather stations of PAGASA. To map the weather information with the FIES datasets, we use the province of residence as the merging variable.

The PAGASA datasets have the following features: First, there are several provinces that host multiple weather stations. Second, there are several provinces in which no weather station is present but it is possible to assign a weather station on the basis of the relative distance between the province and the location of the weather station (in kilometres). In merging the PAGASA dataset with the FIES, we address the first feature by selecting the weather station that is located in or in close proximity to the provincial capital. As an illustration, Quezon province, which is located south of the National Capital Region, has three stations, namely, Tayabas, Infanta, and Alabat. We choose Tayabas because it is the closest to the capital city Lucena while Alabat is an island to the right of the Quezon landmass.

Second, in view of the importance of accounting for similar weather patterns and enhancing data variability, we do not automatically remove households in provinces without weather stations. For instance, the province of Marinduque does not have a weather station. However, it is possible to make a location scan and determine an adjacent province that hosts a weather station. Based on relative distances between the individual weather stations found in Quezon and Marinduque, an adjacent province, we selected Tayabas. Assigning adjacent weather stations to provinces without one maximizes the number of households included in the estimation sample. Without this assignment, there are 24 locations that are dropped out of the sample. This translates to a reduction of 756 households per year (total of 2268 data points). Appendix 1 provides the mapping of the respective weather stations to provinces and cities. The second column identifies the weather station/s that is/are located in a particular province. The third column shows the assigned weather station to provinces that do not host any weather station. The last column provides brief explanatory remarks that justify the mapping.

Based on the consultation with the PAGASA climatologist, rainfall data are highly localized and matching the rainfall data with the FIES provinces can introduce substantial measurement error. However, the PAGASA climatologist has affirmed that weather measurements such as temperature and relative humidity are relatively stable across provinces. This means that temperature and relative humidity data measured in another province can be used for adjacent provinces that do not have weather stations.

Griffiths et al (2005) show that changes in the mean temperature have an effect on changes in extreme temperature in Asia–Pacific. Specifically, for the Philippines, it is found that significant correlation exists between the mean temperature and the frequency of extreme temperature. However, relative humidity can interact with temperature to form heat index. Heat index is a human discomfort index that measures the temperature that the human body perceives of feels. Since the climate in the Philippines is characterized by high temperature, high humidity and abundant rainfall,⁴ heat index appears to be an ideal weather variable that can be linked to consumption and earning patterns. Prolonged activity under the hot sun when heat index is high can have severe consequences such as fatigue, heat cramps, heat exhaustion and heat stroke. Hence, people may be cautious to go out when heat index is high. This can have severe implications on the income of households that rely on agricultural wages, crops and backyard production, entrepreneurship in the agriculture and service sectors, and domestic remittances.

The annual average of relative humidity and temperature are computed based on the monthly weather data collected by PAGASA in 2003, 2006, and 2009. To compute heat index, the temperature data are converted into Fahrenheit using $T_{(°F)} = T_{(°C)} * 9/5 + 32$. Heat index (HI) is then generated using the following formula:⁵

$$HI = 42.379 + 2.04901523 * T + 10.14333127 * R - 0.22475541 * TR - 6.83783 * (10^{-3}) * Tsq - 5.481717 * (10^{-2}) * Rsq + 1.22874 * (10^{-3}) * TsqR + 8.5282 * (10^{-4}) * TRsq - 1.99 * (10^{-6}) * TsqRsq$$

where T is temperature in Fahrenheit, Tsq is squared temperature, R is relative humidity in percentage, and Rsq is squared relative humidity. Similarly, we repeat the same computation using the data on normal temperature and normal relative humidity. The data on normal values, defined as the 30-year average, are also collected by PAGASA between 1970 and 1999 and are used to proxy for the long-run average values.

The difference between the annual average HI and the normal HI values is then generated. This deviation represents weather shocks. To recognize the nonlinear effects of the HI deviation, a squared HI deviation is also used as an additional weather-related variable. Squaring the deviation puts more weight on observations that are very far from the long-run average. This asymmetric treatment may prove useful in providing a more complete characterization of the effects of weather variables on income and on expenditure shares. Extreme weather event as a form of weather shock, such as tropical cyclones, is also considered in section 7. It should be noted that the weather variables used in this research do not include floods or droughts. HI deviation made use of both the temperature and relative humidity while the tropical cyclone data are indicators of the number of typhoons that crossed the province each year. Rainy months in the Philippines begin in June of one year until March of the following year and typhoons typically happen during June up to December of the same year.

⁴ <https://kidlat.pagasa.dost.gov.ph/index.php/heat-index>

⁵ Taken from the National Weather Service-National Oceanic and Atmospheric Administration website.

5.0 VARIABLES AND DEFINITION OF TERMS

5.1 Welfare

To operationalize welfare, the FIES expenditures data at the household level are used. In particular, the FIES has detailed data on household expenditures which include food and non-food items. Food expenditures include rice, cereals, corn, root crops, fruits, vegetables, fruit preparations, meat, dairy, fish, coffee, alcoholic, and non-alcoholic beverages. Food expenditures are also categorized as either food consumed outside of home or at home. Non-food expenditures include expenses on cigarettes/tobacco, fuel, transportation, household operation, personal care, clothing, education, medical care, recreation, and durable and non-durable furnishings. Expenditure shares are computed and are then expressed in per capita terms and deflated by the National Capital Region 2003 prices. All expenditure shares are in logarithmic form.

5.2 Explanatory variables

The explanatory variables include the household head's age, the information on socioeconomic characteristics at the household level, which include the household type (nuclear household indicator), the number of working household members, an indicator for the employment status of the head's spouse, and the indicators for the presence of the under-school age children and the presence of the elderly. The under-school age children are defined to be children below 7 years old while the elderly is household members aged 60 years old and above.

The interactions of young children and the elderly with the rural area dummy are also included to determine whether the effects of these vulnerable groups on expenditure shares differ between urban and rural areas. Year indicators are also included as regressors.

To control for the heterogeneity in the capacity to pay/purchase, an index to proxy for asset ownership is also constructed using the score generated by the principal component analysis (PCA). The PCA is a technique to reduce the dimension of the data by creating uncorrelated indices or components, where each component is a linear weighted combination of the initial variables. The variance of each of the component is generated such that the first component contains the largest variation in the original data; the second explains additional but less variation and so on⁶. An application of PCA is on household assets to create an indicator for socioeconomic status in the absence of income and expenditure data (see for example, Filmer and Pritchett (2001)). Positive scores generated by the PCA are associated with higher socioeconomic status (Vyas and Kumaranayake 2006).

While FIES has collected detailed asset ownership, the assets included in the PCA are those that are collected in all the FIES years. These include assets such as television, video recorder, refrigerator, washing machine, air conditioner, sala set, dining set, telephone, personal computer, gas range, car, and motorcycle. Two factors with eigenvalues greater than 1 are retained based on the Kaiser criterion. The overall Kaiser-Meyer-Olkin measure of

⁶ For technical details, see Filmer and Pritchett (2001).

sampling adequacy is 0.93, which indicates that these assets contain enough similar information to warrant the factor analysis.

Income refers to the household's total income and is composed of *wages*, *other income* and *income from entrepreneurial activities*. *Wages* are from agricultural and non-agricultural sources. *Other income sources* include the net share of crops, cash receipts, gifts and support from abroad and domestic sources, rentals received from non-agricultural lands/buildings, interest, pensions, dividends from investments, income from family sustenance activities and receipts from others sources not elsewhere classified. Examples of receipts from others sources not elsewhere classified are royalties, lump sum for injuries (not covered by workmen's compensation), legal damages received, proceeds from the sale of rights to real property, and salaries and wages from the employment of family members less than 10 years old.

Income is expressed in per capita terms and deflated using NCR 2003 prices. All expenditure shares are in logarithmic form.

6.0 TESTS, ESTIMATION RESULTS AND DISCUSSION

6.1 Tests

Before proceeding with the estimation, the exogeneity of income is tested. Results, presented in the second column of table 1, indicate that income is endogenous for expenditures on cereals, corn, fruits, vegetables, meat and fish; and on broader categories such as foods consumed at home and outside of home. Income is also endogenous for fuel items like LPG, petroleum, and electricity. These expenditure items are estimated using the IV technique, which relies on the validity of the weather variables as appropriate instruments. If the instruments are not valid, OLS estimates would be a more efficient estimator than the IV estimates and OLS would have been a better estimator.

In terms of relevance, deviations of heat index from the normal value can have implications on health and life. Households that rely on incomes from tilling the soil are likely to be affected by the deviation. Households that rely on gifts and supports are likely to be affected as well if the benefactor relies, for example, on entrepreneurship that may be subject to weather conditions (e.g. agricultural or services entrepreneur). As instruments, weather variables should have no direct effect on expenditures as well. If it does, then it is difficult to separate the direct and indirect effects of the weather variables on expenditure shares.⁷ The HI deviation and its square are used as direct explanatory variables of each of the expenditure shares. The joint significance of the instruments is then tested. Column three of table 1 presents the p-values to test $H_0: \beta_{HI_dev} = \beta_{HI_dev_sq} = 0$. If the null hypothesis is rejected⁸, HI deviation and its square are jointly significant in explaining expenditure shares. This means that these variables have a direct impact on expenditure shares and are, therefore, not valid instruments for income. It can be noted from the results that HI deviation and its

⁷ The indirect effects of weather on consumption have been expounded in Wolpin (1982) in his attempt to test the permanent income hypothesis.

⁸ The null hypothesis is rejected for p-values less than 0.10.

square do not have significant and independent effects on the expenditure items for which income is endogenous.

The empirical strategy adopted is, therefore, two-pronged and is summarized in figure 1. For expenditure items for which income is exogenous, we use the fixed effects estimator for panel data (non-IV FE) while for expenditure items for which income is endogenous, we use the fixed effects IV estimator (IV-FE). In this case, HI deviation and the squared deviation are used as instruments. In addition, estimation results treating income as exogenous are also provided. This serves as the baseline estimates.

6.2 Exogenous income assumption: Benchmark non-IV FE estimates

The initial starting point in the empirical analysis is to assume the exogeneity of income which is critical in ensuring that the conditional mean relationships are identified through a linear specification. The fixed effects estimator for panel data is used. The estimates, which serve as the benchmark, are presented in table 2 and results are summarized below.

1. *Elasticity.* Based on the estimates, all expenditure shares are inelastic with respect to income. This means that a 1% increase in household income will lead to a less than 1% increase in expenditures.

2. *Significance.* Income significantly affects expenditures on cereals, corn, fruits, vegetables, meat and fish. Except for meat, expenditures on these items decrease when income increases. Among these food expenses, corn, and cereals expenditures are the highest. An income change negatively affects fuel items such as LPG, petroleum, and electricity.

3. *Necessity versus non – necessity.* Expenses on both goods are affected by income. Except for total meat, expenditures on these items decrease when income increases.

4. *Location.* An income change negatively affects food consumption at home. It does not significantly affect food consumption outside of home.

Table 1. Exogeneity of income and test for the direct effects of HI deviation and its square

	Exogeneity test $cov(income, \varepsilon) = 0$	Test for the direct effects of HI deviation and its square $H_0: \beta_{HI\ dev} = \beta_{HI\ dev\ sq} = 0$
	Exogenous income	
Rice	0.32	
Fruit preparations	0.24	
Beans	0.64	
Chicken	0.42	
Beef	0.24	
Pork	0.25	
Other meat	0.65	
Dairy	0.42	
Coffee	0.67	
Juice	0.14	

Bottled	0.43	
Alcoholic	0.37	
Tobacco	0.87	
Transport	0.18	
Household Operation	0.43	
Clothing	0.23	
Education	0.21	
Recreation	0.71	
Medical care	0.7	
Nondurables	0.6	
Durables	0.88	
Repair	0.81	
Special occasion	0.67	
Gifts	0.75	
Charcoal	0.21	
Candle	0.43	
Water	0.99	
	Endogenous income	
Cereals	0.00	0.89
Corn	0.01	0.27
Fruits	0.00	0.29
Fresh fruits	0.00	0.22
Fruits and vegetables	0.00	0.27
Meat	0.02	0.22
Fish	0.00	0.20
Food consumed at home	0.00	0.33
Food consumed outside	0.07	0.44
LPG	0.04	0.36
Petroleum	0.00	0.23
Electricity	0.00	0.16

Notes:

- (1) ***/*** significant at 10/5/1% level.
- (2) Figures in the second column are p-values to test that income is exogenous. The test is conducted after the fixed effects IV regression for panel data. Income is instrumented by heat index and its square.
- (3) Figures in the third column are p-values of the F-test to test $H_0: \beta_{HI dev} = \beta_{HI dev sq} = 0$. Rejection of the null hypothesis indicates that the deviation of heat index from the long-run averages and the squared deviation are jointly significant in explaining expenditure shares. This means that HI deviation and its square have a direct impact on expenditure shares and are, therefore, not valid instruments for income. Estimated using the fixed effects IV regression for panel data.
- (4) Standard errors are clustered at the provincial level.
- (5) Regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, indicators for the presence of underschool-age children and the presence of the elderly, and year dummies.

5. *Presence of under-school age children and the elderly.* The presence of young children and the presence of the elderly do not significantly affect almost all of the expenditure items. The presence of both in rural households does not have significant effects as well.

6. *Effect of weather-related variables.* Most food expenditures are affected by the HI deviation and the squared deviation. In particular, these significantly and positively affect food items such as fruits, vegetables and foods consumed outside of home. Weather-related

variables also have nonlinear effects on these expenditure items. Weather-related variables do not affect any of the fuel items, however.

Figure 1: Flow of the empirical strategy adopted

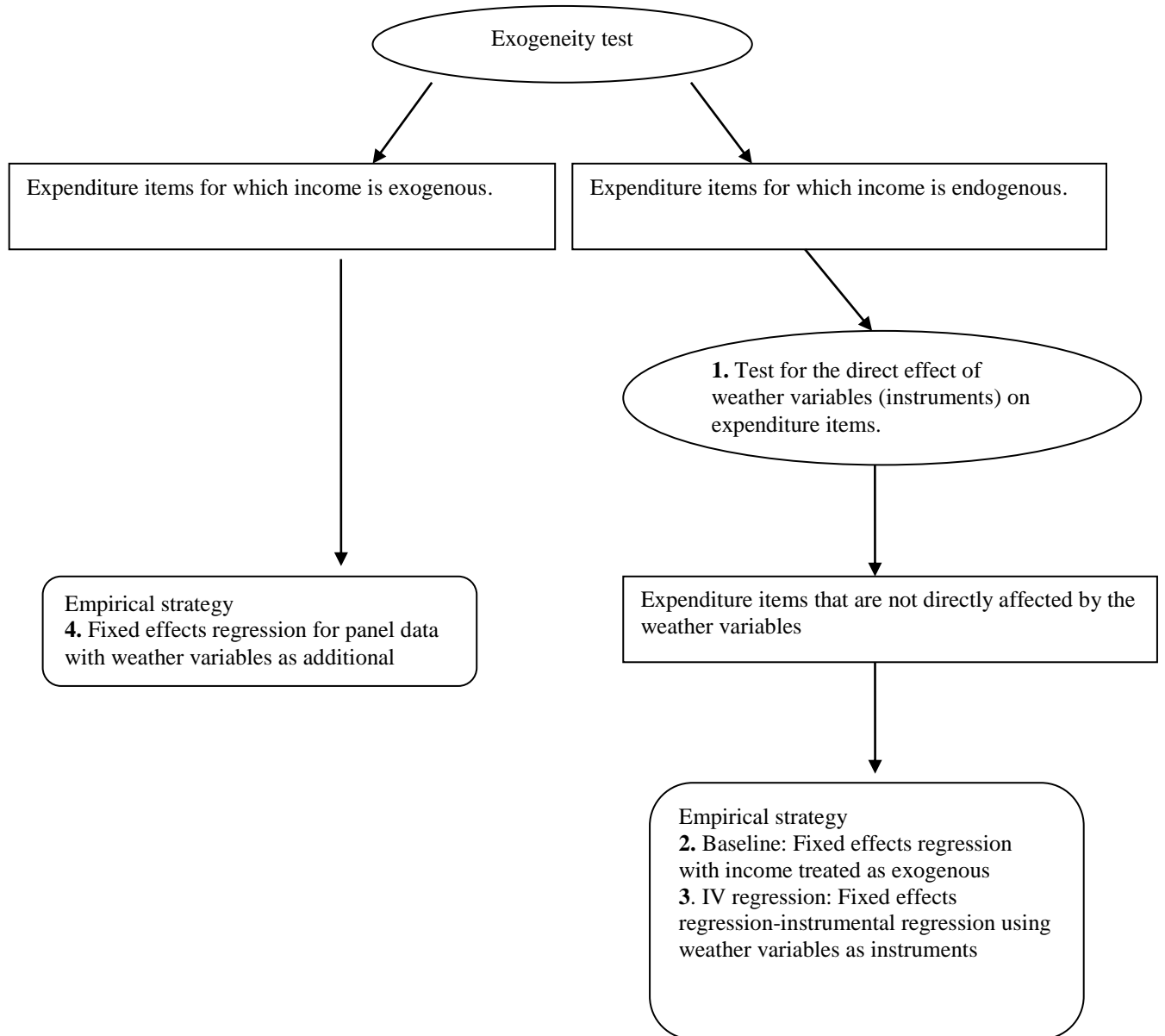


Table 2. Estimates assuming the exogeneity of income, fixed effects regressions

	Income	HI deviation	HI deviation squared	Under-school age kids	Under-school age kids*rural	Elderly	Elderly *rural	R2	Number of observations
Food expenditures									
Cereal	-0.42*** [0.02]	0.01 [0.01]	0.00 [0.00]	-0.03 [0.02]	-0.03 [0.03]	-0.03 [0.03]	0.02 [0.06]	0.28	6086
Corn	-0.48*** [0.08]	0.08 [0.06]	0.01 [0.01]	0.06 [0.09]	-0.24* [0.14]	0.04 [0.17]	0.34 [0.46]	0.06	3437
Total fruits	-0.11*** [0.03]	0.03 [0.02]	0.00* [0.00]	-0.03 [0.02]	0.01 [0.04]	0.03 [0.05]	0.00 [0.06]	0.04	6086
Fresh fruits	-0.01 [0.04]	0.04* [0.02]	0.00 [0.00]	0.00 [0.03]	0.01 [0.06]	0.05 [0.08]	0.01 [0.08]	0.03	6044
Fruit vegetables	-0.19*** [0.03]	0.04 [0.02]	0.00* [0.00]	-0.05* [0.03]	-0.02 [0.04]	-0.01 [0.07]	0.07 [0.12]	0.03	6039
Total meat	0.09*** [0.03]	0.03 [0.02]	0.00 [0.00]	-0.02 [0.03]	-0.03 [0.05]	-0.03 [0.07]	0.17 [0.12]	0.02	5982
Fish	-0.13*** [0.03]	0.04 [0.03]	0.00 [0.00]	-0.03 [0.03]	0.00 [0.04]	0.07 [0.05]	-0.04 [0.11]	0.03	6081
Foods consumed outside of home	-0.20*** [0.01]	0.01* [0.01]	0.00* [0.00]	0.01 [0.01]	0.00 [0.02]	0.00 [0.03]	0.04 [0.04]	0.16	6086
Foods consumed at home	0.05 [0.06]	0.04 [0.04]	0.00 [0.00]	-0.14** [0.06]	-0.09 [0.09]	0.01 [0.17]	0.05 [0.22]	0.03	4293
Non-food expenditures									
LPG	-0.35*** [0.05]	-0.04 [0.03]	0.00 [0.00]	-0.04 [0.07]	-0.03 [0.08]	0.15 [0.12]	-0.07 [0.19]	0.09	2500
Petroleum	-0.38*** [0.07]	-0.03 [0.03]	0 [0.00]	0.12 [0.07]	-0.09 [0.18]	0.08 [0.15]	0.3 [0.30]	0.16	3724
Electricity	-0.27*** [0.03]	-0.03 [0.02]	-0.00* [0.00]	0.01 [0.04]	-0.03 [0.06]	0.09 [0.06]	-0.14 [0.11]	0.1	4946

Notes:

- (1) ***/*** significant at 10/5/1% level.
- (2) Figures in brackets are standard errors.
- (3) Figures are estimates using the fixed effects IV regression for panel data.
- (4) Standard errors are clustered at the provincial level.
- (5) Other regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, and year dummies.

6.3 Endogenous income based on the exogeneity test in table 1: IV-FE estimates

Results treating income as endogenous are presented in table 3. Expenditures on LPG, corn and foods consumed outside of home are excluded since the underidentification test indicates that the instruments are not relevant. The following similarities to and differences from the benchmark estimates are noted below.

1. *Significance.* Similar to the benchmark non-IV FE, income significantly affects most of the expenditure items.

2. *Signs.* The benchmark non-IV FE predicts that the effect of income is negative on fruits and fish. This means that a rise in income without purging the effects of weather is likely to decrease the amount of resources for these food items. In contrast, the IV-FE

estimates show that the effect of income on similar expenditure items is positive. Both the benchmark non-IV FE and IV-FE predict that an income change will increase expenditures on total meat and on fuel items such as petroleum and electricity.

3. *Relative magnitudes.* Except for foods consumed at home, the IV FE estimates are always greater than one. This indicates that expenditure items are responsive to income changes. In contrast, the benchmark non IV-FE estimates indicate inelastic response to an income change.

Looking closely at the results presented in table 3, food items are positively affected by an income change. Except for the total foods consumed at home, food items in table 3 are income elastic. Among these food items, an income change has the highest effect on fresh fruits. Expenditures on vegetables are relatively more responsive than protein-rich foods such as meat and fish. Non-food items are negatively affected by an income change. Between petroleum and electricity, an income change has the higher effect on the latter.

4. *Presence of under-school age children and the elderly.* The presence of young children significantly affects most of the expenditure items using the IV-FE. Similar to the benchmark non-IV FE, the presence of the elderly does not significantly affect most of the expenditure items using the IV-FE. The presence of both in rural households does not have significant effects as well.

Looking closely at the results presented in table 3, the presence of the under-school age children positively affects expenses on food, fruits, and fish. It also has a similar effect on both foods consumed at home or outside of home. Among these food items, young children have the highest effect on fresh fruits consumption. However, the presence of young children has a negative effect on electricity expenditure. In contrast, the presence of the elderly does not have a significant effect on the expenses listed in table 3 except on leafy vegetables. The elderly in rural areas have a negative effect on meat expenditures.

Table 3. Income as an endogenous determinant of expenditure share, fixed effects estimates, deviation of heat index from normal values and deviation squared as instruments

	Income	Under-school age kids	Under-school age kids*rural	Elderly	Elderly*rural	Number of observations	Underid Test§	Overid test§§
Food expenditures								
Cereal	0.29 [0.29]	0.04 [0.05]	0.04 [0.03]	-0.01 [0.05]	-0.06 [0.07]	6035	0.00	0.24
Total fruits	1.25** [0.52]	0.16* [0.08]	0.02 [0.06]	0.02 [0.10]	-0.06 [0.12]	6035	0.00	0.72
Fresh fruits	1.70** [0.71]	0.22** [0.11]	0.04 [0.08]	0.05 [0.13]	-0.09 [0.17]	5987	0.00	0.28
Fruit vegetables	1.20** [0.61]	0.11 [0.10]	0.05 [0.07]	0.05 [0.12]	-0.14 [0.15]	5978	0.00	0.74
Total Meat	1.20** [0.56]	0.09 [0.09]	0.06 [0.06]	0.12 [0.11]	-0.22* [0.13]	5915	0.00	0.93
Fish	1.06** [0.50]	0.13* [0.08]	0.02 [0.05]	0.02 [0.09]	-0.01 [0.12]	6028	0.00	0.22

Foods consumed at home	0.52*	0.10**	0.02	0.03	-0.08	6035	0.00	0.47
	[0.27]	[0.04]	[0.03]	[0.05]	[0.06]			
Non-food expenditures								
Petroleum	-2.62***	-0.23	0.01	0.24	-0.09	3312	0.00	0.35
	[0.80]	[0.20]	[0.18]	[0.32]	[0.37]			
Electricity	-3.84**	-0.51**	-0.04	-0.01	0.31	4760	0.08	0.56
	[1.73]	[0.25]	[0.13]	[0.22]	[0.28]			

Notes:

- (1) */**/** significant at 10/5/1% level.
- (2) Figures in brackets are standard errors.
- (3) Standard errors are clustered at the provincial level.
- (4) Estimated using fixed effects for panel data and using the deviation of heat index from the long-run average and the squared deviation as instruments for income.
- (5) Other regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, indicators for the presence of underschool-age children and the presence of the elderly, and year dummies.
- (6) §Tests the null hypothesis that the equation is under-identified, $cov(instrument, endogenousvariable) = 0$. Rejection of the null implies that the instruments are relevant; that is, the instrument induces change in the endogenous variable.
- (7) §§Tests the null hypothesis that the instruments are uncorrelated with the error term, $cov(instrument, error\ term) = 0$ and that the excluded instruments are correctly excluded from the estimated equation. Rejection of the null implies that the instruments are valid.

6.4 Exogenous income based on the exogeneity test in table 1: non-IV FE estimates

Table 4 presents the estimates of income for expenditure shares that are exogenous based on the exogeneity test presented in table 1. Results are summarized below.

1. *Food*. Food items are inelastic but some food items respond positively while others respond negatively to income. Expenditures on rice and beans are negatively affected while beef expenses are positively affected by an income change.

2. *Sin goods*. Tobacco products are negatively affected by an income change.

3. *Non-food*. Most of the non-food items are income inelastic and respond positively to an income change. These include expenditures on transportation, clothing, recreation, medical care, durable, repair, and special occasions. Repair expenditures have the biggest response while expenses on transportation have the smallest response to an income change.

4. *Weather-related variables*. HI deviation and its square do not affect expenditure items except rice expenditures.

5. *Presence of under-school age children and the elderly*. The presence of young children and the presence of the elderly positively affects expenses on dairy products. The effect of young children is higher, however. Both groups positively affect medical care services. The effect of the elderly is higher, on the other hand. Young children increases repair expenditures while the elderly decreases the expenditures on education and increases

expenses on gifts and on bottled water. The presence of both in rural households does not have significant effects on the expenditure items.

Results above show that treating income as exogenous results in estimates that are downward bias, thereby underestimating the effect of income on the household's resource allocation. Estimates are higher using the estimator that accounts for both endogeneity and unobserved heterogeneity. To summarize, the direction of the IV-FE estimates are the same as the benchmark non-IV FE estimates. However, the magnitudes are different, with the IV-FE estimates pointing to more elastic responses of most of the expenditure shares. While both estimates take into account the longer term characterization of household consumption behaviour and both accounts for the unobserved heterogeneity, the non-IV FE estimates ignore the fact that income variations can be affected by the unobservable characteristics that determine the household's spending behavior. Consider the following plausible correlations of the unobservables, such as attitudes towards shocks and expectations, with income and expenditures. Risk aversion will likely drive households to spend less and invest more and will likely drive households to seek more income-generating opportunities to earn higher income. Similarly, expectations of poor harvest/business will likely drive households to revise their consumption patterns downwards and will likely drive households to become more aggressive in earning income. The scenarios above illustrate how estimates can be downward biased. IV-FE estimator is used to address this issue.

Results based on the IV-FE estimates show that some food items are positively inelastic (like cereals) or positively elastic (like fruits, vegetables, meat, and fish). Non-food expenditures (like petroleum and electricity) are negatively elastic. Results also point to the different needs of vulnerable groups like children and the elderly. Compared with the presence of the elderly, the presence of under-school age children affects more food items.

Results based on the non-IV FE estimates indicate that some food and non-food items are negatively inelastic or positively inelastic. This means that while not responsive to income change, budget is reallocated and the reallocation appears to be from food (such as rice, bottled water and coffee) and utilities (such as water and charcoal) to non-food items (such as transportation, recreation, clothing, medical care, durables, and repair). Within food items, reallocation appears to move from carbohydrate-rich foods (rice and beans) to protein-rich foods (beef). Within non-food items, budget is allocated from fuel/energy items (water utility and charcoal) and tobacco to transportation, clothing, recreation, medical care, durable items, repair, and special occasions. Similar to the IV-FE results, findings from the non-IV FE estimates also point to the different needs of vulnerable groups like children and the elderly. Both groups affect the expenses on dairy products and medical services. However, expenditures on dairy products are affected more by the presence of young children while expenditures on medical services are affected more by the presence of the elderly. Young children increase repair expenditures while the elderly decreases the expenditures on education and increases gift expenses and expenses on bottled water. HI deviation and its square do not affect expenditure items except rice expenditure.

Table 4. Fixed effects estimates of income for expenditure items for which income is exogenous, deviation of heat index from normal values and deviation squared as additional explanatory variables

	Income	HI deviation	HI deviation squared	Underschool age kids	Underschool age kids*rural	Elderly	Elderly *rural	N
Food items								
Rice	-0.43*** [0.03]	-0.03* [0.02]	-0.00* [0.00]	0.00 [0.03]	-0.02 [0.04]	-0.02 [0.09]	-0.06 [0.10]	5891
Fruit preparations	0.09*** [0.03]	0.03 [0.02]	0.00 [0.00]	-0.05 [0.04]	0.03 [0.05]	0.14 [0.10]	-0.17 [0.12]	5982
Beans	-0.15*** [0.04]	0.03 [0.03]	0.00 [0.00]	-0.07 [0.06]	0.00 [0.07]	-0.02 [0.13]	-0.01 [0.16]	5632
Meat items								
Chicken	-0.01 [0.05]	0.02 [0.02]	0.00 [0.00]	-0.06 [0.05]	0.01 [0.06]	0.15 [0.15]	-0.10 [0.17]	5714
Beef	0.27*** [0.07]	0.03 [0.06]	0.00 [0.00]	0.00 [0.12]	-0.01 [0.13]	-0.22 [0.29]	0.19 [0.34]	2919
Pork	0.05 [0.04]	0.03 [0.03]	0.00 [0.00]	0.01 [0.05]	0.06 [0.06]	0.03 [0.12]	-0.11 [0.16]	5651
Other meat	0.02 [0.13]	0.04 [0.09]	0.00 [0.01]	-0.40 [0.39]	0.37 [0.37]	0.57 [0.42]	-0.03 [0.54]	982
Total dairy	-0.02 [0.04]	0.01 [0.02]	0.00 [0.00]	0.40*** [0.04]	-0.05 [0.06]	0.18* [0.10]	-0.09 [0.13]	6004
Non-alcoholic beverages								
Juice	-0.09 [0.06]	0.03 [0.03]	0.00* [0.00]	0.01 [0.06]	-0.12* [0.07]	0.12 [0.13]	-0.15 [0.16]	4463
Bottled	-0.32*** [0.12]	0.07 [0.06]	0.01 [0.01]	0.00 [0.19]	-0.07 [0.30]	0.70* [0.40]	-0.31 [0.63]	1089
Coffee	-0.24*** [0.04]	-0.01 [0.02]	0.00 [0.00]	-0.09** [0.04]	0.13*** [0.04]	0.05 [0.09]	-0.08 [0.10]	6039
Fuel items								
Charcoal	-0.34*** [0.08]	0.03 [0.04]	0.00 [0.00]	-0.12 [0.10]	0.04 [0.13]	-0.05 [0.26]	0.01 [0.23]	2353
Candle	-0.13 [0.08]	0.07 [0.05]	0.01 [0.00]	-0.08 [0.09]	0.13 [0.14]	0.00 [0.29]	0.09 [0.31]	2927
Water utility	-0.40*** [0.06]	-0.01 [0.04]	0.00 [0.00]	-0.08 [0.07]	0.07 [0.10]	-0.16 [0.22]	-0.04 [0.29]	2740
Sin goods								
Alcoholic	0.06 [0.07]	-0.01 [0.05]	0.00 [0.00]	-0.13 [0.14]	0.10 [0.14]	-0.19 [0.23]	-0.08 [0.28]	4512
Tobacco	-0.12** [0.06]	-0.01 [0.03]	0.00 [0.00]	0.13 [0.10]	-0.14 [0.10]	-0.04 [0.23]	-0.17 [0.28]	4258
Non-food items								
Transport	0.15*** [0.04]	0.01 [0.02]	0.00 [0.00]	0.01 [0.04]	-0.05 [0.05]	0.00 [0.06]	-0.10 [0.09]	6033
Clothing	0.24*** [0.04]	0.00 [0.03]	0.00 [0.00]	0.06 [0.05]	-0.05 [0.08]	-0.11 [0.12]	0.22 [0.15]	5913
Education	-0.10 [0.06]	-0.03 [0.05]	0.00 [0.00]	-0.07 [0.10]	-0.12 [0.12]	-0.48* [0.26]	0.00 [0.35]	4818
Recreation	0.16** [0.08]	-0.04 [0.07]	0.00 [0.01]	0.20* [0.11]	0.02 [0.17]	-0.23 [0.22]	0.04 [0.34]	2937
Medical care	0.32*** [0.06]	-0.02 [0.04]	0.00 [0.00]	0.40*** [0.08]	-0.12 [0.10]	0.65** [0.25]	-0.33 [0.28]	5796

Nondurables	-0.04 [0.10]	0.02 [0.09]	0.00 [0.01]	0.03 [0.15]	-0.11 [0.18]	0.01 [0.31]	-0.26 [0.38]	2606
Durables	0.70*** [0.18]	0.01 [0.08]	0.00 [0.01]	-0.15 [0.21]	0.21 [0.32]	0.04 [0.39]	0.01 [0.53]	1533
Repair	0.84** [0.35]	-0.04 [0.13]	-0.01 [0.01]	1.16*** [0.37]	-0.94* [0.49]	-0.14 [0.71]	-0.3 [0.98]	1132
Special occasion	0.22*** [0.06]	-0.02 [0.03]	0.00 [0.00]	0.08 [0.10]	-0.07 [0.10]	0.15 [0.20]	-0.11 [0.20]	4356
Gifts	0.30*** [0.07]	-0.04 [0.05]	0.00 [0.00]	-0.03 [0.11]	-0.04 [0.13]	0.48** [0.22]	-0.62** [0.28]	4772

Notes:

- (1) */**/*** significant at 10/5/1% level.
- (2) Figures in brackets are standard errors. Standard errors are clustered at the provincial level.
- (3) Estimated using the fixed effects IV regression for panel data and including the deviation of heat index from the long-run average and the squared deviation as additional regressors.
- (4) Other regressors include the head's age, a household type indicator, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, and year dummies.

7.0 ALTERNATIVE EXTREME WEATHER VARIABLE: TROPICAL CYCLONE DATA

The exercise above is repeated using extreme weather events, namely, the tropical cyclones that crossed the country. These are also collected by PAGASA and are listed in table 2A. To constitute the indicators, the provinces crossed by the tropical cyclones are identified. The provinces are then assigned the public storm warning signal (PSWS) number, which is based on the intensity, size of circulation and the forecast direction, and the speed of the tropical cyclone. PSWS1 means that the tropical cyclone will have winds of 30-60 kph and intermittent rains. PSWS2 means that the tropical cyclone will have winds greater than 60 kph and up to 100 kph. Winds may bring light to moderate damage. PSWS3 means that the tropical cyclone will have winds greater than 100 kph up to 185 kph. Winds may bring moderate to heavy damage in the agricultural and industrial sector. PSWS4 means that the tropical cyclone will have winds greater 185 kph. Winds may bring heavy damages. The number of tropical cyclones that crossed by PSWS is then counted for each province for 2003, 2006 and 2009. These consists the alternative proxy for extreme weather events. Just like the HI deviation, the tropical cyclone data are used either as instruments if income is endogenous or as additional regressors if income is exogenous.

7.1 Tests

The exogeneity of income is also tested and results are presented in the second column of table 5. The p-values indicate that income is endogenous for expenditures on rice, fruits, vegetables, fish, and juice; on broader categories of total food consumed at home and outside of home; and on broader categories of alcoholic and nonalcoholic beverages. Income is also endogenous for non-food items such as transportation, personal care, clothing, education, medical care, and repair.

The direct effect of the tropical cyclone indicators on the expenditure shares is also tested. Indicators for the number of tropical cyclones with signals number 1, number 2,

number 3, and number 4 are used as direct explanatory variables of each of the expenditure shares. The joint significance of the instruments, $H_0: \beta_{numtc_1} = \beta_{numtc_2} = \beta_{numtc_3} = \beta_{numtc_4} = 0$, is then tested and the p-values are presented in column three of table 5. Results show that the tropical cyclone indicators do not have a significant and independent effect on the listed expenditure items for which income is endogenous.

Table 5. Exogeneity of income and test for the direct effects of tropical cyclone indicators

	Exogeneity test $cov(income, \varepsilon) = 0$	Test for the direct effects of tropical cyclone data $H_0: \beta_{numtc_1} = \beta_{numtc_2} = \beta_{numtc_3} = \beta_{numtc_4} = 0$
Food items	Exogenous income	
Corn	0.21	
Fruit preparations	0.69	
Beans	0.13	
Total Meat	0.3	
Chicken	0.43	
Beef	0.38	
Pork	0.92	
Other meat	0.7	
Dairy	0.64	
Bottled	0.16	
Non-food items		
Tobacco	0.36	
Household Operation	0.49	
Recreation	0.37	
Nondurables	0.18	
Durables	0.65	
Taxes	0.31	
Special occasion	0.9	
Gifts	0.46	
Fuel items		
Charcoal	0.28	
Firewood	0.15	
Petroleum	0.14	
Electricity	0.28	
Candle	0.56	
Water	0.25	
Food items	Endogenous income	
Rice	0.00	0.46
Total fruits	0.00	0.49
Fresh fruits	0.00	0.79
Other vegetables	0.05	0.48
Vegetables	0.00	0.33
Fish	0.02	0.31
Juice	0.00	0.93
Nonalcoholic	0.00	0.30
Alcoholic	0.04	0.93
Food consumed at home	0.00	0.45
Food consumed outside	0.09	0.78
Non-food items		
Total non food	0.00	0.47
Fuel	0.00	0.15

Transportation	0.00	0.15
Personal Care	0.01	0.73
Clothing	0.13	0.67
Education	0.01	0.11
Medical care	0.01	0.41
Repair	0.05	0.34

Notes:

- (1) ***/*** significant at 10/5/1% level.
- (2) Figures in the second column are p-values to test that income is exogenous.
- (3) The test is conducted after the fixed effects IV regression for panel data. Income is instrumented by the number of tropical cyclones by signal warning. Number of TC_1, Number of TC_2, Number of TC_3, and Number of TC_4 are number of tropical cyclones with signal warning 1, 2, 3 and 4, respectively.
- (4) Figures in the third column are p-values of the F-test to test
 $H_0: \beta_{numtc_1} = \beta_{numtc_2} = \beta_{numtc_3} = \beta_{numtc_4} = 0$. Rejection of the null hypothesis indicates that the deviation of heat index from the long-run averages and the squared deviation are jointly significant in explaining expenditure shares. This means that the tropical cyclone data have a direct impact on expenditure shares and are, therefore, not valid instruments for income.
- (5) Estimated using the fixed effects IV regression for panel data. Standard errors are clustered at the provincial level. Regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, indicators for the presence of underschool-age children and the presence of the elderly, and year dummies.

It can be noted that there are more expenditure shares for which income is endogenous using the tropical cyclone data than using the HI deviation data. In particular, income is endogenous for several non-food items for which income is exogenous before. These include expenditures on transportation, personal care, clothing, education, medical care, and repair. Income is now exogenous for fuel items, however.

This result indicates that the effects of the unobservable characteristics differ depending on the weather events. For example, risk-aversion towards shocks is heightened for extreme weather events such as tropical cyclones, which are more destructive than the deviation of heat index from its normal values. Expectations and speed of adjustment to shocks also could have played a role. When households expect destructive weather events, spending patterns are revised faster than when weather events are not as destructive. This revision of spending patterns is most likely the case for households that rely on agricultural wages and on income sources such as backyard production and net share of crops. It can also be the case for households who rely on gifts and support from domestic sources.

7.2 Exogenous income assumption: Benchmark non-IV FE estimates

Results assuming that income is exogenous are presented in table 6 and are summarized below.

1. *Elasticity*. Based on the estimates, all expenditure shares are inelastic with respect to income. This means that a 1% increase in household income will lead to a less than 1% increase in expenditures.

2. *Significance*. Income significantly affects expenditures on rice, fruits, vegetables, fish, and juice. In particular, expenditures on these items decrease when income increases.

Among these food expenses, rice expenditures are the highest. Among the non-food expenditures, expenditures on transportation, clothing, medical services, special occasion, and gifts increase as income increases while expenses on total fuel and personal care decreases as income increases. Among the non-food expenditures, income has the highest effect on medical services.

3. *Necessity versus non-necessity.* Expenses on both goods are affected by income. However, an income change negatively affects expenses on necessity while it negatively or positively affects non-necessity.

4. *Location.* An income change negatively affects food consumption at home. It does not significantly affect food consumption outside of home.

5. *Presence of under-school age children and the elderly.* Young children positively affect expenditures on non-alcoholic beverages and negatively affect foods consumed outside of home. The presence of the elderly positively affects expenditures on vegetable and fuel while it negatively affects expenditures on alcoholic beverages and education. Young children in rural areas do not affect most of the expenditures. They negatively affect coffee expenditures relative to young children in urban areas, however. The elderly in the rural areas does not affect most of the expenditures. They negatively affect vegetable expenditures relative to the elderly in urban areas, however.

6. *Effect of weather-related variables.* The frequency of the occurrence of strong tropical cyclones negatively affects corn and beef expenditures while it positively affects expenses on chicken and other meat. Fuel items, such as firewood and electricity consumption, are negatively affected by frequent strong tropical cyclones.

Table 6. Estimates assuming the exogeneity of income, fixed effects regressions, tropical cyclone data as additional regressors

	Income	Number of TC_1	Number of TC_2	Number of TC_3	Number of TC_4	Underschool age kids	Underschool age kids*rural	Elderly	Elderly *rural	R2	Number of observations
Food items and beverages											
Rice	-0.43*** [0.03]	-0.01 [0.01]	0.01 [0.01]	0.01 [0.03]	-0.04* [0.02]	-0.02 [0.03]	0.02 [0.04]	-0.07 [0.04]	0.06 [0.10]	0.14	6068
Total Fruits	-0.12*** [0.02]	0.01 [0.01]	0.01 [0.01]	-0.02 [0.03]	0.01 [0.03]	-0.03 [0.02]	0.03 [0.04]	0.03 [0.05]	0.00 [0.06]	0.04	6263
Fresh fruits	-0.02 [0.04]	-0.01 [0.02]	0.01 [0.02]	-0.01 [0.04]	-0.03 [0.04]	0.01 [0.03]	0.00 [0.06]	0.07 [0.08]	-0.04 [0.09]	0.03	6221
Total Vegetables	-0.26*** [0.04]	0.02 [0.01]	-0.01 [0.02]	-0.07 [0.05]	0.06 [0.05]	-0.03 [0.03]	0.02 [0.05]	0.13** [0.06]	-0.26** [0.12]	0.04	6229
Beans	-0.16*** [0.04]	-0.02 [0.02]	0.02 [0.02]	-0.04 [0.04]	0.03 [0.04]	-0.06 [0.04]	0.01 [0.07]	0.03 [0.10]	-0.06 [0.15]	0.05	5792
Fish	-0.14*** [0.03]	0.00 [0.01]	0.01 [0.01]	-0.05 [0.03]	0.02 [0.03]	-0.03 [0.03]	0.01 [0.04]	0.08 [0.05]	-0.01 [0.10]	0.03	6258
Juice	-0.08 [0.06]	0.04* [0.02]	-0.01 [0.02]	-0.01 [0.07]	-0.08 [0.08]	-0.12* [0.07]	0.15** [0.07]	-0.01 [0.12]	0.08 [0.15]	0.02	4655
Coffee	-0.23***	0.00	-0.01	0.07*	-0.03	0.05	-0.12***	-0.03	0.02	0.03	6218

Nonalcoholic	[0.04]	[0.01]	[0.01]	[0.03]	[0.04]	[0.03]	[0.04]	[0.06]	[0.10]	0.03	5892
	0.06	-0.01	0.02	-0.01	-0.04	0.09**	-0.01	-0.01	0.01		
Alcoholic	[0.04]	[0.01]	[0.02]	[0.04]	[0.04]	[0.04]	[0.06]	[0.09]	[0.12]	0.02	4603
	0.06	0.09***	0.01	-0.01	-0.01	-0.02	-0.10	-0.27*	0.14		
Food consumed at home	[0.07]	[0.03]	[0.03]	[0.07]	[0.07]	[0.09]	[0.14]	[0.15]	[0.26]	0.16	6263
	-0.21***	0.00	0.00	0.01	-0.02*	0.02	0.00	0.01	0.03		
Food consumed outside	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.03]	[0.04]	0.04	4488
	0.04	0.05**	0.00	-0.03	0.03	-0.15**	-0.08	0.04	-0.06		
	[0.06]	[0.02]	[0.02]	[0.04]	[0.05]	[0.06]	[0.09]	[0.16]	[0.20]		
Non-food items											
Total non-food	0.14***	0.00	-0.01	0.00	0.01	-0.01	0.02	0.02	-0.03	0.1	6263
	[0.01]	[0.00]	[0.01]	[0.01]	[0.01]	[0.01]	[0.02]	[0.02]	[0.03]		
Fuel	-0.31***	0.00	-0.01**	0.00	0.02	-0.01	-0.04	0.10***	-0.08	0.11	6263
	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]	[0.02]	[0.04]	[0.03]	[0.09]		
Transport	0.15***	-0.02	0.00	0.06*	-0.09**	-0.04	0.05	-0.10	0.10	0.07	6208
	[0.04]	[0.01]	[0.01]	[0.03]	[0.03]	[0.04]	[0.05]	[0.08]	[0.09]		
Personal Care	-0.16***	0.00	0.00	0.01	-0.04**	-0.04	0.06	-0.01	-0.02	0.03	6260
	[0.02]	[0.01]	[0.01]	[0.02]	[0.02]	[0.02]	[0.04]	[0.05]	[0.09]		
Clothing	0.25***	-0.01	-0.02	0.03	0.05	0.01	0.07	0.13	-0.25*	0.06	6085
	[0.04]	[0.02]	[0.02]	[0.03]	[0.05]	[0.04]	[0.07]	[0.09]	[0.14]		
Education	-0.06	0.03	-0.05	0.13*	-0.07	-0.20***	0.12	-0.56**	0.04	0.03	4965
	[0.07]	[0.03]	[0.03]	[0.07]	[0.07]	[0.07]	[0.12]	[0.24]	[0.36]		
Medical care	0.38***	-0.03	-0.04	0.06	0.02	0.27***	0.10	0.26	0.33	0.03	5974
	[0.06]	[0.02]	[0.03]	[0.06]	[0.06]	[0.07]	[0.09]	[0.17]	[0.26]		
Repair	0.97***	-0.01	-0.12	0.24	-0.45*	0.20	1.07**	-0.3	0.11	0.14	1171
	[0.35]	[0.07]	[0.11]	[0.20]	[0.25]	[0.32]	[0.50]	[0.60]	[0.87]		
Special occasion	0.22***	0.02	-0.01	0.01	-0.01	0.02	0.09	0.07	0.09	0.01	4528
	[0.06]	[0.02]	[0.05]	[0.07]	[0.06]	[0.06]	[0.09]	[0.11]	[0.19]		
Gifts	0.33***	-0.03	0.03	0.12*	-0.07	-0.07	0.05	-0.07	0.37	0.03	4959
	[0.07]	[0.04]	[0.03]	[0.07]	[0.07]	[0.08]	[0.12]	[0.16]	[0.29]		

Notes:

- (1) */**/** significant at 10/5/1% level.
- (2) Figures in brackets are standard errors. Standard errors are clustered at the provincial level. Figures are estimates using the fixed effects IV regression for panel data.
- (3) Number of TC_1, Number of TC_2, Number of TC_3, and Number of TC_4 are number of tropical cyclones with signal warning 1, 2, 3 and 4, respectively.
- (4) Other regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, and year dummies.

7.3 Endogenous income based on the exogeneity test in table 5: IV-FE estimates

Results treating income as endogenous are presented in table 7. The following similarities to and differences from the benchmark estimates are noted below.

1. *Significance.* Similar to the benchmark non-IV FE presented in table 6, income significantly affects most of the expenditure items.

2. *Signs.* The benchmark non-IV FE predicts that the effect of income is negative on food items. This means that a rise in income without purging the effects of weather is likely

to decrease the amount of resources for these food items. In contrast, IV-FE estimates show that the effect of income on similar expenditure items is positive. Broad categories of foods consumed outside of home and at home also have their signs reversed. Signs are also reversed for expenditures such as transportation, personal care and medical care. Alcoholic and non-alcoholic beverages are significantly affected by an income change using the IV-FE while these are not significantly affected using the benchmark non-IV FE.

Looking closely at the results on IV-FE, Both expenditures on food and non-food items are affected by an income change. While food items are positively affected, rice, fruits, and fish are inelastic while vegetables, coffee, and juice are income elastic. Among the food items, juice expenditures have the highest positive response to an income change. Some non-food items are positively inelastic like personal care while others are negatively elastic like fuel, transportation, education, and medical care. Among the non-food items with negative elasticity, education expenditures have the highest responsiveness to an income change. Among the non-food items with positive elasticity, clothing expenditures have the highest responsiveness to an income change. Expenditures on vegetables and fruits are relatively more responsive than rice and fish. On the other hand, non-alcoholic beverages are more

3. *Presence of under-school age children and the elderly*. The presence of young children significantly affects most of the expenditure items using the IV-FE. Similar to the benchmark non-IV FE, the presence of the elderly does not significantly affect most of the expenditure items using the IV-FE. The presence of both in rural households does not have significant effects as well.

Looking closely at the results presented in table 7, the presence of young children significantly affects most of the expenditure items. In particular, it positively affects food expenses and it has the biggest impact on juice expenditures. It positively affects other non-food items such as personal care and clothing while it negatively affects fuel, transportation, and education. The presence of the elderly has no significant effect on most of the expenditure items. It has a negative effect on education and a positive effect on medical care. In addition, the presence of both groups in rural households does not have significant effects on expenditure items except on meat.

Table 7. Income as an endogenous determinant of expenditure share, fixed effects estimates, tropical cyclone data as instruments

	Income	Underschool age kids	Underschool age kids*rural	Elderly	Elderly *rural	N	Underid Test§	Overid test§§
Food items and beverages								
Total food	0.41** [0.17]	0.06** [0.03]	0.03 [0.02]	0.03 [0.04]	-0.07 [0.05]	6214	0.00	0.01
Rice	0.68* [0.38]	0.13** [0.06]	0.02 [0.05]	0.00 [0.09]	-0.12 [0.11]	5980	0.00	0.08
Total fruits	0.98*** [0.35]	0.13** [0.06]	0.01 [0.05]	0.04 [0.08]	-0.06 [0.10]	6214	0.00	0.39
Fresh fruits	1.63*** [0.54]	0.21** [0.09]	0.06 [0.07]	0.05 [0.12]	-0.05 [0.15]	6165	0.00	0.14

Vegetables	1.18**	0.17**	0.03	-0.13	0.20	6177	0.00	0.95
	[0.47]	[0.08]	[0.07]	[0.11]	[0.14]			
Beans	0.70	0.08	-0.02	-0.06	0.06	6059	0.00	0.00
	[0.43]	[0.07]	[0.06]	[0.10]	[0.13]			
Fish	0.52*	0.06	0.01	0.07	-0.02	6207	0.00	0.49
	[0.31]	[0.05]	[0.04]	[0.07]	[0.09]			
Juice	3.21***	0.45**	-0.05	0.13	-0.07	4284	0.02	0.23
	[1.21]	[0.19]	[0.15]	[0.24]	[0.32]			
Coffee	2.84***	0.45***	0.07	-0.01	-0.08	5778	0.00	0.11
	[0.84]	[0.14]	[0.11]	[0.18]	[0.23]			
Nonalcoholic	1.91*	0.01	0.23	-0.09	-0.26	4250	0.01	0.01
	[1.01]	[0.14]	[0.15]	[0.25]	[0.31]			
Alcoholic	0.41**	0.10***	0.02	0.05	-0.07	6214	0.00	0.03
	[0.18]	[0.03]	[0.03]	[0.04]	[0.05]			
Food consumed at home	0.98*	-0.14	0.11	0.00	0.07	4139	0.00	0.26
	[0.59]	[0.09]	[0.09]	[0.15]	[0.20]			
Food consumed outside	-0.46***	-0.06*	-0.04*	-0.02	0.07	6214	0.00	0.16
	[0.17]	[0.03]	[0.02]	[0.04]	[0.05]			
Non-food items								
Fuel	-1.69***	-0.22***	-0.01	0.01	0.16	6214	0.00	0.05
	[0.38]	[0.06]	[0.05]	[0.09]	[0.11]			
Transport	-1.33**	-0.18*	-0.10	-0.01	-0.01	6153	0.00	0.99
	[0.56]	[0.09]	[0.08]	[0.13]	[0.16]			
Personal Care	0.55*	0.11**	-0.04	-0.03	-0.02	6211	0.00	0.34
	[0.30]	[0.05]	[0.04]	[0.07]	[0.09]			
Clothing	1.04*	0.17*	-0.02	-0.1	0.20	6018	0.00	0.01
	[0.54]	[0.08]	[0.08]	[0.12]	[0.16]			
Education	-2.33**	-0.34**	-0.18	-0.67**	0.14	4703	0.02	0.29
	[1.13]	[0.16]	[0.13]	[0.30]	[0.37]			
Medical care	-1.95*	0.08	-0.15	0.53**	-0.13	5878	0.00	0.46
	[1.00]	[0.17]	[0.14]	[0.23]	[0.30]			
Repair	5.50*	1.70**	-0.82	-0.13	-0.05	507	0.39	0.92
	[3.18]	[0.82]	[0.68]	[0.88]	[1.43]			

Notes:

- (1) */**/** significant at 10/5/1% level.
- (2) Figures in brackets are standard errors.
- (3) Standard errors are clustered at the provincial level.
- (4) Estimated using fixed effects estimator and using and tropical cyclone data as instruments for income. Other regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, indicators for the presence of underschool-age children and the presence of the elderly, and year dummies.
- (5) §Tests the null hypothesis that the equation is under-identified, $cov(instrument, endogenousvariable) = 0$. Rejection of the null implies that the instruments are relevant; that is, the instrument induces change in the endogenous variable.
- (6) §§Tests the null hypothesis that the instruments are uncorrelated with the error term, $cov(instrument, error\ term) = 0$ and that the excluded instruments are correctly excluded from the estimated equation. Rejection of the null implies that the instruments are valid.

7.4 Exogenous income based on the exogeneity test in table 5: non-IV FE estimates

Table 8 presents the estimates of income for expenditure shares that are exogenous based on the exogeneity test presented in table 5. Results are summarized below.

1. *Food*. Based on the results, it can be noted that there is reallocation of income within food items. Food items are inelastic but some food items respond positively while others respond negatively to income. Expenditures on corn, fruit preparations, fruits, and vegetables and beans are negatively affected while total meat expenditures and beef expenses are positively affected by an income change.

2. *Sin goods*. Tobacco products are negatively affected by an income change.

3. *Non-food*. Most of the non-food items respond positively to an income change. These include expenditures on durables, special occasion, and gifts. Expenses on durables have the biggest response. Fuel items are also negatively affected by an income change.

4. *Weather-related variables*. The frequency of strong tropical cyclones (signals number 3 and number 2) positively affects the expenditures on food items such as corn, and fruits and vegetables. It also negatively affects the expenses on beef and positively affects expenses on chicken.

5. *Presence of under-school age children and the elderly*. The presence of young children and the presence of the elderly do not have a significant effect on most of the expenditure items.

Comparison between the benchmark non-IV FE and IV-FE show that treating income as exogenous results in estimates that are downward bias, thereby underestimating the effect of income on the household's resource allocation. Estimates are higher using the estimator that accounts for both endogeneity and unobserved heterogeneity. The direction of the estimates also differs for some of the expenditure items.

Based on the IV-FE, results show that food items are either positively elastic or positively inelastic while non-food items are either negatively elastic or positively elastic/inelastic. This suggests that budget is reallocated and the budget moves from non-food items (such as fuel, education, and medical care) to food items (such as rice, fish, fruits, and vegetables) and non-alcoholic beverages. Within food items, budget is allocated from fish and carbohydrate-rich foods (rice) to fruits and vegetables and coffee and juice. Budget reallocation also occurs from transportation, education, and medical services to personal care and repair. Results also point to the different needs of vulnerable groups like children and the elderly. The presence of young children significantly affects most of the expenditure items. In particular, it positively affects food expenses and it has the biggest impact on juice expenditures. It positively affects other non-food items such as personal care and clothing while it negatively affects fuel, transportation and education. The presence of the elderly has no significant effect on most of the expenditure items. However, it has a negative effect on education and a positive effect on medical care.

Based on the non-IV FE estimates, results show that food and non-food items are either positively inelastic or negatively inelastic, indicating that budget moves from fuel items to other non-food items (such as durables and gifts) and to food items (such as beef). Within food items, budget moves from carbohydrate-rich foods (beans, corn) to protein-rich foods (beef). Budget reallocation also occurs from fuel items to gifts and durables. Results also show that the presence of young children affects expenditures on dairy products while the presence of the elderly has no effect on the expenditure items considered.

Table 8. Fixed effects estimates of income for expenditure items for which income is exogenous , tropical cyclone data as additional explanatory variables

	Income	Number of TC_1	Number of TC_2	Number of TC_3	Number of TC_4	Underschool age kids	Underschool age kids*rural	Elderly	Elderly *rural	N
Food items										
Corn	-0.45*** [0.08]	-0.01 [0.04]	0.02 [0.03]	0.18** [0.08]	-0.09 [0.09]	-0.16* [0.10]	0.22 [0.13]	0.26 [0.33]	-0.2 [0.38]	3549
Fruit preparations	-0.12*** [0.02]	0.01 [0.01]	0.01 [0.01]	-0.02 [0.03]	0.01 [0.03]	-0.01 [0.03]	-0.03 [0.04]	0.03 [0.06]	0.00 [0.06]	6263
Beans	-0.16*** [0.04]	-0.02 [0.02]	0.02 [0.02]	-0.04 [0.04]	0.03 [0.04]	-0.04 [0.06]	-0.01 [0.07]	-0.03 [0.11]	0.06 [0.15]	5792
Total Meat	0.08** [0.03]	0.01 [0.01]	-0.01 [0.01]	0.00 [0.03]	0.01 [0.03]	-0.03 [0.04]	0.01 [0.04]	0.10 [0.09]	-0.12 [0.12]	6159
Chicken	-0.02 [0.05]	-0.01 [0.02]	0.00 [0.02]	0.07* [0.04]	-0.04 [0.04]	-0.02 [0.05]	-0.03 [0.06]	0.09 [0.13]	0.01 [0.16]	5884
Beef	0.26*** [0.07]	-0.02 [0.02]	-0.07*** [0.02]	0.04 [0.07]	0.01 [0.07]	0.03 [0.12]	0.02 [0.13]	-0.15 [0.25]	0.18 [0.31]	2974
Pork	0.04 [0.04]	0.01 [0.01]	-0.01 [0.01]	-0.01 [0.04]	0.03 [0.04]	0.03 [0.05]	0.03 [0.06]	0.04 [0.11]	-0.1 [0.14]	5826
Other meat	-0.02 [0.15]	-0.07 [0.08]	0.10** [0.04]	0.03 [0.11]	-0.11 [0.13]	-0.37 [0.32]	0.34 [0.32]	0.48 [0.42]	-0.09 [0.51]	957
Bottled	-0.33*** [0.11]	-0.07 [0.04]	0.03 [0.05]	-0.14 [0.13]	0.02 [0.12]	-0.04 [0.19]	-0.02 [0.31]	0.49 [0.37]	-0.1 [0.62]	1145
Dairy	-0.04 [0.04]	-0.03** [0.01]	-0.01 [0.02]	0.05 [0.04]	-0.05 [0.03]	0.42*** [0.04]	-0.05 [0.06]	0.15 [0.09]	-0.02 [0.13]	6181
Non-food items										
Tobacco	-0.10* [0.06]	0.00 [0.02]	0.02 [0.02]	-0.02 [0.05]	0.01 [0.06]	0.11 [0.09]	-0.13 [0.09]	0.00 [0.20]	-0.25 [0.26]	4393
Recreation	0.12 [0.08]	0.02 [0.03]	0.01 [0.04]	-0.01 [0.10]	0.13 [0.11]	0.21* [0.12]	0.03 [0.16]	-0.35 [0.23]	0.13 [0.33]	3065
Nondurables	-0.01 [0.10]	-0.05 [0.04]	-0.03 [0.04]	0.03 [0.09]	0.09 [0.10]	-0.04 [0.14]	-0.04 [0.16]	0.04 [0.28]	-0.24 [0.36]	2685
Durables	0.71*** [0.16]	0.07 [0.05]	-0.01 [0.07]	0.03 [0.16]	-0.19 [0.18]	-0.15 [0.20]	0.24 [0.30]	0.05 [0.38]	0.28 [0.50]	1609
Special occasion	0.22*** [0.06]	0.02 [0.02]	-0.01 [0.05]	0.01 [0.07]	-0.01 [0.06]	0.11 [0.09]	-0.09 [0.09]	0.15 [0.19]	-0.09 [0.19]	4528
Gifts	0.33*** [0.07]	-0.03 [0.04]	0.03 [0.03]	0.12* [0.07]	-0.07 [0.07]	-0.02 [0.10]	-0.05 [0.12]	0.3 [0.23]	-0.37 [0.29]	4959
Fuel items										
Charcoal	-0.34*** [0.08]	-0.02 [0.03]	0.00 [0.05]	-0.07 [0.10]	0.03 [0.11]	-0.09 [0.10]	0.04 [0.13]	0.08 [0.24]	-0.12 [0.23]	2466
Firewood	-0.41*** [0.05]	0.03 [0.02]	-0.04* [0.03]	-0.03 [0.07]	0.05 [0.06]	0.02 [0.10]	-0.08 [0.11]	-0.1 [0.25]	0.14 [0.25]	4339
Electricity	-0.28***	-0.01	-0.01	-0.06*	0.04	-0.02	0.05	0.01	0.08	5137

	[0.03]	[0.01]	[0.01]	[0.03]	[0.03]	[0.04]	[0.05]	[0.08]	[0.11]	
Candle	-0.16**	0.06*	-0.03	0.02	0.04	-0.02	0.08	0.07	0.02	3066
	[0.08]	[0.04]	[0.03]	[0.08]	[0.07]	[0.08]	[0.13]	[0.23]	[0.27]	
Water	-0.39***	-0.01	0.00	0.06	-0.07	-0.08	0.07	-0.12	-0.02	2935
	[0.06]	[0.02]	[0.02]	[0.05]	[0.05]	[0.06]	[0.10]	[0.20]	[0.27]	

Notes:

- (1) ***/*** significant at 10/5/1% level.
- (2) Figures in brackets are standard errors.
- (3) Estimated using the fixed effects IV regression for panel data and including the tropical cyclone data as additional regressors. Number of TC_1, Number of TC_2, Number of TC_3, and Number of TC_4 are number of tropical cyclones with signal warning 1, 2, 3 and 4, respectively.
- (4) Other regressors include the head's age, an indicator for nuclear household, number of household members that are employed, an indicator if the spouse is employed, the two asset scores generated by the principal component analysis, and year dummies.

8.0 SUMMARY AND CONCLUSIONS

This paper analyzes the effects of weather events on the welfare of the Philippine households. The estimation strategy is two-pronged. The fixed effects estimator is used to remove the unobserved heterogeneity. The non-IV FE is used on expenditure items for which income is exogenous and the IV-FE on expenditure items for which income is endogenous. To address the endogeneity of income, two sets of instruments are used: the deviation of heat index from its normal values and the number of tropical cyclones that crossed the provinces.

In general, results indicate that treating income as an exogenous variable leads to estimates that are downward bias and it underestimates the effect of income on the household's resource allocation. The bias comes from the unobservable characteristics and its correlation with income and expenditures. For example, strong aversion to shocks will likely cause a downward revision on consumption patterns and will likely drive households to seek more income-generating opportunities to earn higher income. Similarly, expectations of poor harvest/business will likely drive households to revise their consumption patterns downwards. These same negative expectations will likely drive households to become more aggressive in seeking additional income from sources like gifts and supports, by engaging in entrepreneurial activities or by sending other family members to the labor market.

The comparison between the use of HI deviation and tropical cyclone as instruments to income yield some interesting insights as well. There are more expenditure shares for which income is endogenous using the tropical cyclone data than using the HI deviation data. In particular, income is endogenous for several non-food items for which income is exogenous before. This result indicates that the effects of the unobservable characteristics differ depending on the weather events. Risk-aversion towards shocks is heightened for more destructive weather events such as tropical cyclones and the speed of adjustment to these shocks could lead to a faster revision of consumption patterns. This revision is most likely the case for households that rely on certain sources such as agricultural wages, backyard production, and gifts and support from domestic sources.

Results from table 4 show that weather variability, like the HI deviation, does not significantly affect any of the expenditure items. Results from table 8 show that extreme

weather events like tropical cyclones affect food expenditures. Households appear to substitute cheaper food items like chicken for the more expensive foods like beef. Households consume more corn, fruits, and vegetables as well.

Results show that budget moves from one item to another. Using HI deviation as a proxy for weather fluctuation, reallocation appears to move from carbohydrate-rich foods to fish and protein-rich foods. Reallocation also occurs from fuel/energy items to transportation, clothing, recreation, medical care, durable items, repair, and special occasions. Using tropical cyclone as a proxy for weather fluctuation, reallocation between food items goes from carbohydrate-rich foods to fruits and vegetables, coffee, and juice (IV-FE) or to protein-rich foods (non-IV FE). Budget reallocation also occurs from transportation, education, and medical services to personal care and repair (IV-FE) and from fuel items to gifts and durables (non-IV FE).

Results also point to the different needs of vulnerable groups like the children and the elderly. Compared with the presence of the elderly, the presence of under-school age children affects more food items in the IV-FE estimation using HI deviation as a proxy for weather fluctuation. Expenditures on dairy products are affected more by the presence of young children while expenditures on medical services are affected more by the presence of the elderly. Using IV-FE estimator and tropical cyclone data as proxies for weather fluctuations, the presence of young children significantly affects most of the expenditure items while the presence of the elderly negatively affects expenses on education and positively affects expenses on medical care. Using non-IV FE estimator and tropical cyclone data as proxies for weather fluctuations, presence of young children affects expenditures on dairy products while the presence of the elderly has no effect on the expenditure items considered.

These results indicate that using either the IV-FE (for expenditures in which income is endogenous) or the non-IV FE estimator (for expenditures in which income is exogenous) yields similar conclusions: one, budget moves away from carbohydrate-rich food items and two, the presence of the elderly and the presence of under-school age children have different effects on the household expenditures. The presence of under-school age children affects the expenditures of most food items while the presence of the elderly affects expenditures on medical services. Although the results above are based on a simple utility maximization framework, it may be plausible to speculate that weather events may interact with habit persistence in consumption- or the idea that the evolution of consumption may be affected by past consumption. Households differ in the way they maximize their objective functions most possibly because they face different constraints. If the habit stocks evolve so that future stocks persistently depend on past stocks, then the relationship between expenditure shares and income would be stable. It is possible that the parameters in their respective preference structures may or may not be perturbed when income changes.

Consider the case of households with the elderly, an arrangement that is well accepted in the Philippine society. While the overall preference of the household may be influenced or guided by the needs of the elderly, the insignificant effects of the elderly across expenditure item shares may reflect the stability of their consumption patterns. In contrast, children's stock of consumption habits is still evolving, implying that their demand patterns may still change. It is expected that their presence in the household would increase the allocation to

staples, such as rice, and healthy foods, such as vegetables and fruits. Children's habit stocks may not be as persistent as that of the elderly's. Children do form habits but as they grow up, their stock of habits starts to diversify and evolve. This may have significant effects on how households allocate over time. While not exhaustive, this may provide explanations as to why certain food items such as vegetables and non-alcoholic beverages showed highly elastic responses to changes in income.

Understanding how households allocate their resources is an important component of formulating policies to abate the effects of weather variability and possibly extreme weather events. For example, the study shows that households choose cheaper foods but just as nutritious when they are frequently hit by tropical cyclones. Policies to help the poultry industry, such as granting of input subsidy, will stave off the price increase resulting from the damages of tropical cyclones. While the consumption patterns of the elderly are stable, their presence in the household affects the expenditures on medical care. Under the Republic Act No. 9994 and the Republic Act No. 10645, the senior citizens are granted several benefits including discounts on medical services. Government agencies should strengthen the monitoring of compliance and enforce penalties to establishments that refuse compliance. Non-compliance is very common in small establishments in the provinces and rural areas. In general, the study points not only to the role of the strict enforcement of existing government laws for the elderly but also to the strict enforcement of suggested retail prices of staple goods especially in the provinces that are frequently visited by tropical cyclones.

In broader terms, the study points to the desirability of greater forms of investment in resilience against weather events and climate change. Infrastructures are constantly exposed to weather events and investments in high quality roads, seawalls, dams, and drainage system ensure minimal disruption to the delivery of basic services, such as education and health, to affected communities. Weather events can also bring severe health consequences. Floods aid the proliferation of vector-borne or water-borne diseases and extreme hot or cold temperature increases mortality. Barangay health centers should have adequate supplies of medicines and skilled medical staffs. At the household level, poverty is a binding constraint to good investment in resilience against weather events. In 2015, the country has around 22% of its population below the national poverty threshold and the adaptation of the poor population to weather events and to climate change would prove to be difficult. Building houses with good insulation and investment in good air conditioning appliances come at a cost. Households' inability to immediately obtain medical attention is equally costly. Therefore, the government has to continue its efforts towards poverty reduction. To this end, the government should ensure that the Department of Social Welfare and Development internal and external convergence strategy is implemented.

This paper is the first cut in analyzing the effects of weather events on the household welfare in the Philippines. While results yield interesting insights, some caveats are worth bearing in mind. One, the study was not able to explicitly control for insurance against shocks due to data limitation. Two, the way that the panel data were constructed could have excluded households whose optimal response to adverse events was for household head to migrate. Given the data limitation, the findings should be interpreted with the assumption that migration is not a common behavioural response among households. Three, the study did not analyze if past weather events affect current consumption. The consequence of such omission

may be less in the case of heat index deviation than it is in the case of tropical cyclones. These limitations open up new avenues for future research. In addition, a more detailed analysis can be done on fuel expenditures, which appears robustly significant across samples and estimators. Understanding the dynamics of the resource allocation to different sources of fuel is informative in light of the climate change. Energy is one sector that is going to be heavily affected by such phenomenon. Another avenue is to analyze the effects of weather events on detailed income sources. This paper used the aggregate household income and disaggregating this into different sources can shed interesting results as well. In addition, future research using the FIES can address the probable bias resulting from the restrictions done on the final samples. The PSA should also start collecting the FIES data that can be genuinely merged to form a panel dataset.

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APPENDICES

Appendix 1. Mapping of PAGASA weather data and FIES

A	B	Distance (B-A): in km.	Remarks	
Province	Weather station (WS) Location	Assigned WS		
Abra		Sinait	93	The distance between Bangued Abra and the WS in Tuguegarao is 105 km.
Agusan del Norte	Butuan City			
Agusan del Sur		Butuan City	70	Note that this is the distance between two provinces
Aklan		Roxas City	80	The distance between Roxas City, WVisayas and Kalibo, Aklan is 80km
Albay	Legaspi City			
Antique				The distance between Roxas City and San Jose, Antique is 216km; between Iloilo City and San Jose is 97km
Basilan		Iloilo City	97	
		Zamboanga	84	The distance between Basilan and Zamboanga WS is 84km
Bataan				The distance between Balanga, Bataan and Subic Bay freeport is 52; Iba, Zambales to Balanga is 126km.
Bataan		Cubi Point	52	
Batanes	Itbayat; Basco Radar & Synop			
Batangas	Ambulong			
Benguet	Baguio City			
Bohol	Tagbilaran			
Bukidnon	Malaybalay			
Bulacan		Science Garden	40	The distance between Bulacan and Science garden in QC is 40km.
Cagayan	Aparri; Calayan; Tuguegarao			
Camarines Norte	Daet			
Camarines Sur	Virac Radar & Synop			
Camiguin				The distance between Butuan City and Camiguin is 156km; between CDO and Camiguin is 127; Lumbia airport and Camiguin is 136km
Capiz	Roxas City	Cagayan de Oro	127	
Catanduanes				The distance between SW Legaspi City and Catanduanes is 129km; SW Daet and Catanduanes is 286km
Catanduanes		Legaspi City	129	
Cavite	Sangley Point			
Cebu	Mactan Int Airport			
Davao		Davao City	128	The distance between WS Davao City and Davao Region is 128.
Davao de Sur	Davao City			
Davao Oriental		Davao City	172	The distance between WS Davao City and Mati, Davao Oriental.
Eastern Samar	Guiuan			
Ifugao				The distance between Tuguegarao, Cagayan and Ifugao is 204km; Sinait and Ifugao 383km; Baguio and Ifugao 183km
Ifugao		Baguio City	183	
Ilocos Norte	Laoag City			
Ilocos Sur	Sinait			
Iloilo	Iloilo City			
Isabela				The distance between Tuguegarao, Cagayan and Isabela boundary is 100km; between Santiago city and Tuguegaro 126km.
Isabela		Tuguegarao	100	
Kalinga		Tuguegarao		
La Union		Baguio City	64	The distance between San Fernando La Union and Baguio is 64km.
Laguna				The distance between Sangley and Sta Rosa is 43km; between Sangley and Los Banos IS 73
Laguna		Sangley point	73	
Lanao del Norte				The distance between WS Malaybalay Bukidnon and Iligan City in Lanao del Norte is 183km; between CDO and Iligan City 91km.
Lanao del Norte		Cagayan de Oro	91	
Lanao del Sur		Cagayan de Oro		the distance between Marawi City, Lanao del Sur and CDO is 101km.
Leyte	Tacloban City			
Maguindanao	Cotabato City			
Manila	Port Area			

Marinduque		Tayabas	86	The distance between WS Tayabas and Marinduque is 86km; Infanta to Marinduque is 204km; Alabat to Marinduque 167km.
Masbate	Masbate			
Misamis Occidental		Cagayan de Oro	186	The distance between Cagayan de Oro and Misamis Occidental is 186km; Lumbia airport and Misamis Occ is 192km.
Misamis Oriental	Cagayan de Oro; Lumbia Airport			
Mountain Province		Tuguegarao		
Negros Occidental		Dumaguete	88	The distance between Dumaguete, N Oriental and Negros Occ is 167km; Iloilo City and Negros Occ is 88km.
Negros Oriental	Dumaguete			
Northern Samar	Catarman			
Nueva Ecija	Cabanatuan			
Nueva Vizcaya		Baguio City	131	The distance between WS Baguio and Bayombong, N Viscaya is 131km; Cabanatuan and Bayombong 147km.
Occidental Mindoro	San Jose			
Oriental Mindoro	Calapan			
Palawan	Coron; Cuyo; Ouerto Princesa			
Pampanga	Clark Int Airport			
Pangasinan	Dagupan			
Quezon	Alabat; Infanta; Tayabas			
Quirino		Tuguegarao	66	The distance between WS Tuguegarao and Quirino is 66km.
Rizal	Tanay			
Romblon	Romblon			
Samar (Western)	Catbalogan			
Sorsogon		Legaspi City	60	The distance between legaspi city and sorsogon is 60km.
South Cotabato	General Santos			
Southern Leyte	Maasin			
Sultan Kudarat		Cotabato City		
Sulu		Zamboanga	185	The distance between Zamboanga and Tawi-tawi is 185km.
Surigao del Norte	Surigao			
Surigao del Sur	Hinatuan			
Tarlac		Cabanatuan City	51	The distance between Tarlac City and Cabanatuan is 51km.
Tawi-tawi		Zamboanga	185	The distance between Zamboanga and Tawi-tawi is 185km.
Zambales	Iba; Cubi Point, Subic Bay			
Zamboanga del Norte	Dipolog			
Zamboanga del Sur	Zamboanga			
NCR-2nd Dist.	Science Garden			
NCR-3rd Dist.		Science Garden		3rd district includes CAMANAVA cities
NCR-4th Dist.		NAIA		4th district includes Makati, Pasay, Pateros, etc
Aurora	Baler Synop & Radar; Casiguran			
Biliran		Tacloban City		The distance between Tacloban city and Biliran is 98km.
Guimaras		Iloilo City	26	
Sarangani		General Santos	39	
Apayao		Aparri, Cagayan		
Compostela Valley		Davao City	130	Davao City is the closest WS to Compostela.
Zamboanga Sibugay		Zamboanga	92	
Isabela City		Zamboanga	31	
Cotabato City	Cotabato City			

Appendix 2. List of tropical cyclones that crossed the country

2009

TY Kiko	03-09 August
TD Gorio	09-10 July
TS Isang	14-18 July
TS Jolina	30 July- 02 August
TS Feria	23-26 June
TY Dante	01-05 May
TY Emong	06-09 May
TD Urduja	23-25 November
TY Santi	28 October -01 November
TD Maring	08-09 September
TS Nando	12-13 September
TS Ondoy	24-27 September
TY Pepeng	30 September -10 October

2006

TY Seniang	7-12 December
TS Henry	28 July -02 August
TS Domeng	24-27 June
TY Caloy	09-15 May
TY Reming	28 November-03 December
TY Queenie	8-12 November
TY Paeng	27-31 October
TY Milenyo	25-29 September

2003

Typhoon Amang	16-24 April
Typhoon Onyok	29 August-02 September
Typhoon Nina	20-24 August
TD Zigzag	25-28 December
TS Gilas	15-20 July
STY Harurot	19-23 July
TY Egay	13-18 June
TS Chedeng	25-30 May
TS Weng	12-15 November
TS Viring	30 October-04 November
TD Quiel	15-19 September

Source: From <https://kidlat.pagasa.dost.gov.ph/index.php/learning-tools/724-classification-of-tropical-cyclones>:

Note: **Tropical depression (TD)** is a tropical cyclone with maximum sustained winds of up to 61 kilometers per hour (kph) or less than 33 nautical miles per hour (knots).

Tropical Storm (TS) - a tropical cyclone with maximum wind speed of 62 to 88 kph or 34 - 47 knots.

Typhoon (TY) - a tropical cyclone with maximum wind speed of 118 to 220 kph or 64 - 120 knots.

Super typhoon (STY), a tropical cyclone with maximum wind speed exceeding 220 kph or more than 120 knots.