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Nguyen Viet Cuong^{*}

Abstract

Diarrhea is one of the main causes of mortality for under five-year-old children, and this disease can be attributed to deficient hygiene. sanitation. and water supply. Detailed data on piped water and sanitation is very important for targeting, monitoring, and evaluating antipoverty programs. In this study, using a small area estimation method, we estimate per capita expenditure, the poverty rate, and the rates of households with piped water, improved latrines, and hand washing with soap at the provincial and district level in rural Vietnam. It shows that poorer provinces and districts tend to have remarkably lower access to piped water and improved latrine. Provinces in the Northern Mountain and Central Highlands have the lowest proportion of access to piped water and sanitation. There is a great spatial variation in poverty and access to water and sanitation. Within the same provinces, the level of poverty and access to water and sanitation varies largely across districts.

Keywords: Small area estimation, poverty, sanitation, household survey, population census.

JEL: C13; C83; I32; C88.

1. Introduction

Ithough, the worldwide under fivevear-old child mortality rate dropped significantly over time, it is estimated that around 5.2 million children under 5 years of age died in 2019 (Sharrow et al., 2022). Global deaths from diarrhea among under five vear-old children were estimated to account for 19% of total child deaths (Boschi-Pinto et al., 2008), and this massive disease burden is attributed to deficient hygiene, sanitation, and water supply (Bartram and Cairncross, 2010). The importance of sanitation conditions in people's health has been studied substantially in the literature (Bartram et al., 2014), particularly on children's health (Günther and Fink, 2010, Andres et al., 2017; Bohra et al., 2017). Recently, using cross-country data, Headey, and Palloni (2019) show that piped water and better sanitation are associated with reduction in child stunting, diarrhea prevalence and child mortality. Yet, there is still a large proportion of people who do not

International School, Vietnam National University, Hanoi, Vietnam;

Thang Long Institute of Mathematics and Applied Sciences (TIMAS), Thang Long University, Hanoi, Vietnam

have access to it. According to an estimate from the World Bank (2015), 33% of the world population did not have access to improved latrines in 2015.

Most countries have implemented programs to promote access to hygienic or sanitary latrines. An important question in sanitation-supporting programs as well as all targeted programs is how to identify beneficiaries. More detailed information on beneficiaries increases the effectiveness of targeted programs (e.g., Bigman and Fofack (2000) and Elbers et al. (2007)). However, estimation of indicators of living standards such as poverty or sanitation rate in the small areas is challenging. Information on living standard indicators such as poverty is often available from sampled surveys, which are not representative in the small areas. On the other hand, large surveys such as population censuses can be representative in provinces or districts, but these surveys contain only data on basic demographic characteristics and housing conditions but not data on living standard indicators such as income or expenditure.

The problem of data on welfare indicators in small areas can be solved by a small area estimation method. Elbers *et al.* (2002, 2003) propose a method to estimate poverty as well as other welfare indicators in small geographical areas by combining a household survey and a census. The main idea of the method can be described as a two-step procedure. Firstly, a functional relation between expenditure and household characteristics is estimated using data from a household survey. Secondly, this estimated relation is applied in a census to predict expenditure and poverty in small areas such as districts. This method is widely applied to estimate disaggregated welfare indicators including poverty. It has been used in around 40 countries in the world to predict the poverty and other social-economic indicators (Bedi et al. 2007). Poverty maps estimated by this method have been applied and used in poverty monitoring and evaluation, targeting of intervention programs, and administrative management, etc. (see Bedi *et al.*, 2007 for review of applications).

Vietnam has been successful in poverty reduction during the recent decades. A large number of poverty reduction programs have been implemented. Poverty rates have declined remarkably from 58% from 1993 to 14% in 2014 and 7% in 2018.¹ However, there is a large gap in living standards between urban and rural areas. In 2018, the poverty rate was only at 1% in urban areas, while this rate was 10% in rural ones. Access to piped water and sanitation was only limited for rural population. The proportion of rural households with piped water was only 17% in 2014 (this rate for urban households was 71%). In 2018, this proportion was 25% for rural households (compared with 79% for urban households). In 2018 around 76% of rural households had access to improved latrines, compared with more than 97% of urban households with improved latrines. The government of Vietnam, international and domestic organizations have implemented numerous targeted programs to increase people's living standards. Data on living standards of households in small areas are very important for targeting, monitoring and evaluating the targeted programs. Construction of poverty and water and sanitation geographical maps, especially for rural areas, is a valuable advocacy tool

¹ These figures are estimated using Vietnam Living Standard Survey in 1998, Vietnam Household Living Standard Surveys (VHLSS) in 2014 and 2018.

to assist planning and budgeting targeted programs.

This study aims to estimate several indicators of living standards in small areas using the small area estimation method in Vietnam. The small area method is widely used to calculate disaggregated welfare indicators, such as poverty and nutrition intakes (see Bedi et al., 2007 and Rao and Molina, 2015 for review).² Regarding the estimation of WASH, small area estimation has been applied in a few recent studies such as Nguyen (2017), Mokobane (2019), and Ajisegiri et al. (2019). For the case of Vietnam, there are a number of studies which estimate the poverty and inequality in small areas in Vietnam such as Minot et al. (2003), Nguyen (2012), Lanjouw et al. (2017), and Bui and Nguyen (2017). To our understanding, there have been no studies on geographical maps of sanitation in Vietnam. In this study, we use more updated data to estimate living standard indicators of provinces and districts for the year 2014. In addition, we will estimate not only the expenditure mean and the poverty rate but also rates of households with sanitation, hand washing with soap and piped water. We focus on rural Vietnam, since rural households have high poverty and limited access to piped water and sanitation.

The remainder of this paper is structured into five sections. The second section presents the data sets used in this study. The third and fourth sections present specific estimation methods and empirical results of the estimation of expenditure, rates of poverty, sanitation, hand washing with soap Spatial Patterns of Piped Water and Sanitation in Rural Vietnam: An Application of Small Area Estimation

and piped water in rural Vietnam. Finally, the fifth section presents the conclusion.

2. Data sets

This study relies on three data sets. The first dataset is the 2014 Intercensal Population and Housing Survey (henceforth referred to as the 2014 IPS). The 2014 IPS was conducted by GSO. The number of sampled households is 1,114,007. The sample size is around 5% of the total population, and it is representative at the district level. There is one important point of the 2014 IPS that should be noted. The 2014 IPS contains two samples. The 4% sample includes data on age and gender of household members, and the basic characteristics of housing such as types and age of house, living areas, materials of wall and roof. The 1% sample contains more detailed data. In addition to data like the 4% sample, it contains data on education, marital status of household members, ownership of house, the number of rooms, energy sources, used in lighting and cooking, water sources, flush latrine, and ownership of several durables such as television, computer, vehicles, etc.

The second data set is the Vietnam Household Living Standard Survey in 2014 (henceforth referred to as the 2014 VHLSS). The 2014 VHLSSs were conducted in 2014 by GSO with technical support from the World Bank in Vietnam. It includes very detailed data on individuals, households and communes. Individual data consist of information on demographics, education, employment, health, migration. Household data are on durables, assets, production, income and expenditure, and participation in government

² In Viet Nam, this method is wide applied in Vietnam to estimate the poverty and inequality (Minot *et al.*, 2003; Minot and Baulch, 2015; Nguyen et al., 2010; Nguyen, 2011; Nguyen, 2012; and Lanjouw et al., 2017; Nguyen et al., 2017); disability (Mont and Nguyen, 2018); improved latrines (Nguyen, 2017); governance index (Jairo et al., 2015); household business index (Nguyen et al., 2012); and electricity consumption (Nguyen et al., 2021).

programs. There are questions on latrine types used by households. The 2014 VHLSS covered 9,399 households.

The third data set is the Vietnam Multiple Indicator Cluster Survey (henceforth referred to as the 2014 MICS), which was conducted from in 2014 by GSO with financial and technical support from United Nations Children's Fund (UNICEF) and the United Nations Population Fund (UNFPA) in Vietnam. The 2014 MICS contains detailed data on characteristics of children and women in Vietnam. The 2014 MICS also contains data on household living standard including assets, durables, and housing conditions. We have to use this data set in this study, since it contains data on hand washing with soap. The 2014 VHLSS does not contain this information. The 2014 MICS is representative in the urban/rural areas and regions. The number of households sampled in the 2014 MICS is 10.200 households.

3. Small area estimation method

Although the 2014 MICS and the 2014 VHLSS contain data on expenditure, improved latrines, piped water and hand washing with soap, they do not have a large sample to generate the estimates in the small areas such as districts. In this study, we apply the Elbers et al. (2002, 2003) method to combine the 2014 VHLSS with the 2014 IPS to estimate expenditure, poverty, the proportion of households with improved latrines and piped water at the provincial and district levels in 2014. Then we use the 2014 MICS and the 2014 IPS to estimate of the rate of hand washing with soap at the provincial and district levels.

3.1. Estimation of per capita expenditure and poverty

In this study, to estimate per capita expenditure and poverty at the provincial and district level, we use the standard method the Elbers et al. (2002, 2003) combining the 2014 VHLSS and the 2014 IPS. The method can be described by three steps as follows. In the first step, we select common variables of a household survey and a census. The common variables include household demographics, housing conditions, and durables.

In the second step, we regress the variable of the dependent variable, which is a variable of interest such as log of per capita expenditure or availability of improved latrine in households, on the selected common variables using data from the survey. More specifically, we estimate the following model:

$$Log(Y_{ic}) = \alpha + X_{ic}\beta + \eta_c + \varepsilon_{ic}$$
(1)

where Y_{ic} is per capita expenditure of household *i* in cluster *c*, X_{ic} the vector of the common variables, β the vector of regression coefficients, η_c the cluster-specific random effect and ε_{ic} the individual-specific random effect. The subscript *ic* refers household *i* living in cluster *c*.

In the third step, we use the predicted model to estimate per capita expenditure of households in the census:

$$\hat{Y}_{ic} = \exp(\hat{\alpha} + X_{ic}^{Census}\hat{\beta} + \hat{\eta}_c + \hat{\varepsilon}_{ic})$$
(2)

where $\hat{\alpha}$, $\hat{\beta}$, $\hat{\eta}_c$ and $\hat{\varepsilon}_{ic}$ denote the estimates for β , η_c and ε_{ic} . The predicted \hat{Y}_{ic} are used to compute the means of the dependent variable in small areas such as districts. The predicted expenditure is also used to estimate the poverty rate of small areas. The point estimates as well as the standard errors of the satisfaction level are calculated by Monte-Carlo simulations.

3.2. Estimation of improved latrine, piped water and hand washing with soap

The dependent variables in this case are binary variables indicating whether households use improved latrines, piped waters for drinking, and hand washing with soap. The small area method in this case is similar to the case of estimating expenditure and poverty. However, unlike log of expenditure, the dependent variables are binary, and we use a probit model as follows:

$$\Pr(Y_{ic} = 1 \mid X) = \Phi(\theta + X_{ic}\delta)$$
(3)

where $\Pr(Y_{ic} = 1 | X)$ is a dependent variable of household *i* in cluster *c*, denoting the probability of having improved latrines. Φ is the cumulative distribution function of the standard normal distribution. X_{ic} the vector of the common variables like those in equation (1). Equation (3) is estimated by maximum likelihood. We use similar specifications to estimate the probability of households having piped water as well as the probability of households having hand washing with soap.

We use a nonparametric bootstrap technique instead of simulation techniques of Elbers et al. (2002, 2003) to estimate standard errors. Specifically, we resample clusters (villages) in both the household survey and the population census, and estimated the probit model of improved latrines using the resampled household survey and apply it to the resampled census to get the estimate at the district level. After 200 simulations, we obtained the distribution of district-level estimates and use this distribution to estimate standard errors.

For sensitivity analysis, we also estimate (3) using linear probability models and apply the standard models of Elbers et al. (2002, 2003) in computing the standard errors. The Spatial Patterns of Piped Water and Sanitation in Rural Vietnam: An Application of Small Area Estimation

probit model and linear probability model produces very similar estimates. Since the probit model yields lower standard errors, we use the results from the probit model for interpretation.

We combine different surveys and the 2014 IPS to estimate the coverage of improved latrines, piped water and handwashing with soap. Specifically, we combine the 2014 VHLSS and the 2014 IPS to estimate the coverage of improved latrines. We first use the 2014 VHLSS to model the probability of households having improved latrines and apply this model to the 2014 IPS to estimate the rate of households.

Regarding piped water, we use the 1% sample of the 2014 IPS to model the probability of households having piped water, and then apply this model to the 4% sample to predict the probability of households having piped water in this 4% sample. We pool actual data on piped water in the 1% sample and predicted data on piped water in the 4% sample to estimate the proportion of piped water at the provincial and district levels. It should be noted that we use the 1% sample of the 2014 IPS instead of the 2014 VHLSS to model the probability of piped waters since the 1% sample of the 2014 IPS is more comparable with the 4% sample of the 2014 IPS. The two samples were conducted by the same team of interviewers in the same time period.

Data on hand washing with soap are available in the 2014 MICS (not in the 2014 VHLSS as well as the 1% sample of the 2014 IPS). Hand washing with soap is defined at the household level. Based on the availability of data, a household is defined to have hand washing with soap if they have water, a handwashing facility, and soap or detergent at washing places. For province and district

estimates, we combine the 2014 MICS and the 2014 IPS. We estimate a probit model of handwashing with soap using data from the 2014 MICS and apply this estimated model to the 2014 IPS to predict the proportion of households with handwashing with soap at the provincial and district levels.

4. Empirical results

The first step in the small area estimation method is to define the dependent and select explanatory variables in regression models. Table 1 presents a definition of the dependent variables in this study.

The next step is to select common explanatory variables in the regression models. These variables should meet the following criteria:

- Available in both the household survey and the census.
- Household survey and census are comparable (in terms of both questionnaires similarity and summary statistics similarity).
- Sufficiently correlated with household expenditure or income.

After carefully screening the questionnaires and examining the data (comparing summary statistics), we selected 43 common household variables in the 2014 VHLSS and the 2014 IPS (Table A.1 in Appendix). We also constructed commune level data from the census and merged these variables with the household survey. For example, we construct the percentage of Kinh people of communes, the average household size of communes, the proportion of households having motorbike, etc. Note that these variables are comparable by construction.

There are four regression models corresponding to the four dependent variables: log of expenditure per capita, the use of improved latrine, the use of piped water, and hand-washing with soap. Poverty is estimated using predicted per capita expenditure. For each model, we tried different regressions, e.g., one regression for one region or one regression for two regions. We tried a large number of model specifications to examine the sensitivity of the estimates to the set of explanatory variables. We select models which have robust and low standard errors of the estimates. In this report, we will present the final models which are used to estimate the indicators in small areas. The regression results are lengthy, and we put them in the Appendix (Tables A.2 to A.10). Overall, the

Name	Туре	Definition
Log of per capita expenditure	Continuous	Total expenditure of household divided by the number of household members
Poverty status	Binary	Poor if per capita expenditure below 11,563 thousand VND/person/ year
Improved latrine	Binary	Households using latrines, which include Septic/semi-septic tank; Flush/soak pit; Improved toilet with vent; Double septic tank
Piped water	Binary	Household using piped water for drinking
Hand-washing with soap	Binary	Households have water, a hand-washing facility, and soap or detergent at washing places

Table	1.	Dependent	variables
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R-squared as well as pseudo R-squared are very high.

After estimating the models of expenditure, improved latrines, piped water, and handwashing with soaps, we apply these models to the 2014 IPS to estimate the dependent variables at small areas. Table 2 presents the estimates of dependent variables of the six regions in rural Vietnam. The per capita expenditure of rural households was 22,229 thousand VND in 2014. The poverty rate was 18.6%. The proportion of households using improved latrines and the proportion of households using piped waters were 72.2% and 16.1%. The proportion of households with handwashing with soap was 81.3%. Midlands and Northern Mountains was the poorest region, while Southeast was the richest one.

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Interestingly, Mekong River Delta has higher per capita expenditure and lower poverty than Northern Mountains and Central Highlands, but Mekong River Delta has the lowest rate of improved latrines.

Table 3 presents by province the predicted per capita expenditure and poverty rate in rural Vietnam. The poorest region is Northern Mountain, then followed by Central Highlands. Lai Chau, Dien Bien, Son La are three poorest provinces with a poverty rate of nearly 70%. As expected, Hanoi and Ho Chi Minh city are the richest cities.

Table 4 presents the rate of households with improved latrines, the rate of households with piped waters, and the rate of households with hand-washing with soap at the provincial level. There is a great variation in the

Region	Per capita expenditure of rural households	Percentage of rural poor households	Percentage of rural households with improved latrines	Percentage of rural households with piped water	Percentage of rural households with soap hand wash
Red River Delta	25607.7	6.9	95.2	21.6	93.7
	(595.3)	(0.8)	(0.7)	(1.8)	(1.1)
Northorn Mountaina	15411.9	44.2	53.9	2.7	65.8
	(405.2)	(2.0)	(1.7)	(0.6)	(4.1)
Coastal Central	21442.9	19.2	78.9	11.6	84.4
	(487.0)	(1.7)	(1.7)	(1.3)	(2.1)
Central Highlands	18007.0	39.1	52.8	3.1	76.0
	(1027.8)	(3.6)	(2.5)	(1.3)	(2.5)
Southeast	28280.5	6.6	92.6	14.9	80.6
	(917.7)	(1.3)	(1.0)	(2.8)	(3.0)
Mekong River Delta	23080.0	10.5	50.7	29.3	77.8
	(397.4)	(1.0)	(1.9)	(1.9)	(2.1)
Total	22229.2	18.6	72.2	16.1	81.3
	(256.9)	(0.7)	(0.8)	(0.8)	(1.2)

Table 2. Regional estimates

Note: standard errors in parentheses.

Source: Estimation from the 2014 VHLSS and the 2014 MICS.

proportion of access to improved latrines. Some provinces such as Ha Giang and Lai Chau had this proportion less than 20%, while in several provinces in Red River Delta and Southeast this proportion is above 90%. The access to piped water is very limited in poor

regions, less than 5% in most provinces in Northern Mountain and Central Highlands. The proportion of rural households with hand washing with soap was higher, but still relatively low in provinces in Northern Mountain.

Region name	Province name	Number of	Number of households		xpenditure of useholds	Percentage hous	Percentage of rural poor households	
		All	Rural only	Mean	Std. error	Mean	Std. error	
Northern Mountain	Ha Giang	175,580	142,799	12940.6	613.3	56.89	3.69	
Northern Mountain	Cao Bang	131,228	98,117	16469.6	820.7	36.25	4.33	
Northern Mountain	Bac Kan	79,340	64,340	13108.3	985.3	54.88	6.16	
Northern Mountain	Tuyen Quang	198,057	170,336	17788.1	1201.3	34.83	4.94	
Northern Mountain	Lao Cai	157,907	114,636	14246.5	891.8	50.52	4.87	
Northern Mountain	Dien Bien	119,371	95,696	11080.2	625.8	67.44	3.89	
Northern Mountain	Lai Chau	88,131	68,479	10844.2	663.4	68.63	4.29	
Northern Mountain	Son La	267,671	222,348	12239.6	509.7	59.19	3.39	
Northern Mountain	Yen Bai	202,167	154,109	15335.7	937.1	44.40	5.05	
Northern Mountain	Hoa Binh	206,183	170,954	16969.2	881.8	35.44	4.30	
Northern Mountain	Thai Nguyen	331,761	227,299	20196.8	1080.5	22.24	4.00	
Northern Mountain	Lang Son	190,266	149,539	16030.3	833.7	37.25	4.45	
Northern Mountain	Bac Giang	422,177	371,645	21807.2	1079.0	18.64	3.53	
Northern Mountain	Phu Tho	378,452	310,020	20466.2	1059.7	24.96	3.75	
Red River Delta	Ha Noi	1,872,611	930,084	34238.3	1594.3	2.28	0.86	
Red River Delta	Quang Ninh	330,408	124,653	24124.4	1497.4	10.51	2.93	
Red River Delta	Vinh Phuc	275,160	204,230	25037.3	1656.7	9.55	2.88	
Red River Delta	Bac Ninh	305,801	221,918	32396.4	3097.6	2.69	2.09	
Red River Delta	Hai Duong	532,006	406,332	22982.1	1247.9	7.09	2.27	
Red River Delta	Hai Phong	566,089	308,274	29260.5	2696.5	2.30	1.42	
Red River Delta	Hung Yên	339,513	297,255	27689.4	2448.0	3.37	1.87	
Red River Delta	Thai Bình	574,257	520,330	20369.2	1830.6	11.33	4.96	
Red River Delta	Ha Nam	237,417	201,271	21758.7	2684.1	10.72	6.28	
Red River Delta	Nam Dinh	580,516	477,375	22820.6	1428.7	8.58	2.93	
Red River Delta	Ninh Bình	278,232	223,330	22493.8	1664.1	8.84	3.46	
Central Coast	Thanh Hoa	933,367	799,843	21142.2	1018.5	18.52	2.71	
Central Coast	Nghe An	766,835	635,486	21105.9	1483.7	19.93	3.73	
Central Coast	Ha Tinh	375,951	318,559	23782.9	1417.7	12.05	2.92	
Central Coast	Quang Binh	233,182	184,474	25328.5	1844.1	11.49	3.15	
Central Coast	Quang Tri	160,717	113,490	24428.7	1759.1	14.86	4.04	

Table 3. Provincial estimates of per capita expenditure and poverty rate

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Region name	Province name	Number of	households	Per capita e rural ho	xpenditure of useholds	Percentage of rural poor households		
		All	Rural only	Mean	Std. error	Mean	Std. error	
Central Coast	Thua Thiên Hue	294,079	149,728	25289.6	1824.5	8.68	2.97	
Central Coast	Da Nang	249,146	32,622	29765.5	4827.8	5.65	5.07	
Central Coast	Quang Nam	394,865	320,822	23850.1	1425.2	14.95	2.83	
Central Coast	Quang Ngãi	341,710	288,526	23727.2	1482.8	13.68	3.02	
Central Coast	Binh Dinh	423,517	293,859	26156.3	2155.1	7.68	2.89	
Central Coast	Phú Yên	248,225	177,688	22347.2	1627.4	13.31	4.12	
Central Coast	Khanh Hoa	306,578	172,779	23506.2	1738.4	12.84	3.80	
Central Coast	Ninh Thuan	147,572	92,628	18865.1	1511.5	21.68	6.18	
Central Coast	Binh Thuan	303,717	182,331	27158.1	2826.9	5.94	3.78	
Central Highlands	Kon Tum	117,877	76,434	17596.2	2163.4	50.22	4.67	
Central Highlands	Gia Lai	324,461	221,902	18301.4	940.5	41.27	2.74	
Central Highlands	Dak Lak	447,756	332,443	18651.7	854.9	34.34	2.95	
Central Highlands	Dak Nong	139,172	117,354	21742.7	1451.6	27.29	4.22	
Central Highlands	Lâm Dong	333,041	200,213	24657.3	1790.2	25.19	3.83	
South East	Binh Phuoc	241,976	192,339	30143.1	1861.3	3.00	1.54	
South East	Tay Ninh	300,078	243,874	23130.1	1852.8	12.88	5.04	
South East	Binh Duong	610,199	123,176	34041.1	2396.3	1.66	1.10	
South East	Dong Nai	743,233	504,039	31272.7	1948.2	2.80	1.42	
South East	Ba Ria - Vung Tau	284,540	139,343	33313.0	2589.8	1.99	1.36	
South East	Ho Chí Minh	2,077,661	382,023	46050.7	3831.5	0.43	0.57	
Mekong River Delta	Long An	398,128	324,671	28328.9	1005.4	5.16	0.94	
Mekong River Delta	Tien Giang	475,519	402,509	25148.4	1337.4	8.33	2.30	
Mekong River Delta	Ben Tre	379,066	339,612	27337.3	1102.2	5.64	1.41	
Mekong River Delta	Tra Vinh	279,553	233,169	23800.1	1025.1	10.82	2.17	
Mekong River Delta	Vinh Long	295,121	242,368	27227.1	1237.0	5.79	1.53	
Mekong River Delta	Dong Thap	441,252	356,789	23492.0	871.1	9.49	1.71	
Mekong River Delta	An Giang	558,074	388,169	22447.7	787.9	9.88	1.86	
Mekong River Delta	Kiên Giang	439,303	325,247	21350.1	698.1	13.66	1.94	
Mekong River Delta	Can Tho	320,761	103,984	19925.5	1338.4	16.89	4.60	
Mekong River Delta	Hau Giang	196,224	148,442	19650.8	1117.9	18.11	3.89	
Mekong River Delta	Soc Trang	328,819	225,125	21826.3	773.2	11.50	1.77	
Mekong River Delta	Bac Liêu	211,217	153,797	21727.7	919.0	11.56	2.28	
Mekong River Delta	Ca Mau	302,200	232,321	21751.4	832.2	12.35	2.13	

Source: Estimation from the small area estimation.

 Table 4. Provincial estimates of the proportion of households with improved latrine,

 piped water and handwashing with soap

Region name	Province name	Percentage of rural F households with improved ho latrines		Percenta household washing	Percentage of rural households with hand washing with soap		ge of rural ith piped water
		Mean	Std. error	Mean	Std. error	Mean	Std. error
Northern Mountain	Ha Giang	19.85	4.54	25.00	5.37	0.33	0.06
Northern Mountain	Cao Bang	19.51	3.56	74.85	1.76	1.62	0.23
Northern Mountain	Bac Kan	53.68	2.91	64.14	1.75	4.56	0.36
Northern Mountain	Tuyen Quang	55.18	2.84	67.97	2.21	5.12	0.34
Northern Mountain	Lao Cai	43.68	2.34	83.92	4.77	3.18	0.32
Northern Mountain	Dien Bien	28.09	2.07	48.33	2.62	2.91	0.30
Northern Mountain	Lai Chau	22.89	2.12	42.98	3.08	3.15	0.32
Northern Mountain	Son La	33.34	2.10	47.20	2.36	7.42	0.35
Northern Mountain	Yen Bai	49.54	1.92	73.89	4.56	3.75	0.29
Northern Mountain	Hoa Binh	57.17	2.43	67.02	1.80	4.75	0.31
Northern Mountain	Thai Nguyen	78.82	1.61	81.86	1.20	6.69	0.35
Northern Mountain	Lang Son	25.37	4.13	74.97	2.40	5.05	0.32
Northern Mountain	Bac Giang	90.48	0.91	92.65	2.05	1.49	0.13
Northern Mountain	Phu Tho	86.69	0.89	83.50	1.16	11.14	0.38
Red River Delta	Ha Noi	96.69	0.52	96.47	1.07	12.88	0.30
Red River Delta	Quang Ninh	90.92	0.81	75.41	4.43	12.54	0.71
Red River Delta	Vinh Phuc	96.42	0.57	87.89	1.39	1.99	0.23
Red River Delta	Bac Ninh	97.41	0.57	91.07	0.75	11.27	0.45
Red River Delta	Hai Duong	97.31	0.50	93.04	1.04	52.69	0.60
Red River Delta	Hai Phong	92.85	1.03	92.42	0.89	35.33	0.71
Red River Delta	Hung Yên	97.36	0.51	99.58	2.04	2.62	0.14
Red River Delta	Thai Bình	98.09	0.40	96.91	0.90	20.88	0.46
Red River Delta	Ha Nam	83.93	3.39	81.94	4.16	12.20	0.51
Red River Delta	Nam Dinh	96.31	0.60	95.30	0.98	38.45	0.46
Red River Delta	Ninh Bình	80.63	3.59	95.82	0.87	27.92	0.60
Central Coast	Thanh Hoa	78.80	1.67	93.54	1.34	4.95	0.17
Central Coast	Nghe An	80.95	1.84	82.91	1.34	8.48	0.30
Central Coast	Ha Tinh	93.88	2.53	89.35	1.30	6.67	0.36
Central Coast	Quang Binh	73.83	1.80	79.18	2.02	9.52	0.49
Central Coast	Quang Tri	77.89	1.65	71.16	3.78	22.12	0.77
Central Coast	Thua Thiên Hue	85.68	1.41	75.26	3.42	69.27	0.83
Central Coast	Da Nang	90.60	1.37	64.34	5.90	54.92	1.95
Central Coast	Quang Nam	77.90	1.38	66.61	4.51	4.30	0.24
Central Coast	Quang Ngãi	72.42	1.59	89.49	1.19	4.19	0.31
Central Coast	Binh Dinh	74.32	1.97	91.15	1.30	11.65	0.47

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Region name	Percen household Region name Province name Ia		Percentage of rural Per seholds with improved hour latrines wa		ge of rural Is with hand with soap	Percentage of rural households with piped water	
		Mean	Std. error	Mean	Std. error	Mean	Std. error
Central Coast	Phú Yên	66.04	2.48	89.03	1.28	11.28	0.50
Central Coast	Khanh Hoa	85.61	2.42	90.88	1.09	32.39	0.70
Central Coast	Ninh Thuan	80.30	3.00	84.47	1.78	67.02	0.95
Central Coast	Binh Thuan	80.76	2.09	69.32	4.68	38.90	0.87
Central Highlands	Kon Tum	40.43	2.61	55.30	3.99	1.98	0.26
Central Highlands	Gia Lai	44.19	2.43	76.80	1.83	1.24	0.12
Central Highlands	Dak Lak	36.35	3.55	79.18	1.51	4.50	0.29
Central Highlands	Dak Nong	51.85	2.77	81.89	3.50	1.97	0.23
Central Highlands	Lâm Dong	69.73	2.22	78.58	1.53	2.31	0.25
South East	Binh Phuoc	82.51	1.58	61.92	3.45	1.08	0.13
South East	Tay Ninh	79.91	1.99	61.39	3.33	1.54	0.16
South East	Binh Duong	92.98	1.12	91.20	3.06	11.59	0.72
South East	Dong Nai	90.45	1.12	84.37	2.36	11.17	0.40
South East	Ba Ria - Vung Tau	90.56	1.29	82.61	3.12	54.22	1.04
South East	Ho Chí Minh	96.00	0.91	97.61	0.85	16.21	0.73
Mekong River Delta	Long An	68.77	1.95	90.10	2.75	6.09	0.27
Mekong River Delta	Tien Giang	64.86	1.92	78.81	1.74	7.27	0.25
Mekong River Delta	Ben Tre	52.04	2.34	81.42	2.19	22.37	0.52
Mekong River Delta	Tra Vinh	35.82	1.81	75.07	2.17	27.14	0.65
Mekong River Delta	Vinh Long	54.06	2.05	77.42	1.89	51.32	0.73
Mekong River Delta	Dong Thap	59.04	2.42	76.97	3.01	53.15	0.67
Mekong River Delta	An Giang	82.06	2.89	91.97	2.23	71.37	0.58
Mekong River Delta	Kiên Giang	38.51	1.98	78.14	3.61	12.51	0.49
Mekong River Delta	Can Tho	50.22	1.87	80.67	4.30	24.70	0.97
Mekong River Delta	Hau Giang	40.05	2.16	83.35	4.13	16.23	0.61
Mekong River Delta	Soc Trang	39.84	2.22	70.42	2.40	21.05	0.60
Mekong River Delta	Bac Liêu	46.95	2.43	52.87	3.16	6.97	0.45
Mekong River Delta	Ca Mau	38.68	2.16	52.10	3.04	6.69	0.32

Source: Estimation from the small area estimation.

Figures from 1 to 4 show the spatial distribution of the welfare indicators by districts in 2014. Poverty rates are highest in the mountainous Northern areas and lowest in the Mekong and Red River Deltas. Disaggregating down to the district level reveals a greater degree of heterogeneity in both poverty

and sanitation variables. Several districts in provinces Lai Chau, Dien Bien, Ha Giang and Cao Bang have very low proportions of access to improved latrines and piped water. The map of handwashing with water and soap also shows a similar pattern. Districts in Northern Mountain have a lower proportion of this indicator.



Figure 1. The percentage of poor households of districts in rural Vietnam

Note: This figure only presents the map of the mainland of Vietnam. **Source:** Estimation from the small area estimation using the 2014 VHLSS and the 2014 IPS.





Note: This figure only presents the map of the mainland of Vietnam. **Source:** Estimation from the small area estimation using the 2014 VHLSS and the 2014 IPS.

Figure 3. The percentage of households with piped water of districts in rural Vietnam



Note: This figure only presents the map of the mainland of Vietnam. **Source:** Estimation from the small area estimation using the 2014 IPS.

Figure 4. The percentage of households with hand-washing with soap in rural Vietnam



Note: This figure only presents the map of the mainland of Vietnam. Source: Estimation from the small area estimation using the 2014 MICS and the 2014 IPS.

5. Conclusions

Vietnam is a country which has been successful in poverty reduction and sanitation improvement. However, there is still a large proportion of households which do not have access to piped water and sanitary latrines, especially in rural areas. To design sanitation support programs, it is very important to have more detailed information on the location of households which lack the access to piped water and sanitary latrines. In this study, we use the small area estimation method and data from the household surveys and midterm population census to estimate per capita expenditure, the poverty rate, and the rates of households with sanitation, hand washing with soap and piped water of provinces, districts and communes in rural Vietnam.

The results show a strong spatial variation in poverty, piped water, and sanitation in Vietnam. Most provinces in Northern Mountain and Central Highlands regions have high poverty and low access to piped water and sanitary latrines. Although Mekong River Delta has higher income than Northern Mountain and Central Highlands, it has the lowest proportion of households with improved latrines. It implies that information on not only monetary poverty but also nonmonetary dimensions such as sanitation is important for poverty targeting. In addition, water and sanitation data in more disaggregated areas is more informative for targeting of the support programs. In some provinces with middle rates of piped water and improved latrines, there are districts with a very low rate of piped water and improved latrines.

Our study suggests several policy implications. Firstly, support on sanitation should be provided for districts with low coverage, especially those in Northern Mountain and Central Highlands. Secondly, different interventions can be tailored to different ethnic groups. Thirdly, policies to promote economic development and reduce inequality are very important. Our analysis shows a strong correlation between per capita expenditure and sanitation indicators, suggesting that economic growth can result in the improvement of sanitation.

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Table A.1. Summary statistics of variables used in the 2014 VHLSS and the 2014 IPS

		The 201	4 VHLSS	The 2014 IPS		
Explanatory variables	Туре	Mean	Std. Dev.	Mean	Std. Dev.	
Household size	Discrete	3.796	1.564	3.732	1.651	
Number of migrant members in households	Discrete	0.233	0.209	0.236	0.742	
Age of head	Discrete	51.222	14.306	49.236	15.103	
Head is male	Binary	0.729	0.444	0.721	0.448	
Head living with spouse	Binary	0.772	0.420	0.744	0.436	
Age of head's spouse	Discrete	35.943	22.405	33.434	22.619	
Proportion of children in households	Continuous	0.197	0.202	0.198	0.206	
Proportion of members aged 15-24	Continuous	0.225	0.224	0.255	0.257	
Proportion of members aged 25-60	Continuous	0.415	0.260	0.405	0.271	
Proportion of members aged 61+	Continuous	0.163	0.294	0.142	0.282	
Proportion of female member	Continuous	0.523	0.212	0.517	0.225	
Urban dummy	Binary	0.325	0.369	0.339	0.474	
Household owns a house	Binary	0.940	0.237	0.908	0.289	
Living area (m2)	Continuous	24.740	20.657	25.285	22.779	
Pillar house made of concrete	Binary	0.365	0.481	0.357	0.479	
Pillar house made of stone	Binary	0.459	0.498	0.473	0.499	
Pillar house made of steel	Binary	0.098	0.298	0.087	0.281	
House roof made of concrete	Binary	0.223	0.416	0.212	0.409	
House roof made of tile	Binary	0.284	0.451	0.276	0.447	
House wall made of brick	Binary	0.825	0.380	0.835	0.371	
House wall made of wood	Binary	0.103	0.303	0.093	0.291	
Having a new house	Binary	0.620	0.486	0.587	0.492	
Kinh dummy	Binary	0.866	0.341	0.864	0.343	
Small sample size (number of observation is 358649)						
Proportion of members with lower secondary	Continuous	0.236	0.276	0.239	0.284	
Proportion of members with upper secondary	Continuous	0.231	0.296	0.238	0.310	
Proportion of members with post secondary	Continuous	0.073	0.183	0.077	0.192	
Having gas cook	Binary	0.632	0.264	0.647	0.478	
Using piped water	Binary	0.349	0.477	0.354	0.478	
Using deep well	Binary	0.267	0.443	0.286	0.452	
Using protected well	Binary	0.158	0.364	0.151	0.358	
Using rain water	Binary	0.114	0.318	0.107	0.309	
Using flush toilet	Binary	0.696	0.460	0.714	0.452	

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		The 2014	VHLSS	The 2014 IPS	
Explanatory variables	Туре	Mean	Std. Dev.	Mean	Std. Dev.
Have no toilet	Binary	0.041	0.199	0.040	0.197
Having television	Binary	0.930	0.256	0.939	0.240
Having computer	Binary	0.219	0.414	0.251	0.434
Having internet connection	Binary	0.203	0.188	0.206	0.404
Having telephone	Binary	0.901	0.298	0.850	0.357
Having fridge	Binary	0.616	0.486	0.590	0.492
Having a washing machine	Binary	0.302	0.459	0.309	0.462
Having heater	Binary	0.236	0.425	0.242	0.428
Having air conditioning	Binary	0.137	0.344	0.133	0.340
Having motorbike	Binary	0.833	0.373	0.846	0.361
Having a car	Binary	0.018	0.133	0.031	0.173
Number of observations		9399		1,114,007	

Source: Estimation from the 2014 IPS and the 2014 VHLSS.

Fundameters veriables	L	arge model.		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Intercept	9.4464	0.0630	0.0000	10.7561	0.3244	0.0000	
Have computer (yes=1, no=0)	0.1451	0.0228	0.0000				
Have a deep well (yes=1, no=0)	-0.0493	0.0241	0.0408				
Have a fridge (yes=1, $no=0$)	0.1031	0.0229	0.0000				
Have a heater (yes=1, no=0)	0.1129	0.0213	0.0000				
Living area per capita (m2)	0.0058	0.0005	0.0000	0.0079	0.0006	0.0000	
Log of household size	-0.3556	0.0248	0.0000				
Hh. head living with spouse				0.1316	0.0251	0.0000	
Proportion of members aged 25-60				0.1861	0.0344	0.0000	
Proportion of households with male heads in district				-1.5231	0.3861	0.0001	
Household size				-0.0560	0.0076	0.0000	
Proportion of lower-secondary school	0.1190	0.0310	0.0001				

Table A.2. GLS regression of log of per capita expenditure in Red River Delta using the 2014 VHLSS

Funlandamu variablaa	L	arge model.		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Head is male	0.0571	0.0195	0.0035				
Proportion of migrants in district	0.3628	0.1556	0.0198				
Have a motorbike (yes=1, no=0)	0.1509	0.0276	0.0000				
Proportion of households with solid pillar house in district	0.3655	0.1335	0.0063	0.6652	0.1540	0.0000	
Household with stone pillar house	-0.0638	0.0189	0.0007	-0.0832	0.0267	0.0019	
Have a protected well (yes=1, no=0)	-0.0725	0.0395	0.0664				
Have a telephone (yes=1, no=0)	0.1827	0.0329	0.0000				
Have a television (yes=1, no=0)	0.1423	0.0430	0.0010				
Proportion of hh. members with upper- secondary	0.3518	0.0351	0.0000				
Have a washing machine (yes=1, no=0)	0.1163	0.0221	0.0000				
House with a concrete roof				0.1105	0.0221	0.0000	
Hanoi city dummy	0.2246	0.0508	0.0000	0.1959	0.0596	0.0010	
Bac Ninh province dummy	0.2462	0.0853	0.0040	0.3509	0.0908	0.0001	
Hai Phong city dummy	0.1626	0.0601	0.0069	0.2572	0.0677	0.0001	
Thai Binh province dummy	-0.1933	0.0594	0.0012	-0.1990	0.0651	0.0023	
Hung Yen province dummy				0.1378	0.0795	0.0831	
Ha Nam province dummy				-0.2092	0.1042	0.0448	
Proportion of members aged 15-24				0.4031	0.0556	0.0000	
Urban dummy*Age of head's spouse				-0.0014	0.0006	0.0324	
Urban dummy*Concrete house pillar				0.0989	0.0413	0.0166	
Urban dummy*Proportion of members aged 15-24				-0.2666	0.0841	0.0015	
Urban dummy*Proportion of members above 60	-0.1865	0.0542	0.0006				
Urban dummy*Living area per capita (m2)	0.0014	0.0007	0.0621	0.0028	0.0008	0.0004	
R-squared adjusted	0.6946			0.5778			
Obs.	1992			1992			
Rho	0.1630			0.156			

Source: Estimation from the 2014 VHLSS.

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Table A.3. GLS regression of log of per capita expenditure	in Midland
and North Mountain using the 2014 VHLSS	

Evelopetero veriebles	L	arge mode.		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Intercept	9.3271	0.0638	0.0000	8.9522	0.1030	0.0000	
Proportion of members aged 25-60	0.1468	0.0387	0.0002	0.2724	0.0534	0.0000	
Have a computer (yes=1, no=0)	0.0790	0.0339	0.0201				
Proportion of members above 60 in the district	-1.5867	0.4052	0.0001				
Household with a flush latrine	0.0964	0.0259	0.0002				
Have a fridge (yes=1, no=0)	0.1581	0.0244	0.0000				
Have a heater (yes=1, no=0)	0.1449	0.0311	0.0000				
Kinh (Kinh=1, ethnic minorities=0)	0.1812	0.0280	0.0000				
Living area per capita (m2)	0.0052	0.0005	0.0000	0.0076	0.0008	0.0000	
Log of household size	-0.4116	0.0264	0.0000				
Proportion of members below 15				-0.4288	0.0597	0.0000	
Household size				-0.0607	0.0082	0.0000	
Proportion of lower-secondary school	0.1581	0.0373	0.0000				
Have a motorbike (yes=1, no=0)	0.2435	0.0299	0.0000				
Household with a latrine	-0.1621	0.0340	0.0000				
Have a telephone (yes=1, no=0)	0.1475	0.0312	0.0000				
Have a washing machine (yes=1, no=0)	0.2145	0.0311	0.0000				
Have a television (yes=1, no=0)	0.1045	0.0315	0.0009				
Bac Kan province dummy	-0.1495	0.0907	0.0996	-0.3068	0.1094	0.0051	
Phu Tho province dummy				-0.1221	0.0569	0.0320	
Concrete house pillar				0.1640	0.0385	0.0000	
House with a wood wall				0.0833	0.0361	0.0212	
House with a concrete roof				0.2667	0.0392	0.0000	
Proportion of hh. members with upper- secondary	0.4323	0.0420	0.0000				
Proportion of urban population in district	0.2081	0.0749	0.0055				
House with a brick wall	0.0808	0.0260	0.0019	0.2734	0.0358	0.0000	
Urban dummy*Age of head's spouse in the district				-0.0122	0.0045	0.0070	
Urban dummy*Log of household size				0.1531	0.0697	0.0282	
Urban dummy*Proportion of members below 15 in district				2.5514	0.5680	0.0000	

Explanatory variables	L	arge model		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Urban dummy*House with concrete roof				-0.2086	0.0629	0.0009	
Average living area per capita (m2) in district				0.0223	0.0038	0.0000	
R-squared adjusted	0.7411			0.5754			
Obs.	1662			1662			
Rho	0.1090			0.1010			

Source: Estimation from the 2014 VHLSS.

	1	arne model		Small model			
Explanatory variables	 Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Intercept	9.0802	0.1031	0.0000	9,1971	0.3855	0.0000	
Have a computer (ves=1 $no=0$)	0 1939	0.0271	0.0000	0.1011	0.0000	0.0000	
Proportion of members aged 25-60	0.1000	0.0211	0.0000	0.3752	0.0394	0.0000	
Proportion of members above 60	-0.0862	0.0341	0.0115	0.07.02	010001	0.0000	
Household with a flush latrine	0.1145	0.0228	0.0000				
Have a fridge (ves=1, $no=0$)	0.2057	0.0207	0.0000				
Have a heater (ves=1, $no=0$)	0.1535	0.0285	0.0000				
Concrete house pillar				0.1687	0.0269	0.0000	
Household size	-0.0403	0.0172	0.0190	-0.1223	0.0206	0.0000	
Kinh (Kinh=1, ethnic minorities=0)	0 2216	0.0351	0 0000	0	0.0200	0.0000	
l iving area per capita (m2)	0.0068	0.0006	0.0000	0 0115	0 0007	0 0000	
Log of household size	-0 1972	0.0661	0.0029	0.3272	0 0729	0.0000	
Proportion of lower-secondary school	0 1161	0.0349	0.0009	0.0272	0.0720	0.0000	
Have a motorbike (ves=1 $n_0=0$)	0 1873	0.0267	0.0000				
Household with a latrine	-0.0631	0.0356	0.0765				
Proportion of members below 15	-0 1745	0.0503	0.0005				
House with steel nillar in the district	-0 2817	0.0855	0.0010	0 0069	0.0016	0 0000	
Household with piped water	0.0546	0.0256	0.0330	0 1075	0.0437	0.0139	
House with concrete roof in the district	0.0040	0.0200	0.0000	0.1070	0.0407	0.0100	
Have a telephone (ves= 1 no= 0)	0.1892	0.0284	0.0000				
Thanh Hoa province dummy	-0.1404	0.0204	0.0000				
Binh Dinh province dummy	0.1120	0.0534	0.0361				

Table A.4. GLS regression of log of per capita expenditure in Central Coast using the 2014 VHLSS

Evaloratory variables	L	arge model		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Binh Thuan province dummy	0.1663	0.0576	0.0039	0.2388	0.0876	0.0064	
Have a television (yes=1, no=0)	0.1552	0.0307	0.0000				
Proportion of hh. members with upper- secondary	0.3129	0.0396	0.0000				
Have a washing machine (yes=1, no=0)	0.1067	0.0284	0.0002				
Proportion of members aged 15-24 in the district	0.7799	0.3142	0.0131				
Urban dummy*Household with stone pillar house	-0.0854	0.0273	0.0018				
Urban dummy*Under five-year-old child mortality rate in district							
Urban dummy*House with a tile roof							
Proportion of households with male heads in district				-0.8032	0.3700	0.0301	
House with a steel pillar				0.0954	0.0390	0.0144	
House with a concrete roof				0.1920	0.0355	0.0000	
Average living area per capita (m2) in district				0.0134	0.0047	0.0042	
House with a brick wall				0.2530	0.0464	0.0000	
Proportion of household with a brick wall house in district				0.2679	0.1101	0.0150	
Proportion of members aged 15-24				0.3538	0.0495	0.0000	
R-squared adjusted	0.7144			0.5008			
Obs.	2067			2067			
Rho	0.0966			0.1860			

Source: Estimation from the 2014 VHLSS.

Articles

Table A.5. GLS regression of log of per capita expenditure in Central Highland using the 2014 VHLSS

Funlanataru uniahlan	L	arge model.		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Intercept	9.0329	0.0781	0.0000	7.7578	0.2131	0.0000	
Have a computer (yes=1, no=0)	0.1419	0.0434	0.0011				
Household with a flush latrine	0.2140	0.0392	0.0000				
Household size	-0.0677	0.0112	0.0000	-0.0577	0.0155	0.0002	
Kinh (Kinh=1, ethnic minorities=0)	0.3230	0.0378	0.0000				
Living area per capita (m2)	0.0101	0.0011	0.0000	0.0175	0.0014	0.0000	
Have a motorbike (yes=1, no=0)	0.2740	0.0509	0.0000				
Household with a latrine	-0.2164	0.0460	0.0000				
Proportion of members below 15	-0.3148	0.0736	0.0000				
Households use rain water for drinking	0.2465	0.0944	0.0093				
Have a television (yes=1, no=0)	0.1867	0.0506	0.0002				
Proportion of hh. members with upper- secondary	0.5033	0.0673	0.0000				
Have a washing machine (yes=1, no=0)	0.2150	0.0417	0.0000				
Proportion of members aged 25-60				0.6059	0.0889	0.0000	
Hh. head living with a spouse				0.1750	0.0570	0.0022	
Proportion of members aged 15-24				0.4168	0.0904	0.0000	
Average living area per capita (m2) in district				0.0397	0.0072	0.0000	
Proportion of migrants in district				0.4194	0.1692	0.0135	
House with a concrete roof				0.3438	0.1512	0.0233	
House with a brick wall				0.3289	0.0463	0.0000	
House with a wood wall in the district				0.5102	0.1971	0.0099	
Urban dummy*Average household size in district				0.0692	0.0192	0.0003	
Urban dummy*Head is male				-0.1544	0.0799	0.0538	
R-squared adjusted	0.7863			0.6422			
Obs.	651			651			
Rho	0.1560			0.084			

Source: Estimation from the 2014 VHLSS.

Articles

Explanatory variables	L	arge model		Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Intercept	9.6163	0.0795	0.0000	10.0053	0.0738	0.0000	
Have a computer (yes=1, no=0)	0.1441	0.0265	0.0000				
Have a heater (yes=1, no=0)	0.1964	0.0299	0.0000				
Kinh (Kinh=1, ethnic minorities=0)	0.1640	0.0439	0.0002				
Living area per capita (m2)	0.0079	0.0006	0.0000	0.0119	0.0006	0.0000	
Household size				-0.0657	0.0089	0.0000	
Proportion of members below 15				-0.1511	0.0643	0.0189	
Hh. head living with a spouse				0.0994	0.0280	0.0004	
Proportion of members above 60				-0.2799	0.0668	0.0000	
Log of household size	-0.3388	0.0262	0.0000				
Have a motorbike (yes=1, no=0)	0.5344	0.0582	0.0000				
Concrete house pillar	0.2064	0.0419	0.0000	0.3248	0.0597	0.0000	
House with a tile roof	0.0726	0.0384	0.0590				
House with a concrete roof				0.0856	0.0460	0.0632	
Household with stone pillar house				0.1341	0.0549	0.0146	
Tay Ninh province dummy	-0.2837	0.0743	0.0001	-0.3359	0.0933	0.0003	
Ho Chi Minh city dummy	0.1884	0.0422	0.0000	0.2795	0.0500	0.0000	
Proportion of hh. members with upper- secondary	0.3538	0.0372	0.0000				
Have a washing machine (yes=1, no=0)	0.0923	0.0252	0.0003				
Urban dummy*Have deep well (yes=1, no=0)	-0.0719	0.0361	0.0465				
Urban dummy*Have fridge (yes=1, no=0)	0.1901	0.0398	0.0000				
Urban dummy*Have motorbike (yes=1, no=0)	-0.3246	0.0579	0.0000				
Urban dummy*Household with stone pillar house	0.1777	0.0475	0.0002				
R-squared adjusted	0.6424			0.4964			
Obs.	1122			1122			
Rho	0.1180			0.143			

Table A.6. GLS regression of log of per capita expenditure in Southeast using the 2014 VHLSS

Source: Estimation from the 2014 VHLSS.

Table A. 7. GLS regression of log of per capita expenditure in Mekong River Delta using the 2014 VHLSS

Fundamentariables	I	Large mode	l	Small model			
Explanatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
Intercept	9.5644	0.0539	0.0000	9.3830	0.0590	0.0000	
Have a computer (yes=1, no=0)	0.1681	0.0281	0.0000				
Proportion of members above 60	-0.1591	0.0359	0.0000				
Household with a flush latrine	0.0741	0.0204	0.0003				
Have a fridge (yes=1, no=0)	0.1958	0.0200	0.0000				
Have a heater (yes=1, no=0)	0.2191	0.0444	0.0000				
Living area per capita (m2)	0.0052	0.0005	0.0000	0.0078	0.0006	0.0000	
Log of household size	-0.3728	0.0251	0.0000				
Household size				-0.0477	0.0079	0.0000	
Proportion of lower-secondary school	0.1446	0.0402	0.0003				
Proportion of migrants in district	0.3667	0.1270	0.0039				
Have a motorbike (yes=1, $no=0$)	0.2428	0.0238	0.0000				
Proportion of members below 15	-0.1244	0.0490	0.0112				
Concrete house pillar	0.0546	0.0220	0.0131	0.0974	0.0301	0.0012	
House with a tile roof	0.0973	0.0325	0.0028	0.1117	0.0400	0.0053	
Have a telephone (yes=1, no=0)	0.1351	0.0330	0.0000				
Tien Giang province dummy	-0.1245	0.0457	0.0065	-0.1252	0.0535	0.0194	
Kien Giang province dummy	0.1171	0.0417	0.0051				
Can Tho city dummy	-0.0958	0.0513	0.0620	-0.1545	0.0594	0.0094	
Bac Lieu province dummy	0.1626	0.0623	0.0091				
Ca Mau province dummy	0.1391	0.0519	0.0074				
Have a television (yes=1, no=0)	0.1179	0.0327	0.0003				
Proportion of hh. members with upper- secondary	0.3592	0.0450	0.0000				
House with a brick wall	0.0811	0.0283	0.0042	0.3217	0.0329	0.0000	
House with a wood wall	0.0683	0.0265	0.0101	0.1602	0.0327	0.0000	
Have a washing machine (yes=1, no=0)	0.1521	0.0280	0.0000				
Urban dummy*Hh. head living with a spouse	-0.0632	0.0237	0.0078				
Proportion of members aged 25-60				0.2920	0.0410	0.0000	
Under five-year-old child mortality rate in district				-0.0053	0.0022	0.0158	
Hh. head living with a spouse				0.0908	0.0252	0.0003	
Proportion of migrants in district				0.6243	0.1460	0.0000	

Articles

Exploratory variables	L	arge model		Small model			
Explaitatory variables	Coefficient	Std. Err.	Prob >t	Coefficient	Std. Err.	Prob >t	
House with a steel pillar				0.1094	0.0341	0.0013	
House with a concrete roof				0.2599	0.0702	0.0002	
Hau Giang province dummy				-0.1789	0.0747	0.0168	
Proportion of members aged 15-24				0.3619	0.0513	0.0000	
Urban dummy*Living area per capita (m2)				0.0042	0.0008	0.0000	
R-squared adjusted	0.6010			0.4011			
Obs.	1896			1896			
Rho	0.0810			0.066			

Source: Estimation from the 2014 VHLSS.

Table A.8. Probit regression of improved latrines in the 2014 VHLSS

	Small models				Large models		
Explanatory variables	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	
House with a brick wall	1.0810***	0.8464***	1.3359***	1.0334***	0.8092***	0.7834***	
	(0.0917)	(0.1072)	(0.1009)	(0.1113)	(0.1423)	(0.1185)	
Average living area per capita (m2)	0.0711***			0.0469***			
in district	(0.0102)			(0.0123)			
House with a concrete roof	0.7866***						
	(0.1244)						
Urban dummy (urban=1, rural=0)	0.9902***	0.5770***	0.5526***	0.4555***	0.3695***	0.3023***	
	(0.1292)	(0.1087)	(0.0905)	(0.1447)	(0.1194)	(0.1156)	
House with a tile roof	0.3630***						
	(0.0826)						
Concrete house pillar	0.5982***	0.6357***		0.5982***		0.3393***	
	(0.1408)	(0.1002)		(0.1528)		(0.1069)	
Average age of household head in	0.0902***						
district	(0.0148)						
Average proportion of members	-4.4186***						
aged 25-60 in district	(1.0841)						
Age of head's spouse	0.0054***	0.0092***			0.0080***		

		Small models			Large models	
Explanatory variables	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta
	(0.0018)	(0.0019)			(0.0018)	
Proportion of members below 15 in		-12.7258***			-9.7194***	
district		(1.3189)			(1.4633)	
Living area per capita (m2)		0.0203***	0.0104***		0.0150***	
		(0.0039)	(0.0022)		(0.0035)	
Proportion of household with a tile		-0.6884***	2.7450***		-0.5765***	4.3320***
roof house in district		(0.1514)	(0.5736)		(0.1718)	(0.6178)
Average household size in district		0.4228**	0.4996***		0.7923***	0.5225***
		(0.1870)	(0.1371)		(0.1876)	(0.1437)
Proportion of migrants in district		2.3542***	1.7019***			1.9779***
		(0.6193)	(0.3286)			(0.3241)
Household size		0.0764***	0.1170***			
		(0.0277)	(0.0237)			
Proportion of households with solid			1.3828***			-0.5827***
pillar house in district			(0.3349)			(0.1585)
House with a wood wall			0.4781***			0.3786***
			(0.1126)			(0.1114)
Proportion of households with a			5.8566***			
concrete roof in district			(1.8723)			
Household with a stone pillar house			2.3277***			
			(0.3277)			
Proportion of households with a			1.8620***			
wood wall house in district			(0.3927)			
Kinh (Kinh=1, ethnic minorities=0)				0.7697***	0.4775***	
				(0.1084)	(0.1082)	
Have a fridge (yes=1, no=0)				0.5880***	0.5207***	0.5524***
				(0.0895)	(0.1037)	(0.0738)
Proportion of hh. members with				1.1537***	0.8177***	1.1108***
upper-secondary				(0.2149)	(0.1817)	(0.1988)
Have a washing machine (ves=1				0.9950***	1.0091***	0.9442***
no=0)				(0.2840)	(0.2194)	(0.1617)
Proportion of household with a steel				-0.9962***		
pillar house in district				(0.2270)		

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		Small models		Large models		
Explanatory variables	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta
House with a steel pillar				0.3583***		
				(0.1118)		
Have a motorbike (yes=1, no=0)				0.2507***		0.3196***
				(0.0907)		(0.0902)
Household with piped water					0.4902***	0.5561***
					(0.1376)	(0.0885)
Household with a stone pillar house					-0.3606***	0.7101***
					(0.1019)	(0.1342)
Have a telephone (yes=1, no=0)					0.3703***	
					(0.0995)	
Proportion of urban population in						0.3736*
district						(0.1915)
Proportion of members above 60						0.4981***
						(0.1259)
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-4.6161***	-0.1166	-5.1917***	-1.7856***	-2.0857***	-3.7358***
	(0.5355)	(0.5859)	(0.6530)	(0.3063)	(0.6460)	(0.6099)
Observations	3,654	2,718	3,018	3,654	2,718	3,018
R-squared	0.541	0.328	0.415	0.611	0.407	0.486

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Source: Estimations from the 2014 VHLSS.

Table A.9. Probit regression of piped water using the 2014 IPS

Explanatory variables	Red River Delta	Northern Midlands and Mountains	Central Coast	Central Highlands	Southeast	Mekong River Delta
Household size		-0.0763***		-0.0428***	0.0454***	
		(0.0107)		(0.0142)	(0.0104)	
Number of migrant members in households	0.0661***	0.1457***	0.0765***			0.0559***
	(0.0189)	(0.0211)	(0.0160)			(0.0136)
Household head is male (male=1; female=0)	-0.0732***	-0.2832***	-0.1120***		-0.1615***	-0.1388***
	(0.0272)	(0.0354)	(0.0258)		(0.0423)	(0.0154)
Age of hh. head's spouse	0.0013***	0.0055***	0.0027***			
	(0.0005)	(0.0008)	(0.0005)			
Proportion of children (age<15)	0.1611***	0.3175***	0.1456***			
	(0.0519)	(0.0713)	(0.0472)			
Thai Nguyen province		1.0817***				
		(0.0712)				
Proportion of members aged 25-60		0.1675***	0.1288***			0.1210***
		(0.0460)	(0.0321)			(0.0261)
Per capita living area	0.0020***	0.0031***	0.0025***		0.0046***	0.0017***
	(0.0004)	(0.0008)	(0.0004)		(0.0008)	(0.0004)
House with a concrete pillar		0.2771***	0.4441***	0.3695***		0.2110***
		(0.0697)	(0.0585)	(0.0592)		(0.0222)
House with a stone pillar		0.2032***	0.3082***		-0.2558***	
		(0.0647)	(0.0575)		(0.0409)	
House with a concrete roof		0.4103***	0.1284***			0.2897***
		(0.0393)	(0.0350)			(0.0729)
Household with a tile roof	-0.2379***	0.1105***	-0.0752***	-0.2057***		-0.0882***
	(0.0180)	(0.0322)	(0.0223)	(0.0711)		(0.0272)
House wall made of brick		0.3599***	0.1459***		0.3374***	0.3638***
		(0.0658)	(0.0492)		(0.0752)	(0.0232)
Having a new house	-0.0723***	-0.0711***	-0.0563***		-0.1235***	-0.0697***
	(0.0173)	(0.0272)	(0.0176)		(0.0346)	(0.0156)
Proportion of child mortality		-0.0109***	-0.0099***	0.0147***	0.0435***	0.0182***
		(0.0015)	(0.0011)	(0.0036)	(0.0058)	(0.0016)
Average household size in district		-0.9604***	1.0302***		2.4837***	
		(0.1120)	(0.1038)		(0.1876)	
Age of household head in district	0.4883***	0.1263***	-0.3100***		-0.3228***	0.0954***

Explanatory variables	Red River Delta	Northern Midlands and Mountains	Central Coast	Central Highlands	Southeast	Mekong River Delta
	(0.0145)	(0.0214)	(0.0150)		(0.0365)	(0.0088)
Age of hh. head's spouse in district	-0.5582***	0.1585***	0.2165***		0.6867***	-0.0976***
	(0.0172)	(0.0275)	(0.0183)		(0.0605)	(0.0061)
Proportion of children (age<15)_m	-2.5283***	5.3181***	-13.421***	15.797***	16.4165***	
	(0.7835)	(1.6666)	(1.4334)	(2.5668)	(1.7771)	
Proportion of members aged 15-24_m	8.6161***	8.8153***	-15.390***	10.614***		2.0501***
	(0.6589)	(1.4108)	(1.0674)	(2.0987)		(0.4827)
Proportion of members aged 25-60_m	-3.2390***	-6.4950***	-4.8112***	16.3984***	-6.8882***	6.0655***
	(0.6202)	(0.8850)	(0.7301)	(2.7151)	(1.7577)	(0.4846)
Proportion of female population in district	-13.599***	11.331***	7.8266***	6.7399***		
	(0.9707)	(1.5072)	(0.8123)	(2.2500)		
Share of urban population in district	-0.6616***	1.3810***	0.6073***	1.0049***	2.2480***	0.6106***
	(0.0772)	(0.1443)	(0.0704)	(0.1744)	(0.1390)	(0.0620)
Average living area in district	-0.0195***	0.0519***	-0.0279***			-0.0595***
	(0.0046)	(0.0062)	(0.0039)			(0.0046)
Proportion of households with a	-6.6136***	1.4039***	2.4723***	3.2840***	-16.768***	
concrete pillar house in district	(0.8740)	(0.2169)	(0.3118)	(0.3559)	(2.3506)	
Proportion of house with steel pillar in district	-8.0988***	0.6761***	3.2650***		-8.5122***	1.0656***
	(1.2897)	(0.1639)	(0.3432)		(2.1832)	(0.1320)
House with a concrete roof in district	4.9199***	0.7677***			4.7088***	1.7640***
	(0.1061)	(0.2051)			(0.9751)	(0.6221)
Proportion of house roof made of tile in district		0.9975***	-0.8142***	-0.9172***	-4.4901***	-0.8278***
		(0.1107)	(0.0607)	(0.2263)	(0.5116)	(0.1637)
Proportion of house with brick wall in district	10.4665***	-1.0806***		-10.263***	5.3683***	0.9437***
	(1.1440)	(0.1692)		(1.3210)	(1.5235)	(0.1164)
Household head living with spouse in district	24.7659***	4.2382***	-16.877***	-4.8215***	-52.063***	
	(0.9558)	(1.2126)	(1.0860)	(1.1463)	(3.4434)	
Age of household head	-0.0023***					-0.0030***
	(0.0007)					(0.0005)
Proportion of members aged 15-24	0.1874***		0.1105***		-0.2780***	
	(0.0427)		(0.0410)		(0.0625)	

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Explanatory variables	Red River Delta	Northern Midlands and Mountains	Central Coast	Central Highlands	Southeast	Mekong River Delta
Proportion of house with a wood wall in district	27.3362***		-1.0194***	-10.177***	-6.0123***	0.3172***
	(2.5800)		(0.2435)	(1.2934)	(0.8978)	(0.1178)
Proportion of migrants in district	3.0132***		0.6101***		-0.9526***	
	(0.2308)		(0.1844)		(0.2411)	
Pate of male boucehold heads in district	-8.2649***		2.0100***		6.5428***	
nale of male nousenoid neads in district	(0.5095)		(0.3480)		(0.8626)	
Proportion of houses with a stone pillar in district	-7.1820***		1.5564***		-14.178***	
	(0.8678)		(0.3200)		(2.2806)	
Pillar house made of steel			0.2299***		-0.4709***	0.1142***
			(0.0591)		(0.1193)	(0.0242)
Proportion of mortality rate in district			-5.2383***	-13.495***	-20.247***	-7.703***
			(0.5953)	(1.7709)	(2.3679)	(0.5669)
Household head living with a spouse					0.1764***	
					(0.0467)	
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-18.170***	-22.263***	17.0613***	-5.0995**	24.0711***	-5.3608***
	(1.4276)	(2.1128)	(1.3336)	(2.2091)	(2.3396)	(0.5639)
Observations	51,702	49,445	56,154	16,588	19,487	55,886
R-squared	0.280	0.277	0.308	0.158	0.311	0.261

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Articles

 Table A.10. Probit regression of handwashing with soap using the 2014 MICS

		Small models		Large models		
Explanatory variables	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta
Proportion of households with a concrete	-1.1086***		2.8730***			2.3296***
pillar house in district	(0.3272)		(0.5616)			(0.5533)
Age of household head	-0.0163***			-0.0120***		
	(0.0038)			(0.0029)		
Proportion of members aged 61+ in district	8.8678***		10.5089***	7.9552***		9.5184***
	(0.8030)		(2.7046)	(0.8053)		(2.5636)
Having a telephone	0.5499***		0.3900***			
	(0.1293)		(0.1286)			
Proportion of children (age<15)	-1.0399***					
	(0.2596)					
Proportion of members aged 15-24	-1.3717***		-0.4332***	-0.6402***		-0.3407***
	(0.2205)		(0.1320)	(0.1451)		(0.1290)
Proportion of members aged 25-60	-0.6429***					
	(0.1792)					
Having a computer	0.3968***	0.3050***				
	(0.1042)	(0.1160)				
Proportion of house roofs made of tile in district	0.8049***			0.8595***		
	(0.2323)			(0.2429)		
Proportion of migrants in district	2.8143***			2.6285***		
	(0.5105)			(0.4678)		
Flush toilet	0.4417***		0.3004***			
	(0.0843)		(0.0754)			
Having a television	0.3064***					
	(0.1068)					
Having a fridge	0.5652***	0.2891***	0.3362***			
	(0.0837)	(0.0871)	(0.0698)			
Having a car	1.1033***					
	(0.3805)					
Bac Giang province	0.6641***			0.5267***		
	(0.1564)			(0.1451)		

		Small models	;		Large models	
Explanatory variables	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta
Household size		0.0589***				
Proportion of house with a wood wall in district		(0.0183) -1.5851***				
		(0.3463)				
Proportion of houses with steel pillar in district		2.3457***			1.1629***	
Proportion of members aged 25-60_m Washing machine		(0.4178) 7.7586*** (1.4382) 0.3035*** (0.1132)	8.8464*** (1.8230)		(0.3113)	8.5254*** (1.7365)
Proportion of house with a stone pillar in district		0.8927***	3.1128***		1.1391***	2.3053***
Kinh (Kinh=1, ethnic minority=0)		(0.1777) 0.8773*** (0.1056) -0.0382***	(0.6660)		(0.1816)	(0.6508)
		(0.0102)				
Household head is male (male=1; female=0)			-0.3413***	-0.3085***		-0.3923***
			(0.0708)	(0.1090)		(0.0827)
Proportion of house with a brick wall in district			-2.9387***			-2.0465***
Having an air conditioner			(0.5590) 0.6011*** (0.1268)			(0.5458)
Proportion of members with lower secondary			0.4478***			
House wall made of brick			(0.1483) 0.2752*** (0.0824)			0.5778*** (0.0744)
Average age of household head in commune			-0.0981***		0.0934***	-0.1030***

Articles

	Small models			Large models			
Explanatory variables	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	Red River Delta, and Northern Midlands and Mountains	Central Coast, and Central Highlands	Southeast and Mekong River Delta	
			(0.0275)		(0.0117)	(0.0266)	
Proportion of children (age<15)_m			4.9768***			5.0523***	
			(1.8369)			(1.8072)	
House with a concrete roof				0.4767***	0.4492***		
				(0.0857)	(0.1383)		
House wall made of wood				-0.4622***			
				(0.0940)			
Share of urban population in district					0.7120***		
					(0.1281)		
Province dummies	Yes	Yes	Yes	Yes	Yes	Yes	
Constant	-0.6896**	-2.6996***	-1.6211	-0.2417	-4.5820***	-0.8276	
	(0.3408)	(0.5192)	(1.2409)	(0.2335)	(0.6401)	(1.1818)	
Observations	3,348	3,329	3,302	3,348	3,329	3,302	
R-squared	0.342	0.171	0.203	0.274	0.104	0.162	

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1