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IMPACT EVALUATION OF IRRIGATION ON RURAL HOUSEHOLD WELFARE: EVIDENCE FROM VIETNAM

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Abstract

This paper examines the effect of communal irrigation plants on income and agricultural activities of rural households in Vietnam. Household-level and commune-level data from VHLSS 2010-2012 were analyzed using fixed effect regression. The paper finds no evidence of significant impacts of communal irrigation plants on households' income, income structure and rice cultivation activities. These results imply the weak operation and maintenance of public irrigation plants as well as the lack of integrated water resource management to ensure water input for irrigation systems.

Keywords: irrigation systems; household welfare; impact evaluation; Vietnam.

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1. Introduction

Irrigation infrastructure has long been considered crucial to the economic development in rural areas, especially for regions which rely heavily on agriculture for income and livelihoods. In these regions, raising farm productivity and creation of livelihoods are essential for poverty alleviation, and irrigation acts as a springboard for economic development. Since the 1950s, countries have tried to expand the coverage of irrigation infrastructure with the most significant achievement witnessed in South and East Asia. The area with access to irrigation has doubled during 1960s-2000s with the most World Bank lending granted in the period of 1975-1985. The rapid expansion of irrigation schemes has contributed to the increased farm yield and the resultant drop in the world price index (Lipton et al 2003, Bhattarai et al 2002, Hussain and Hanjra 2004, Hussain 2007, Smith 2004). The direct benefits are transferred to improved household income by increased farm yield, expanded cultivation area, crop diversification, enhanced crop intensity, boosted use of high yield varieties. The indirect benefits can be seen in additional labour demand, improved wage rate, lower price of food grain, better nutrition, reduced out-migration, promoted trading, promoted research and development in fertilizers and high yield varieties.

Surrounded by the sea to the east and south, and topographically characterized by a dense river system and two fertile deltas, the deep root of Vietnam's civilization lies in the practice of paddy rice cultivation in which irrigation plays a critical role. The first water management work was built, both for flood control and irrigation, in the 8th century, including a dense network of semi dykes, pumps and sluices (Pham and Shannon 2010). Along with the Green Evolution in the South and East Asia during the 1960s-1970s, Vietnam has made massive investment to expand the irrigation system, resulting to nearly half of the agricultural area irrigated, per capita crop output doubled, helping to move Vietnam out of the group of poorest countries towards lower-middle income countries. The poverty headcount fell significantly from 58% in the early 1990s to below 10% by 2010 (WB, 2012) based on the basic needs poverty line agreed in the 1990s. Still, according to the updated GSO-WB poverty line and methodology, 20.7 percent of Vietnam's population is still poor in 2010, whereas this indicator is 27% in rural areas (WB, 2012), requiring the Vietnamese government to take stronger actions to eradicate poverty. The Master plan of production development of agriculture to 2020 and a vision toward 2030 (MARD 2012) has set the task to continue investment into irrigation towards modernization, improving efficiency of water supply for agriculture, ensuring water for 4.5 million hectare annual land, targeting 100% rice-growing area sufficiently watered for two cultivating seasons.

The question raised here is whether investments in irrigation have a significant impact on rural poverty and rural household welfare. There are few studies examining the impact of irrigation in Vietnam. A study by JBIC in 2001 estimates that paddy rice yield increases from 16 to 35% where access to irrigation is available. As a result, productivity in the Mekong Delta doubles from 4.5 tons/ha in 1975 to 9.5 tons/ha in 1990 and food outputs escalate from 16 million tons in 1986 to 34 million tons in 1999 (JBIC, 2001).

This paper will examine the effect of irrigation infrastructure on rural household welfare. Rural population makes up two thirds of Vietnamese population (GSO, 2011) and relies heavily on crop income. The share of agricultural income has declined over time but remains as the major income source for the poorest 40 percent of the rural population. The share of income from agricultural and related activities continues to be substantial among poorer households and has grown for the poorest quintiles since 1993 (McCaig et al. 2009). Using data from VHLSS 2010-2012, this paper will conduct an impact evaluation of communal small-scale irrigation plants on rural household income and farming activities.

2. Literature Review

The last five decades witness the most remarkable expansion of the global irrigation system. The area equipped for irrigation doubled during the period 1960-2010. Lending for irrigation accounted for roughly 7 percent of total World Bank lending from 1953-1990 and is the largest recipient of public agricultural investment in the developing countries (Jones, 1995). From 1953 to 1990, this lending amounted to 31$ billion US Dollars in constant term. Investment into irrigation reached its peak in the late 1970s and early 1980s, when the annual growth rate of irrigated area converged 2.5% compared to 2% during the 1960s. After that, the lending to irrigation decreased or was integrated into rural development projects.

There are several reasons for this decline in trend. Thanks to the falling food price which is resultant from the already existing irrigation system, better seeds, the application of fertilizers and other agricultural technologies, agricultural problems become less urgent. Instead, the need to maintain and update the existing systems to increase efficiency is raised. Additionally, early projects were conducted in the best farming areas which are most economically attractive and where benefits can be most optimally exploited, leaving less attractive areas in terms of economic rate of return.

However, irrigation will continue to play a critical role in food security aside from other indirect benefits. As demand for food rises, induced by population growth and improved income, the agriculture sector will have to catch up whereby the additional output will come mainly from irrigated land (Jones 1995). Globally, irrigated agriculture contributes more than 40% of the total food production but occupies only 17% of the total agricultural land (Fereres & Soriano 2006). The International Water Management Institute has pointed out the mains goals for irrigation investment are to reduce rural poverty and to keep up with global demand for agricultural produce, aside from adaptation to water scarcity and climate change (IWMI 2007). This study will focus on the impact of irrigation in rural welfare enhancement.

Irrigation infrastructure is believed to have multifold effect on household welfare and on the economic development of the wider community. The most visible impact of irrigation can be seen in farming households' income. Lipton et al. (2003) identify several channels through which access to irrigation boosts farm output and improves household income. Firstly, irrigation increases farm yield through the stable and sufficient water supply. The output of crops and pastures is affected not only by the total amount of rainfall, but also by the frequency and duration of rainfall during a particular period and the water demand of plants at different growth stages. The irrigation system enables stable water supply which is regulated to match the demand by different kinds of crops at different phase of development (Shaxson & Barber, 2003). Farm output is therefore ensured as it is less vulnerable to fluctuation of rainfall pattern. Secondly, regular water supply and drainage allows multiple cropping. Earlier, farmers have to adjust their cropping season to the rainfall pattern and this normally allows one season annually. By adjusting the water level in the rainy periods and storing water for drought periods

Thirdly, irrigation enables horizontal expansion of irrigation by allowing a greater area of land to be cultivated where normally the rain-fed production is not feasible. This is not only true to drought-prone areas where agraland is limited by water scarcity but only to sub-humid or semi-arid regions which are characterized by rainless months between rainy seasons. Through well-managed regulation of water flow, irrigation systems help reduce problem of flooding and soil salinization, thus reserving cropland. What is more, the irrigation induced increase in farm yield promotes the use of high-yielding varieties, fertilizers and multiple cropping, resulting in a higher farm output. Assured by the stable output, the farmers will be motivated to increase investment for better seeds and other input factors, thus enabling further improvement of farm productivity. The stable water supply also enables the diversification of crops as well as the switching from staples to higher-value, market-oriented produces. Farmers switch from drought-resistant plants to water-tolerant ones which promise higher price and better marketability. Furthermore, thanks to the stable farm output, the farming households are less vulnerable to external shocks such as food price or natural disasters. Especially for households whose subsistence income level relies heavily on farming to overcome poverty, their vulnerability to external shock is among the main reasons for them to fall back into poverty trap. On the whole, access to irrigation provides farming households with a better-off condition to achieve higher and more sustainable source of income.

But the impact of irrigation equipment is not limited to accessible farm households and can be extended to a broader community. The irrigation induced increase in farm output also stimulates demand for farm labour, thus enhances the employment opportunities in the rural areas and reduce migration to urban areas. Increased investments expand the farm size resulting in the demand for additional labour force, offering landless labourers a stable source of income. This changes the rural wage structure and lessens the pressure of migration to urban areas. Additionally, higher farm yield enables a reduction in food price. This allows better access to food for all, but particularly beneficial to landless and subsistence families which normally spend more than half of their income on food (Bhattarai et al, 2002). This is particularly true for rice, taking into consideration the concentration of supply chain in the world rice market and the volume of irrigation investment into rice projects (Jones 1995). irrigation system plays the catalyst role in changing the whole socio-economic situation of the commune and benefiting households with better welfare conditions (Lipton et al 2003, Bhattarai et al 2002, Hussain and Hanjra 2004).

A consensus seems to exist among scholars that the indirect benefits can be much higher thanks to its multiplier or spillover effect (Lipton et al. 2003, Bhattarai et al. 2002, Hussain 2007). While the direct benefits of irrigation access mostly accrue to farming households, the spectrum of indirect impacts extends outward to a larger beneficiaries group, ranging from landless laborers to a wider community. The impact of irrigation infrastructure is not limited to increased income of farming households but reaches out to promote the socio-economic development of rural areas which then sequentially promote more investment into irrigation. This repetitive circle of forth and back effect magnifies the original impact of irrigation, making it extremely difficult to capture the total return on irrigation investment.

Numerous empirical researches have been conducted in an effort to find support for the analytical framework on the correlation between irrigation and household welfare. Hussain and Wijerathna (2004) studied six countries comprising of Bangladesh, India, Pakistan, China, Indonesia and Vietnam which make up of totally 51.1% of world net irrigated area. Comparative assessment was undertaken in 26 large- and medium scale canal systems using household-level data from the 2001-2002 agriculture year. The results indicate that there is a strong linkage between irrigation and poverty. For 22 systems of the examined countries the study reveals a positive net benefit of irrigation illustrated as the net value of farm production per irrigated area unit minus that per non-irrigated area unit, except for China where the indicator was not calculated. The result ranges from 23 USD/ha in Hakra, Pakistan, to 478 USD/ha in Krogowana, Indonesia. In general, in South Asia, where the average land size per household is larger and the distribution of land and water is highly inequitable, crop productivity is much lower and cropping pattern is less diversified. The poverty performance of irrigation in South Asia is weaker compared to South East Asia, implied by the lower net irrigation benefit. Taking the average, poverty in regions with irrigation settings is 20-30% lower than in rain-fed systems.

By using a sample of 1199 households from randomly selected 60 villages from the China National Rural Survey, Huang et al (2006) also seek to find evidence of irrigation's impact on crop yields and revenue. In their descriptive model, average yield of irrigated plots are significantly higher than that of non-irrigated plots for almost all crops included in the survey. Specifically, wheat yields on irrigated plots are 70.9% higher than that of non-irrigated plot, the number for cotton is 177% and maize 16.4%. Irrigation also improves crop production by enabling cultivation rotation. For example, the annual yield of wheat-rice rotation far exceeds that of single season of wheat or rice. The results indicate that irrigation improves crop yield both in terms of increasing productivity and enabling crop rotation. Overall, revenue from irrigated plots are on average 79% higher than that of non-irrigated plot, the specific number is higher in poorer villages. The multivariate model has similar implications, though the magnitude of differences is lower, most likely because other factors influencing crop yields and revenue are controlled. For example, results from the regression show that irrigation increases wheat yield by 17.7%, cotton by 28.4% and maize by 29.4%, while increasing crop revenue by 76.1% on average.

In an effort to demonstrate the importance of irrigation in poverty alleviation, Narayanamoorthy (2001) conducted a quantitative analysis covering 14 major states of India using data at four different points of time during the 1970s and 1980s. He measures the development level of irrigation in these states using irrigated area in hectare per thousand rural population and examines its impact on real wage rate of agricultural laborers, foodgrain production per head of rural population and other proxies for rural poverty. His analysis shows that real wage of agricultural laborers positively correlates with the development of irrigation. He explains this incident by reasoning that the extension of irrigation not only increases demand for agricultural labour but also reduces the price of essential commodities, thus improving real wages. His results also indicate a positive impact of irrigation on foodgrain production per head of rural population. The value of regression coefficients ranges from 1.41 to 2.14 over the four periods, all at a significance level of 1%; furthermore, the magnitude of correlation between irrigation and foodgrain production per head of rural population increases overtime over the four surveyed periods. Finally, he concludes that one hectare increase in irrigated area per thousand rural population reduces poverty occurrence by 0.12% in the period 1972-1973 and 0.08% in the period 1983-1984.

Gebregziabher and Namara (2008) also tried to examine the impact of small-scale irrigation settings on poverty incidence in the state of Tigray, Ethiopia, by using propensity score matching method. Their study area covers six communities which are geographically dispersed within the state, from which 613 households are chosen as sample. Using data from 2004/2005 agricultural year, they observe no significant differences between irrigators and rain-fed farmers in terms of demographic characteristics, level of education and resource endowments. However, irrigators have more diversified sources of income and significantly higher non-crop income, mostly from livestock. In general, the total income of irrigators is 50% higher than that of rain-fed farmers, while the level of expenditure by 8.6% higher. The calculated mean poverty rate among irrigators is also lower than that of rain-fed farmers which are 44% and 56% respectively, implying the crucial role of irrigation investment as a poverty alleviation policy in Ethiopia.

Dillon (2008) examined the impact of internationally financed irrigation projects in form of motorized pumps on household consumption, agricultural production and nutrient intakes in northern Mali. Descriptive statistics show that mean agricultural output in pump-irrigated farms is 2.1 tons per season, compared to 643kg in farms using lake-recession system and 288 in rain-fed farms. The total household consumption in pumping system is 50% higher than that of lake-recession and rain-fed system. Both difference-in difference matching and propensity score matching indicate significant effect of irrigation projects at 1 and 5 percent level. The coefficient of irrigation on total agricultural production ranges from 1.25 to 1.83 tons per household in propensity score matching and from 1.17 to 1.89 tons per households in difference-in-difference matching. The impact of irrigation projects n household calories and protein intakes are also statistically significant.

Hail (2008) analyzed household-level data of 602 randomly selected households in five drought prone villages of Northern Ethiopia in the 2005/06 and concluded that on average, household with access to deep wells have 23% lower poverty incidence than non-irrigation user households. Similarly, households with access to shallow well irrigation have on average 9% lower property incidence than those without access. Hail also highlights that access to deep well or shallow well irrigation has a significant effect in increasing per capita expenditure of beneficiary household.

However, empirical findings on the impact of irrigation on poverty have never been polarized. Fan et al. (2000) state that the government investment in irrigation infrastructure has a modest impact on the expansion of agricultural production and has hardly any impact on rural poverty and inequality in income distribution. They use state-level data from 1970-1993 to estimate the effect of eight different types of government expenditure on poverty in India, namely investment in research and development, irrigation, road, education, power, soil and water, rural development and healthcare. Their results show that irrigation investments rank 7 out of 8 in terms of poverty alleviation impact. An additional investment of 100 billion rupees in irrigation reduces rural poverty incidence by marginally 0.05%, much lower than the level of 0.65% of road investment. Similarly, irrigation investments perform poorly in terms of reducing the number of poor. Every additional million rupees investment in irrigation helps 9.7 people escape poverty, a very modest impact in comparison with 123.8 by road or 84.5 by research and development investment. Using identical methodology of decomposing total factor productivity of different crops, Jin et al (2002) and Rosegrant and Evenson (1992) share the view that there is no linkage between irrigation and poverty reduction in South Asia in general and in China and India in specific while highlighting the role of technology improvement and research stock in enhancing the total factor productivity in agriculture.

The lack of consensus regarding the correlation between irrigation application and poverty reduction is attributed to the selection of methodology, states Gebregziabher (2009). Studies using aggregate data often fail to find any significant impact of irrigation on poverty alleviation while small-scale or village-level data appear to support the hypopaper. The ranging magnitude of impact of can be attributed to several factors such as the natural characteristics of the location of irrigation settings, the typology of the irrigation settings or the operation and management mechanism of the irrigation scheme which all affect its efficiency and capacity.

Ut and Kajisa (2003) observe a parallel trend between rice production and irrigation using the data from 1980 to 2000 in Vietnam. They conclude that the remarkable increase in rice production and the improved cropping intensity during the two decades is associated with an increase in irrigation rate. Parallel to this trend is an intensified application of fertilizer and high-yielding modern varieties.

In a comprehensive country report for Vietnam, IWRM (2003) examined two irrigation systems in Nam Duong (Nam Dinh Province) of the Red River Delta and Nam Thach Han (Quang Tri Province) of the Central Vietnam. The study uses income as the main indicator of welfare and points out that household income is largely dependent on seasonal agricultural income. The research team concludes that irrigation-related variables such as irrigation area, location along the irrigation system (middle section, tail-end section) are significant in predicting poverty. This study contributes to the view that investment in irrigation in the two project sites has a positive impact on income improvement, but fails to make a general conclusion for a national scale due to the unrepresentativeness of the two examined irrigation systems.

Van der Walle (1996) uses data from Vietnam Living Standard Survey 1992-1993 to identify the determinants of crop income. She concludes that irrigated annual crop land is the third relevant determinant of household's crop income after primary education of household head and household size. To be concrete, an additional are of 100m2 irrigated annual crop land raises an additional income of 48.572 dongs. Furthermore, the marginal effect of irrigated annual land on net crop income is more than double of the marginal effect of non-irrigated annual land (19.994 VND/100m2) or that of perennial land (21.269 VND/100m2). The results even indicate that family labour becomes less of a constraint for households with larger area of irrigated land, implying that the access to irrigation frees labour force, possibly from water fetching activities.

Several other studies examined the irrigation system on Vietnam on a site-scale or concentrate on the operation and management of the existing irrigation systems (Fontenelle 2001, Malano et al 2004) or the performance of different irrigation technologies (Chinh et al 2013) but seemed to neglect the impact of irrigation on household welfare or fail to examine this impact on a wider scale. The question of to what extent irrigation improves welfare in Vietnam remains unanswered. This paper using household- and commune-level data from the VHLSS of 2010-2012 will seek to examine the nation-wide effect of irrigation infrastructure.

3. Data and methodology

3.1 Data source

The paper uses panel data from the Vietnam Household Living Standard Surveys 2010 and 2012 collected by the General Statistics Office. The surveys contain detailed information on households including basic demographic features, employment condition, education level, health condition, income and expenditure level, housing conditions, fixed assets, participation in different poverty alleviation programs and access to water sources. Also included in the VHLSS are commune-level data featuring demographic characteristics, current economic situation and access to different aid programs, statistics on agricultural production, irrigation and other infrastructure availability as well as educational, healthcare and social issues. The household-level data sample of VHLSS 2010-2012 is composed of 9399 households, of which 6,696 households are from rural and 2,703 from urban communes. Urban households are ignored leaving rural households the object of examination in this paper.

The commune-level data sample consists of 2,199 communes categorized into six geographical locations: Red River Delta, Midlands and Northern Mountains, Northern and Coastal Centre, Highlands, Southeast and Mekong Delta. This geographical feature will also be taken into account when examining the effect of irrigation infrastructure as it is rational to assume different impact on different geographic regions with different terrain typology.

The household-level and commune-level data set will be merged to form a panel data sample which is subject to quantitative investigation.

3.2 Irrigation development in Vietnam

Due to the crucial role of agriculture to the Vietnamese economy not only in terms of contribution to GDP but also with regards to employment for over 30% of total workforce, special attention has been paid to irrigation planning and management over different periods. Alone in the period of 1996-2000, the government has spent 14.1 trillion VND in irrigation. FAOSTATS reports that until 2011, nearly half of the agricultural land is irrigated. Irrigation includes both large-scale (networked) and small scale (wells, pumps) system and is mostly supplied by surface water. Data till 2014 by Water Resource Department (MARD) report 904 irrigation systems of mid- and large scale with serving area of at least 200 ha, of which 110 have a serving area of 2000ha upwards. The data also report 6.914 lakes for different irrigating purposes, 10.076 dams, 13.347 pump stations, 5.500 drainage systems, 254.815km canals. The two major deltas are equipped with complex hydraulic systems incorporating flood control, drainage, saline intrusion control and irrigation functions, whereas the irrigation functions rely mostly on canal systems with pumping stations and on-farm water control (Van de Walle, 1996). Outside the deltas, irrigation is less developed.

The available irrigation infrastructure ensures water supply for 7 million hectares of rice field for three crop seasons. Additionally, this system regulates water for 1,5 million hectares vegetables and industrial plants and supplies domestic water for 84% population (MARD 2014).

The access of household to irrigation infrastructure calculated on VHLSS2010-2012 is illustrated in Table 2. The table presents the percentage of households living in a commune with a public-ran irrigation infrastructure across six geographic regions. As already mentions, households in the two major deltas are well-equipped with irrigation, with about two thirds of households living in a commune with at least a commune-operated irrigation plant. Surprisingly, households in Midlands and Northern Mountains, which are normally believed to have lower infrastructure development, have the best access to irrigation with over 80% communes have at least one communal small-scale irrigation plant. These regions appear to receive the most irrigation investment throughout 2010-2012 as the increase in the percentage of household with access to irrigation is the most remarkable. The southeast region has a modest percentage of household access to irrigation and this indicator even decreased over time, which can be explained by the rapid industrialization in this area.

Regions	Year	
Geographic region	2010	2012
Red River Delta	78.1	73.4
Midlands and Northern Mountains	74.9	80.8
Northern and Coastal Central	67.2	70.3
Central Highlands	59.5	60.5
Southeast	39.1	30.8
Mekong Delta	67.3	71.1
Total	67.9	68.2

Table 1: Access to irrigation infrastructure by geographic region (Author's calculation using VHLSS 2010-2012)

3.3 Methodology

In order to examine the impact of irrigation infrastructure on household welfare, this paper uses fixed-effect method.

Let Y be a vector denote household welfare indicators including per capital income, employment day and farm yield per year. The following equation describes the relationship between irrigation setting and household welfare:

$$Y_{ijt} = \beta_0 + \beta_1 X_{ijt} + \beta_2 I_{jt} + \beta_3 C_{jt} + u_{ij} + v_j + \varepsilon_{ijt} \quad (1)$$

whereas the subscripts i, j, t indicate household i from commune j at time t with t=1 referring survey year 2010 and t=2 referring survey year 2012. X is a vector consisting of household variables. I is a dummy variable indicating whether irrigation infrastructure is available in the commune with I=1 indicating availability and I=0 otherwise. C is a vector of control variables including different commune characteristics. u_{ij} and v_j are respectively unobserved time-invariant features of household and commune. ε_{ijt} is an error term. The impact of irrigation infrastructure on household welfare is measured by the determinant β_2.

The question on the impact of irrigation on household welfare poses the problem of endogeneity. Generally, communes with larger cultivation area and higher farming population are more likely to be invested with irrigation infrastructure, household in these communes are more likely to have better income and higher farm yield. It is difficult to extract the effect of irrigation setting from other unobserved factors. Therefore, fixed-effect regression is used in this paper to estimate the equation (1) to drop the effect of unobserved time-invariant characteristics of households and communes. It is assumed that time variant unobserved variables are not correlated with irrigation settings in equation (1).

4. Findings and analysis

This section represents all the empirical findings on the impact of small-scale irrigation plants managed by commune on household welfare. The control variables include household-level and commune-level variables. Household-level variables include the area of annual and perennial land, household size, the percentage of children and elderly in household size. Commune-level variables include whether the commune has small-scale irrigation plants managed by commune, car road and the distance from the commune to the nearest town. The reason for including commune-level variables is that decisions on irrigation investments, like most of infrastructure investments, are made using various information about the commune.

Table 3 displays the descriptive results of outcome variables. For both the cases of 2010 and 2012, the mean per capita income is higher in commune without a commune-managed small-scale irrigation plant. Similarly, household income level from all three sources – crop, livestock, forestry and fishery – is lower in commune with irrigation plants with the only exception of livestock income in 2012 in which household income from livestock is higher in commune with irrigation plants. The income structure is quite similar among households in communes with and without irrigation plants managed by commune. There are no significant differences in household's rice-growing area and yield between communes with and without irrigation plants. Results from this table indicate that households in communes with irrigation plants do not outperform those in communes without the infrastructure in terms of economic activities.

Outcome variable	Year	Mean	
		Commune without irrigation plants managed by commune	Commune with irrigation plants managed by commune
Per capita income (in Thousand VND)	2010	15646.27	14133.23
	2012	23608.68	20934.3
Crop income (in Thousand VND)	2010	13195.65	11751.08
	2012	22546.3	16658.01
Livestock income (in Thousand VND)	2010	3523.95	3012.78
	2012	4529.75	4945.30
Income from fishery and forestry (in Thousand VND)	2010	3396.65	2635.15
	2012	4272.45	3374.87
Share of crop income (%)	2010	23.97	24.88
	2012	22.60	23.77
Share of livestock income (%)	2010	6.40	6.20
	2012	5.80	6.63
Share of income from forestry and fishery (%)	2010	5.97	5.65
	2012	5.60	4.76
Household's rice-growing area (m2)	2010	12894.83	12429.10
	2012	7385.60	6840.16
Household's rice yield (kg)	2010	6136.37	6358.31
	2012	3973.44	3666.78

Table 2: Summary of outcome variables (Own calculation using VHLSS 2010-2012)

Table 4 represents a summary of the explanatory variables. The summary of household-level variables implies no systematic demographic differences among households in communes with and without an irrigation plant. Similarly, analysis of commune-level variables shows no significant differences between communes with and without a small-scale irrigation setting in terms of the access to car road and the distance to town.

Explanatory variables	Year	Mean	
		Commune without irrigation plants managed by commune	Commune with irrigation plants managed by commune
Household's annual land area (m2)	2010	3974.058	3855.746
	2012	3674.292	4144.942
Household's perennial land area (m2)	2010	2610.83	1232.575
	2012	3528.393	1454.504
Household size	2010	4.109101	3.954415
	2012	4.004455	3.90973
Percentage of children in household (%)	2010	.2215426	.2060743
	2012	.2136766	.1983486
Percentage of elder people in household (%)	2010	.1276713	.1321588
	2012	.1341898	.1563438
Distance from the commune to the nearest town (km)	2010	12.19427	10.80977
	2012	109.6644	112.5865
Commune with car road (%)	2010	.8818917	.8901784
	2012	.9182681	.9272467

Table 3: Summary of explanatory variables (Own calculation using VHLSS 2010-2012)

Table 5 illustrates the impacts of commune-level small irrigation plants on household per capita income and household income from crop, livestock and fishery and forestry. There are no significant effects on commune-level small irrigation plants on per capita income or on different income sources. This indicates that investments in commune-level small-scale irrigation plants do not improve rural income level as hypothesized.

Explanatory variables	Log of per capita income	Log of household's crop income	Log of household's livestock income	Log of household's income from forestry and fishery
Log of household's annual land area	0.0139***	0.1260***	0.0344*	0.0165
	(0.0053)	(0.0182)	(0.0184)	(0.0208)
Log of household's perennial land area	0.0109**	0.0306***	0.0153	0.0129
	(0.0046)	(0.0090)	(0.0138)	(0.0124)
Household size	-0.0800***	0.0868***	0.0896***	0.0475
	(0.0118)	(0.0196)	(0.0326)	(0.0350)
Percentage of children in household	-0.2613***	0.0786	-0.3701	-0.5766*
	(0.0946)	(0.1705)	(0.3161)	(0.3360)
Percentage of elder people in household	-0.2129**	-0.2108	0.4540	-0.1771
	(0.0960)	(0.1878)	(0.3588)	(0.3140)
Commune with small irrigation plants managed by commune	-0.0069	-0.0369	-0.0857	0.0614
	(0.0211)	(0.0338)	(0.0726)	(0.0704)
Distance from the commune to the nearest town (km)	0.0000	0.0002*	0.0001	0.0001
	(0.0001)	(0.0001)	(0.0002)	(0.0002)
Commune with car road (%)	-0.0091	-0.1386**	-0.0336	0.0979
	(0.0363)	(0.0641)	(0.1006)	(0.1088)
2012.year	0.4061***	0.2727***	0.3867***	0.1955***
	(0.0134)	(0.0231)	(0.0459)	(0.0465)
Constant	9.6533***	7.8549***	7.1808***	7.2924***
	(0.0652)	(0.1573)	(0.2140)	(0.2438)
Observations	6,045	4,756	3,567	2,716
R-squared	0.389	0.183	0.107	0.045
Number of i	3,078	2,540	2,120	1,622

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

Table 4: Impacts of commune-level small irrigation on rural households' income

Table 6 represents the impacts of commune-level small irrigation plants on household's income structure. Here, the share of crop income, livestock income and income from forestry and fishery activities in household's total income are investigated. The results show no significant effect of small-scale irrigation plants on the share of crop income and the share of forestry and fishery income. Interestingly, small-scale irrigation plants has a significant effect on the share of livestock income, whereas the share of livestock income in household's total income is 1.25% lower in commune with commune-managed small irrigation plants than in commune without one. This raises a consideration of whether the access to small-scale irrigation in communes brings out shifting of household's economic activity from livestock to other form. However, there is no evidence that income structure is changed in favor of cropping or fishery and forestry, implying the invalidity of this consideration.

Explanatory variables	Share of crop income	Share of livestock income	Share of income from forestry and fishery
Log of household's annual land area	1.8515***	0.1325	-0.0201
	(0.1887)	(0.0849)	(0.0710)
Log of household's perennial land area	0.5326***	0.1260	0.0975
	(0.1624)	(0.0977)	(0.0784)
Household size	-0.9470***	-0.0052	-0.3798**
	(0.3428)	(0.1858)	(0.1927)
Percentage of children in household (%)	2.4657	-0.0321	-1.4811
	(3.2792)	(1.8683)	(1.8484)
Percentage of elder people in household (%)	1.5537	3.9340	-2.1703
	(2.9703)	(2.7014)	(1.7418)
Commune with small irrigation plants managed by commune	-0.3924	-1.2541***	0.0542
	(0.6596)	(0.4018)	(0.4330)
Distance from the commune to the nearest town (km)	-0.0005	0.0038**	-0.0012
	(0.0035)	(0.0019)	(0.0021)
Commune with car road (%)	-2.2526*	-1.5417*	1.5978*
	(1.2007)	(0.8551)	(0.8894)
2012.year	-1.5190***	-0.3153	-0.6034**
	(0.4544)	(0.2755)	(0.2516)
Constant	18.9145***	7.0465***	6.3688***
	(2.1581)	(1.2808)	(1.1854)
Observations	6,045	6,045	6,045
R-squared	0.063	0.010	0.008
Number of i	3,078	3,078	3,078

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

Table 5: Impacts of commune-level small irrigation on income structure

In Table 7, the impacts of commune-managed small irrigation plants on household's rice-growing area and rice yield are illustrated. The results show that there are no significant effects of commune-managed small irrigation plants on either household's rice-growing area or household's rice yield. This results are consistent with the speculation represented in Table 3 that commune-managed small irrigation plants has no significant effect on crop income.

Explanatory variables	Log of rice-growing area	Log of rice yield
Log of household's annual land area	0.4392***	0.4221***
	(0.0662)	(0.0612)
Log of household's perennial land area	0.0119**	0.0114**
	(0.0048)	(0.0053)
Household size	0.0480***	0.0493***
	(0.0134)	(0.0129)
Percentage of children in household (%)	-0.1201	-0.0307
	(0.0999)	(0.1124)
Percentage of elderly in household (%)	-0.1703	-0.1263
	(0.1038)	(0.1070)

Commune with small irrigation plants managed by commune	-0.0174	-0.0034
	(0.0196)	(0.0226)
Distance from the commune to the nearest town (km)	0.0001	-0.0001
	(0.0001)	(0.0002)
Commune with car road (%)	0.0519	0.0583
	(0.0361)	(0.0418)
2012.year	-0.6198***	-0.5392***
	(0.0159)	(0.0170)
Constant	5.1997***	4.5200***
	(0.5076)	(0.4753)
Observations	3,641	3,641
R-squared	0.703	0.626
Number of i	1,944	1,944

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

Table 6: Impacts of commune-level small irrigation on household's rice area and rice yield

Finally, fixed effect regression was run separately for six geographical regions to examine whether the impact of irrigation differs among these regions. Table 8 represents only the irrigation coefficients for six regions, the full regression results are found in the annex. Communal small irrigation plants are found to have a significant impact on per capita income in the Midlands and Northern Mountains. Small irrigation plants also appear to help increase income from forestry and fishery in this region, but reduce the share of livestock income at the same time. Only in Red River Delta do commune-managed irrigational plants appear to have a significant impact on crop income, probably due to the extensive rice cultivation in this second largest delta of Vietnam. Interestingly, communal irrigation plants seem to reduce the share of livestock income in Mekong Delta. This similarity with the case of Midlands and Northern Mountains seems to indicate that the access to communal irrigation enables a move away from livestock towards other farm activities.

	Log of per capita income	Log of household's crop income	Log of household's livestock income	Log of household's income from forestry and fishery	Share of crop income	Share of livestock income	Share of income from forestry and fishery	Log of rice area	Log of rice yield
Red River Delta	-0.0594	-0.1245**	-0.0206	-0.2525	-0.7461	-1.0109	0.2120	0.0037	-0.0184
	(0.0477)	(0.0541)	(0.2018)	(0.2777)	(1.2279)	(0.9912)	(0.8269)	(0.0294)	(0.0322)
Midlands and Northern Mountains	0.1370***	-0.0234	-0.0439	0.2502**	-1.3146	-2.9663***	0.1211	-0.0669	-0.1009*
	(0.0501)	(0.0650)	(0.1386)	(0.1162)	(1.2927)	(1.1083)	(0.7945)	(0.0555)	(0.0539)
Northern and Coastal Central	0.0364	-0.0099	-0.1027	-0.0068	-1.3839	-1.0816	0.0243	-0.0360	0.0413
	(0.0390)	(0.0625)	(0.1210)	(0.1325)	(1.4260)	(0.8474)	(0.8300)	(0.0338)	(0.0366)
Central Highlands	-0.0838	-0.1728	0.1421	0.1481	-3.2893	0.6823	0.5759	-0.0002	-0.1692
	(0.0693)	(0.1165)	(0.1882)	(0.3027)	(2.8643)	(1.1808)	(1.2989)	(0.0918)	(0.1115)
Southeast	-0.0114	0.5187	-0.1444	1.0155	5.2089**	0.2357	0.5567	0.0843	-0.0403
	(0.0688)	(0.3188)	(0.3643)	(0.6701)	(2.6311)	(0.3974)	(0.5797)	(0.2486)	(0.1783)
Mekong Delta	-0.0556	0.0592	-0.1131	-0.0652	0.4701	-1.5590**	-1.0042	0.0388	-0.0403
	(0.0458)	(0.0995)	(0.1952)	(0.1520)	(1.5190)	(0.6646)	(1.4200)	(0.0460)	(0.1783)

Table 7: Irrigation coefficients for six geographical regions

Overall, this study does not find any significant effects of commune-level irrigation plants on household welfare. Self-managed commune-level irrigation settings appear to fail to improve household income or change income structure. Although irrigation infrastructure is expected to improve cropping performance, analysis shows no significant evidence on the expansion of rice-growing area or the improvement of rice yield. The reasons for these findings can be various.

Firstly, VHLSS questionnaire includes information on whether the commune has at least one irrigation plants under its own management. By this formulation, the provided information excludes all other form of irrigation typologies such as large dams and hydraulic structures managed by the state or micro-level irrigation tools self-managed by households such as pumps and tube-wells. Obviously, the typology of the irrigation plants also influences its performance. As already pointed out by Hail (2008) for the case of Northern Ethiopia, deep wells outperform shallow wells in terms of poverty alleviation whereas pond has no effect in improving incomes because regular water seepage reduces efficiency of the pond. Dhawan (1988) reports that groundwater irrigation performs better than surface water irrigation. His analysis shows that private tube-wells can enhance farm output twice the level public canals do as the farmers have better control over the water supply. Generally, private small-scale irrigations are better suited to the resource constraints of small households than commune-level irrigations which rely heavily on natural resource (Lipton et al 2003).

Furthermore, no household-level information is provided on how far the farm household is situated along the water distribution channel, making the general examination of the impact of the irrigation plants difficult. Obviously, whether the household is located on head or tail of the distribution channel influences its access to irrigation water significantly, especially when water is scarce. Generally, it is expected that households near the irrigation headwork have reliable access to water whereas those at the end of the system have far less timely and sufficient water supply. March et al (2004) prove that this is indeed the case for the Cu Chi (Ho Chi Minh City) and Dan Hoai (Ha Tay Province) by showing that rice yield for farms at the end of the system is much lower than that of farms near the system headwork. Due to the limitations of the available data in this paper, the impact of irrigation infrastructure is neutralized.

Aside from the limitation of data, there are objective reasons for the unclear effect of irrigation on rural welfare. With the main function of providing water to where and when it is needed, an irrigation plants must ensure flexibility, reliability and adequacy. Vietnamese systems often lack in one or more of these attributes, depending on the location-specific conditions of the system. (Malano et al 2004). The crucial element required of an irrigation scheme is the need to regulate water flows. Therefore, the operation and efficiency of an irrigation infrastructure relies heavily on water management. Only when the water is sufficiently provided could the whole irrigation system perform the function of distributing water to where it is needed on a timely manner. Harris (2006) points out that a number of inefficiencies in water management exist in Vietnamese irrigation system. The sources of inefficiency include the timing of water release, the inability of the system to meet peak water requirements and the lack of infrastructure to minimize losses and leakages. He investigate three irrigation schemes in Cu Chi (Ho Chi Minh City), La Khe and Dan Hoai (Ha Tay Province) and reports that all three schemes have the problem of uneven water distribution resulting in water logging in rainy season and water stress in dry season, thus reducing crop yield.

Another issue which needs consideration is the operation of the irrigation plants. The questions raised here is how often the asset is used, how frequent it is renovated and how often the structure breaks down. Again, Harris (2006) points out that the irrigation fees are generally insufficient to cover the operation and maintenance cost of irrigation schemes, leading to frequent system breakdowns or below capacity performance. Irrigation management companies often rely on government subsidies to make up for the shortfalls, which results in the poor management and lack of motivation for service improvement. The consequence of the weak operation and maintenance is often that the plant fails to irrigate the designed area. It is often cited on media that water reservoirs are empty in dry seasons or irrigation plants suffer from design or planning errors making them unable to deliver water. It is estimated that, nationwide, the system actually irrigates 68% of the designed area (MONRE 2012). Dau Tieng irrigation system (Binh Duong Province), for example, was reported to effectively watered 63 percent of the design area (WB, 1997)

This paper also tries to examine the channel through which irrigation might affect household income, namely through the expansion of growing area of rice as the main crop in Vietnam. In consistency with the effect on crop income, irrigation does not appear to affect rice-growing area. One reason for this might be the centrally regulated allocation of land in Vietnam. Agricultural land is allocated on the headcount basis rather through market mechanism. Additionally, most irrigation infrastructure is located in densely populated deltas, the fragmented farm size limits the impact of irrigation. Another reason might be the price effect of irrigation. Irrigation investment and the associated intensive use of other agricultural inputs are expected to reduce the price of food grains. The main beneficiaries of this price effect are, however, not the farm households, but the rural landless labourers and low-income urban consumers. This has been illustrated for the case of India by Datt and Ravallion (1998). Faced by the heavy subsidization of food grains by the developed ountries the rice price has been artificially depressed so that there is a tendency to shift to higher-value crops, leading to the nation-wide shrinkage of rice-growing area (Barker et al 2004).

5. Conclusions

This paper seeks to examine the impact of commune-level small-scale irrigation infrastructure on rural household welfare using fixed effect method and data. Analysis of data from VHLSS 2010-2012 shows that commune-managed small irrigation plants appear to have no significant effect in improving household's income or in changing household's income structure. Two main channels through which irrigation might affect rural households' income which are expansion of rice-growing area and improvement of rice yield were also examined. The results imply that commune-level small irrigation plants have no significant impact on rice-growing area nor rice yield. This implication appears to be consistent with the previous conclusion that small irrigation plants managed by communes have no significant impact on household crop income. Interestingly, analysis indicates a negative significant effect of communal small irrigation on the share of livestock income.

Separate fixed effect regression for six geographical regions give similar results. Generally, there is no significant evidence that communal irrigation plants improve rural household income nor change household income structure, except for the single case of Midlands and Northern Mountains. Although communal irrigation was found to somewhat change the income structure in one or two regions, this is not sufficient to form a systematic conclusion.

Empirical findings from this paper imply that despite massive public investments into irrigation infrastructure, this system does not function as effectively as expected and fail to deliver the necessary service to support rural economic activities. Weaknesses in the operation and maintenance of public irrigation plants have been pointed out, such as the timing of water release incompatible with crop demand, the inability of the system to meet peak water requirements and the lack of infrastructure to minimize losses and leakages during distribution. It is therefore recommended to establish a new pricing mechanism or cost-sharing structure to ensure the recovery of operation and maintenance costs for available irrigation plants. IWRM recommends that the greater the degree of operation and maintenance cost recovery is, the better the irrigation system performs (IWRM 2003). The current subsidies for irrigation companies should be eliminated. As the collected irrigation fees are insufficient to cover the operation and maintenance cost, irrigation companies rely on government subsidies to make up for the shortfalls. The reliance on subsidies has created a culture of poor management and lack of accountability and new investments have been made without thorough consideration of economic viability and farm profitability (IFPRI 2007, Harris 2006).

Technical staff in charge of irrigation operation at commune level should be trained on hydraulic and crops knowledge. Farmers should be encouraged to participate more actively in the operation of communal irrigation plants to ensure that the water delivery plans match with their interest and crop demand. The involvement of farmers in the design and operation process and their investment in the scheme in terms of labour is crucial for sustainable development of irrigation infrastructure. Farmers should be aware of their rights as beneficiaries as well as intervention methods to ensure efficient service delivery of communal irrigation plants (FAO, 1999)

The importance of integrated water resource management to ensure input water for irrigation system should also be highlighted. While agriculture consumes up to 80% of Vietnam's surface water (MONRE 2012), the increasing severity of water scarcity due to upstream economic activities and saline intrusion causes additional difficulties to the assurance of input water for irrigation system. This problem requires inter-sectoral and sometimes transboundary coordination to ensure the water demand of downstream inhabitants. In the context of water resource management, climate change is a cross-cutting issue as it makes the problem of unequal water distribution around the earth more severe. The impact of climate change on irrigation in terms of distorted rainfall pattern, severe natural phenomena or saline intrusion should be considered but irrigation is also a practical instrument to mitigate climate change impacts for rural and agriculture-reliant population.

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