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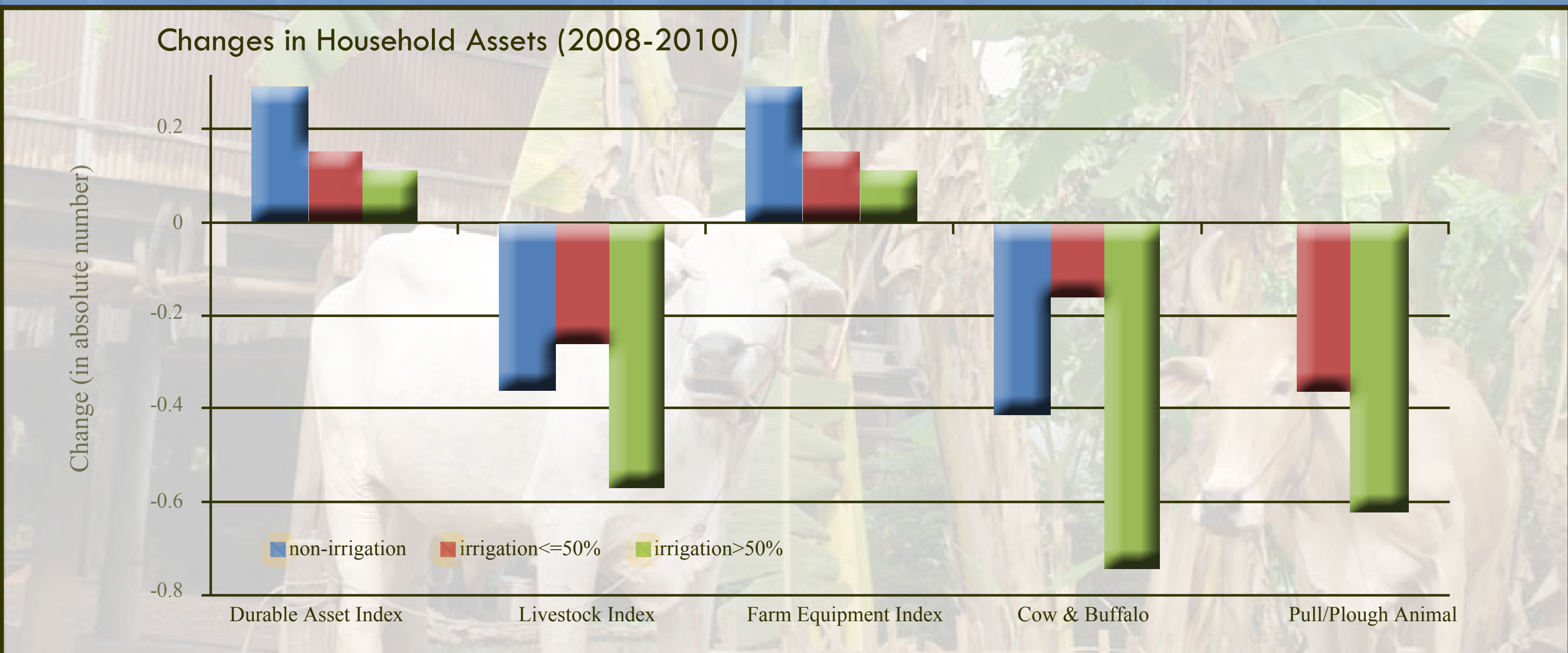
THE IMPACT OF IRRIGATION ON HOUSEHOLD ASSETS



TONG Kimsun, HEM Socheth and Paulo SANTOS

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Acronyms and Abbreviations

ADB	Asian Development Bank
ANOVA	Analysis of Variance
AusAID	Australia Aid for International Development
CDRI	Cambodia Development Resource Institute
FGD	Focus Group Discussion
FWUC	Farmer Water User Community
GDP	Gross National Product
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
LIML	Limit-information Maximum Likelihood
MAFF	Ministry of Agriculture, Forestry and Fisheries
MEF	Ministry of Economy and Finance
MOWRAM	Ministry of Water Resources and Meteorology
NGO	Non-government Organisation
NIS	National Institute of Statistics
NSDP	National Strategic Development Plan
OLS	Ordinary Least Squares
RUPP	Royal University of Phnom Penh
TSLS	Two-stage Least Squares
USDA	United States Department of Agriculture
USYD	University of Sydney
WB	World Bank
WRMRCDP	Water Resource Management Research Capacity Development Programme

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Abstract

This paper is based on data from 220 selected households surveyed during 2008-2010 and is intended to shed some light on the relationship between irrigation and household assets such as durable assets, livestock, farm equipment, cows and buffalo, and pull/plough animals. Since irrigation is widely seen as being an endogenous variable, the Instrumental Variable Regression Model is used to measure the effect of irrigation on household assets. Empirical results suggest that irrigation is unlikely to have a positive impact on the amount of durable assets, livestock, farm equipment, cows and buffalo and pull/plough animals. However, our analysis indicates that human capital does play a critical role in durable assets accumulation. These results could reflect the fact that irrigation systems in Cambodia do not function well enough to have a significant impact on household assets accumulation. Under these circumstances, investment in irrigation should be focussed more on achieving a balance between the expansion of irrigation systems and improvements in irrigation system efficiency, i.e. ensuring the availability of water in both wet and dry seasons, establishing appropriate levels of water for effective irrigation and ensuring equitable water allocation across the regions. Our findings provide further support for the widely held view that increased investment in a combination of human capital and irrigation infrastructure could have a stronger impact on the amount of household assets than investment in the development of infrastructure alone.

1 Introduction

The government of Cambodia has acknowledged that a well-functioning physical infrastructure is a prerequisite for sustainable economic development, growth and poverty reduction. For this reason, further rehabilitation and construction of physical infrastructure is defined as one of the most important components of Rectangular Strategy Phase II; this component consists of four sub-components: (1) rehabilitation and construction of transport networks; (2) water resources and irrigation system management; (3) development of the energy sector (including oil and gas) and the electricity network; and (4) development of information and communication technology (RGC 2009).

During 2006-2008, the Ministry of Water Resources and Meteorology (MOWRAM) made significant progress in rehabilitating, maintaining and constructing irrigation infrastructure through the implementation of 144 irrigation projects with the capacity to provide irrigation to 267,224 hectares MOWRAM (RGC 2009). As of the end of 2008, irrigated land accounted for 827,373 hectares, equivalent to 31.6 percent of the total cultivated land area (2,615,714 hectares) (RGC 2009).[1] Looking ahead, the government will continue to prioritise the rehabilitation, maintenance, construction and management of irrigation infrastructure in order to boost agricultural production. It aims to enhance the efficiency of irrigation management by integrating the concept of Participatory Irrigation Management and Development (PIMD) into water sector policy and establishing Farmer Water User Communities (FWUCs).

It is widely noted that irrigation generates various benefits which may contribute to poverty reduction and economic growth (e.g. Dillon 2011; Hussain 2007a; Hossain 2007b; Hussain & Hanjra 2004). Hussain and Hanjra (2004) describe three main pathways to irrigation development:

- Micro-pathway: through increasing returns to physical, human, and social capital of poor households (productivity)
- Meso-pathway: through integrating the poor into factor-product and knowledge/information markets (market participation)
- Macro-pathway: through improving national growth rates and creating second-generation positive externalities (economic growth).

1 According to MOWRAM, 1,120,246 hectares, equivalent to 43 percent of total cultivated land, is irrigated (CDRI 2010). Due to the lack of data on the area of irrigated land over the years, it is extremely difficult to evaluate the pace of irrigation expansion. FAO (2005) reports that the proportion of irrigated land to total cultivated land in Cambodia was only 20 percent.

With the financial support of AusAID, the Economic Component of the Water Resource Management Research Capacity Development Programme (WRMRCDP)[2] attempted to address three important themes: (1) water productivity, (2) the role of emigration, agricultural extension services and credit constraints on agricultural intensification, and (3) the impact of irrigation on household socioeconomic status.

This study addresses the third theme and aims to examine the relationship between the presence of irrigation and the amount of household assets such as durable assets, livestock, farm equipment, cows and buffalo, and pull/plough animals. The paper is organised as follows: section two reviews relevant literature, section three describes characteristics of the data collected, while chapter four discusses the empirical approach used and presents the findings. Section five concludes the study.

2 The WRMRCDP consists of three components: Physical, Governance and Economic (CDRI 2010)

2 Literature Review

As of 2005, irrigated agricultural land in Cambodia accounted for just 19.6 percent of the total cultivated area (FAO 2005). Recognising the importance of water sector development to achieving broader objectives of rural and agricultural development, economic growth, employment generation and increased wages, and overall socioeconomic welfare, the government has been promoting irrigation rehabilitation and construction.

Although irrigation infrastructure is believed to be a key catalyst to increased overall growth in the agricultural sector, the extent to which this is true has not been extensively tested. Wokker *et al.* (forthcoming) use a two-period panel dataset collected by CDRI in 2008-2009 to estimate the relationship between paddy productivity and water availability at plot level. By taking into account the heterogeneity of farmers and plots, and self-selection of supplementary irrigation, they found that the marginal return to farmers from irrigation was quite low during the wet season and high during the dry season, though the extent of usable irrigation infrastructure during the dry season was limited.

The study by Wokker *et al.* (ibid.) demonstrates the seasonal marginal return of having irrigation infrastructure; it remains unclear however, whether irrigation infrastructure in Cambodia leads to improvements in the livelihoods of the poor, looking in particular at the accumulation of farm assets as an indicator of this. Recent econometric studies from other countries illustrate a robust story that irrigation facilities shift in cropping patterns in favour of high value cash crops, increase crop production, farm equipments and durable assets, and have a positive impact on socioeconomic status such as income, nutrition and health i.e. reduced poverty and inequality.[3] For example, Dillon (2011) used panel data from a 245 household survey collected in northern Mali in 1997-98 and 2006 to assess the impact of small-scale irrigation on household consumption, assets, and informal insurance. Using propensity score matching and difference-in-difference matching estimators to correct the selectivity bias, Dillon (ibid.) found that irrigation increases household consumption, agricultural production and livestock holding, reduces covariate risk and reinforces informal food sharing networks, which allow households to insure against idiosyncratic risk. These studies confirm previous theoretical and empirical research on the impact of irrigation on production and consumption (e.g. Hussain & Hanjra 2004).

Huang *et al.* (2006) used a nationally representative sample of 1199 households in 60 villages across six provinces of rural China to measure the effect of irrigation on yields and crop revenues, as well as incomes in poor areas. Estimates by multivariate regression demonstrated that irrigation contributes to an increase in yields for almost all crops and income for farmers in all areas. The importance of crop income in poor areas and the strong relationship between crop revenue and irrigation supports the case for the importance of irrigation in past and future poverty alleviation in China. Huang *et al.* (2005, cited in Zhou *et al.* 2009) also studied the

3 See Hanji (2006) and Hussain (2007a, 2007b) for a detailed literature review on the impact of irrigation on cropping patterns, socioeconomic status, accumulation of assets and quality of life, and the impact of commercialisation on food consumption , nutrition and health and the nutrition status of adolescent girls.

relationship between the presence of irrigation and rural poverty and inequality, concluding that irrigation increases income and reduces poverty and inequality in rural China.

Other articles focus on the irrigation-poverty nexus. Such studies include a review of evidence from 45 micro-level irrigation studies (Silliman & Lenton 1985); 35 longitudinal village level studies in India (Jayaraman & Lanjouw 1999); a synthesis of eight village level studies from seven Asian countries including Bangladesh, China, India, Indonesia, Nepal, Philippines and Thailand (David & Otsuka 1994); a long-term (1988-1994) multi-country study in Bangladesh, India, Botswana, Ethiopia, Tanzania, Niger, Zimbabwe, Boliva, Chile, Costa Rica, Honduras, Mexico and other Latin American countries (von Braun 1995); an empirical study on the socioeconomic impacts of canal irrigation over 30 years in India (Kishore 2002), and an evaluation survey of rural roads and transport, water supply and sanitation, energy and irrigation sub-sectors in two provinces in the Central Highlands of Vietnam (Songco 2002). All of these studies reaffirmed the important role of irrigation in enhancing crop intensification, generating employment, promoting growth, and enhancing and sustaining rural livelihoods.

The review of related literature for this study reveals that there are no studies which have empirically examined the impacts of having irrigation on socioeconomic status, based on such indicators as asset accumulation, income, nutrition, health and poverty, in Cambodia. To fill this knowledge gap, this study attempts to measure the effect of irrigation on the level of household assets including durable assets, farm equipment, cows and buffalo and pull/plough animals.

3 Data Sources

This study used the same household data as that used in Wokker *et al.* (forthcoming) and Tong *et al.* (forthcoming) which was collected by CDRI in collaboration with MOWRAM and the Ministry of Agriculture, Forestry and Fisheries (MAFF). The survey covered 10 irrigation schemes located around the Tonle Sap Basin across three provinces, Kompong Chhnang, Kompong Thom and Pursat. Three hundred households were originally surveyed in early 2008, followed by four follow-up surveys in 2008 and 2009 to capture detailed information on migration, nutrition, agricultural expenditure and production, land ownership (investment/irrigation), shocks to agricultural production, livestock, agricultural extension services and remittances in both wet and dry seasons.[4] The sample attrition from the baseline survey was 26 percent, but the test for difference in the means of key important variables such as wealth, demographics and plot characteristics showed no statistically significant differences between the sub-sample and original survey (Wokker *et al.* forthcoming). Furthermore, a second baseline survey was conducted in August 2010 to update data regarding household characteristics, livestock and other capital assets[5].

It should be noted that different studies define different irrigation variables: examples of these are the availability of irrigation at plot level (Wokker *et al.* forthcoming; Huang *et al.* 2006), surface and groundwater irrigation (Huang *et al.* 2006; Zhou *et al.* 2009), and area of irrigated land per person (Zhou *et al.* 2009). For the purpose of this study, we define the irrigation variable as the proportion of an irrigated plot to the total plot per household.

In addition to quantitative data, we also collected qualitative data by conducting six focus group discussions with local farmers who were residing in the selected 10 irrigation schemes.

4 Thirty households in each scheme were randomly selected for the survey.
5 See Tong *et al.* (forthcoming) for further explanation on the second baseline survey.

4 Empirical Approach and Estimates

4.1 Econometric Model

To examine the impact of irrigation on household assets, we used the reduced form equations derived from a theoretical model of rural household decision-making to specify the factors that potentially affect household asset investments, as follows:

$$I_i = \alpha_0 + \alpha_1 D_i + \alpha_2 X_i + \alpha_3 V_i + \epsilon_i \qquad (1)$$

where I_i denotes the household asset holding; D_i is the proportion of irrigated plot to total plot; X_i represents the initial household characteristics such as household head's gender, age, education and experience, household size and the number of dependants; V_i denotes village characteristics; and ϵ_i is a random error term. Holding other variables constant, the parameter α_1 can be interpreted as the parameter of interest, measuring the effect of irrigation on asset holding.

It is widely noted that the irrigation variable is endogenous due to non-random irrigation programme placement (Dillon 2011; Huang *et al.* 2006). Bias occurs if intentional or targeting rules are used to allocate projects to villages. For example, if irrigation programmes are allocated to highly productive areas to ensure programme success or to less productive areas to target the poor, estimates of the programmes' impact derived from outcome indicators will contain upward or downward bias, respectively.

To address the non-randomised programme placement in the villages, we employed the instrumental variable regression model. This method requires some additional information i.e. a new variable Z that satisfies two assumptions: (1) Z is not correlated with ϵ, (2) Z is correlated with D. Wooldridge (2002) notes that the covariate between Z and the unobservable error ε can never be checked or even tested. Practically, one must maintain this assumption by appealing to economic behaviour. By contrast, the condition that Z is correlated with D can be tested by estimating the simple regression between D and Z, given a random sample from the population.

A simple regression framework can be written as:

$$D_i = \pi_0 + \pi_1 Z + u_i \qquad (2)$$

Following Wokker *et al.* (forthcoming), we used the position of the scheme along the watershed as an instrumental variable for irrigation because its geographical location is likely to correlate with irrigation programme placement and unlikely to directly affect household asset accumulation. A scheme's position was defined as downstream, midstream or upstream. Given these dummies, equation (2) can be re-written as:

$$D_i = \pi_0 + \pi_1 Z_1 + \pi_2 Z_2 + u_i \qquad (3)$$

Then the best instrumental variable for D_i is the linear combination of Z_i, which is the fitted value of equation (3): $\widehat{D}_i$. Once we have $\widehat{D}_i$, we can plug it into equation (1):

$$I_i = \alpha_0 + \alpha_1 \widehat{D}_i + \alpha_2 X_i + \alpha_3 V_i + \epsilon_i \qquad (4)$$

Given the above explanation, it is obvious that the parameter of interest is estimated through two stages. The first stage is to run the regression in equation (3), where we obtain the fitted value $\widehat{D}_i$. The second stage is the Ordinary Least Squares (OLS) regression of equation (4). However, most recent econometric packages include special commands for Two-Stage Least Squares (TSLS) which removes the need to perform the second stage manually.[6] But the endogeneity test must be performed to verify that the variables treated as endogenous in the model are in fact exogenous, to report the first-stage regression statistics in order to assess the explanatory power of the instruments, and lastly to perform the over-identifying restrictions test which is required when the number of additional instruments exceeds the number of endogenous regressors.

4.2 Empirical Estimates

The descriptive statistics of the variables used in the regression analysis are presented in Table 1.

Table 1: Descriptive Statistics of Dependent and Independent Variables

	Mean	Std. dev.	Min	Max
Dependent variables (2010)				
Durable asset index[7]	0.16	1.61	-1.99	7.51
Livestock index[8]	-0.48	0.65	-1.39	2.28
Farm equipment index[9]	0.07	1.34	-2.39	5.81
Cow and buffalo	3.15	2.55	0.00	15.00
Pull/plough animal[10]	1.28	1.17	0.00	4.00
Independent variables (2008)				
Irrigation	0.67	0.33	0.00	1.00
Household head gender (1=male)	0.84	0.37	0.00	1.00
Household head age (years)	49.90	12.55	23.00	81.00
Household head marital status (1=married)	0.85	0.36	0.00	1.00
Household head education (years)	4.64	2.54	1.00	12.00
Household size	6.04	2.21	2.00	16.00
Number of dependents	1.95	1.51	0.00	6.00

Source: CDRI Survey Data (2008-2010)

6 The standard errors and test statistics obtained from the second stage manually are not valid (Wooldridge 2002)

7 Durable asset index, farm equipment index and livestock index are estimated using the Principal Component Analysis Method. Durable assets include large tractor, small tractor, pull/plough machine, draught animal, water pump, sprinkler, motorised thresher, hand thresher, rice winnower, rice mill, motorised insecticide pump, hand insecticide pump, ox-cart, small hand-cart (pulled by person), motor-bike, bicycle, TV, cassette player, radio, sewing machine, generator, and other major assets.

8 Livestock index includes beef cattle, breeding bulls, pigs, chickens, ducks and other poultry.

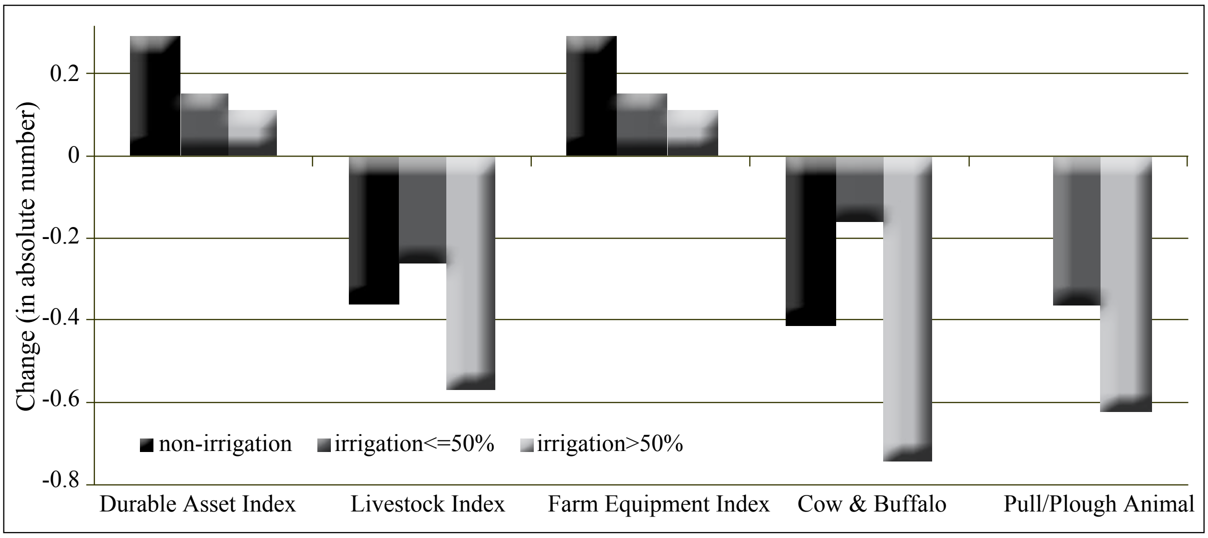
9 Farm equipment index includes large tractor, small tractor, pull/plough machine, water pump, motorised thresher, hand thresher, rice mill, motorised insecticide pump, hand insecticide pump, ox-cart, and small hand-cart (pulled by person).

10 Pull/plough animals is a subset of total number of cow and buffalo owned by household used particularly for farming activities

Findings show that approximately 84 percent of the households in the sample population were headed by a male and 85 percent of household heads were married. The average education level of the household heads was relatively low – only 4.6 years of education indicating that the majority of them had not completed primary school, and the average age was 50 years. The average size of the sample households was approximately six persons and the number of dependents was approximately two.

The changes in the durable asset index and the farm equipment index between 2008 and 2010 were positive, whereas the livestock index, cow and buffalo, and pull/plough animal values were negative regardless of the status of irrigation (Figure 1). A number of questions arise from these results. For example, why were livestock holdings in general decline over the study period? Was the decline largely due to the decrease in livestock in non-irrigation households? Table 2 examines household assets by irrigation status in more detail.[11]

Figure 1: Changes in Household Assets (2008-2010)



The overall pattern shows that the livestock index and cow and buffalo numbers decreased in all household groups, i.e. non-irrigation, irrigation less than 50 percent and irrigation more than 50 percent. However, the decrease in livestock index and cow/buffalo values for households with more than 50 percent irrigated plots was larger than for households with no irrigated plots. In contrast, the increase in durable assets index and farm equipment index values for households with no irrigated plots was greater than for households with irrigated plots. Pull/plough animal numbers of households with irrigated plots of both less and more than 50 percent declined sharply, while those of households with no irrigated plots remained constant.

In addition, we note that the average of each indicator's index value differs to a varying extent among the three household groups. These variations were tested for statistical difference using the Analysis of Variance (ANOVA), which provides a statistical result demonstrating whether the means of several groups are all equal. We found that there are no statistically significant differences among the three groups for all assets in both the survey years, except the livestock index values in 2008, because the corresponding F statistics are relatively small (less than two) and not statistically significant at the 10 percent confidence level.

11 The irrigation variable at the household level was estimated by dividing the number of irrigated plots by total plots. Given this figure, we categorised the 220 households into three groups: non-irrigation, irritation<=50 percent and irrigation>50 percent.

Table 2: Household Assets by Irrigation Status

	Non-irrigation	Irrigation <=50%	Irrigation >50%	ANOVA		Total
				F Statistic	Significant level	
No. of households	17	61	142			220
Durable asset index						
2008	-0.56	0.07	0.07	1.15	0.317	0.02
2010	-0.27	0.22	0.18	0.64	0.526	0.16
Livestock index						
2008	-0.32	-0.22	0.11	2.81	0.062	-0.01
2010	-0.68	-0.47	-0.45	0.92	0.401	-0.48
Farm equipment index						
2008	-0.34	0.05	0.00	0.59	0.553	-0.01
2010	-0.16	0.09	0.08	0.27	0.760	0.07
Cow and buffalo						
2008	3.35	3.54	3.82	0.37	0.688	3.70
2010	2.94	3.38	3.08	0.34	0.710	3.15
Pull/plough animal						
2008	1.59	1.56	1.89	0.70	0.499	1.77
2010	1.59	1.20	1.27	0.74	0.477	1.28

Source: CDRI Survey Data (2008-2010)

The above descriptive statistics only reveal a simple correlation between irrigation and household assets; the underlying relationship might be concealed by the relationship between household assets and other confounding factors such as better economic opportunities and/or household characteristics. To address the weaknesses of the descriptive analysis, an econometric method was applied.

The irrigation coefficients for the durable assets index, livestock index, cow and buffalo, and pull/plough animal equations (estimated by OLS) are negative but not statistically significant at the 10 percent confidence level (Table 3). Only the irrigation coefficient for the farm equipment index equation has the expected sign but it is not statistically significant at the 10 percent level. Holding other factors constant, the statistical insignificance of the irrigation coefficient means that an increase in irrigated land has no significant effects on household asset accumulation. As noted earlier, OLS estimates would not be consistent if the irrigation variable was endogenous.

To address the endogeneity of the irrigation variable, we employed an Instrumental Variable Regression Model. Table 4 presents the estimation results. Except for the estimated irrigation coefficient for the pull/plough animal equation which has an opposite sign[12], the remaining irrigation coefficients for the other equations are in line with OLS estimates.

12 The irrigation coefficient for the pull/plough animal equation is negative for OLS, but positive for TSLS.

Table 3: Determinants of Household Assets in 2010 (OLS)

Variables	Durable assets index	Livestock index	Farm equipment index	Cow & buffalo	Pull/ plough animal
Irrigation	-0.239	0.104	-0.340	0.098	-0.085
Household head gender (1=male)	-0.335	0.177	-0.057	0.586	0.651**
Household head age	0.012	0.003	0.011	0.004	0.003
Household head marital status (1=married)	0.781*	-0.002	0.287	0.339	-0.267
Household head education (years)	0.110***	0.007	0.082**	-0.007	-0.036
Household size	0.162	0.302***	0.265*	1.288***	0.572***
Household size squared	0.002	-0.018***	-0.013	-0.070***	-0.039***
Number of dependents	-0.163*	-0.008	-0.045	-0.222	0.073
Kompong Thom	0.393	0.101	0.451**	0.080	-0.068
Pursat	1.150***	0.067	1.292***	-1.066**	-0.154
Constant	-2.371***	-1.956***	-2.329***	-2.006	-0.888

Note: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent. Source: Authors' calculations

Our results also show that the coefficients of the education level of the household head for the durable assets index are positive and statistically significant at the 10 percent level. This implies that human capital contributes greatly to durable assets accumulation. Similarly, household size is positively associated with livestock, cow and buffalo and draught animal numbers. Those assets would decline if the household size was to exceed seven to eight persons per household.

With regards to geographical differences, households in Pursat and Kompong Thom are likely to have more durable assets and farm equipment than those in Kompong Chhnang. But the number of cows and buffalos in Pursat seems to be lower than in Kompong Chhnang.

To verify whether we could treat the irrigation variable as exogenous, we conducted the endogeneity test. The Wooldridge score and regression-based test[13] are both highly significant for all equations except the durable assets index equation[14] – meaning that the irrigation variable must continue to be treated as endogenous. However, the first statistical process showed that the instruments, i.e. the dummies for midstream and downstream locations, were weakly correlated with the irrigation variable. A study from Monte Carlo indicates that the Limited-Information Maximum Livelihood (LIML) estimator performs better than the TSLS in these circumstances (Poi 2006; Stock *et al.* 2002). To examine the validity of our instruments, an over-identifying restrictions test was performed. It indicated that both instruments were valid. Following Stock *et al.* (2002), the LIML estimator is reported in Table 5: the statistically significant coefficients are, to a large extent, consistent with the TSLS results.

13 Durbin and Wu-Hausman statistics are reported after TSLS estimations if robust standard error is not requested.

14 Even if the irrigation variable is exogenous, the TSLS estimates are still consistent (Stata Manual)

Table 4: Determinants of Household Assets in 2010 (TSLS)[15]

Variable	durable assets index	livestock index	farm equipment index	cow & buffalo	pull/plough animal
Irrigation	-3.090	2.594	-4.681	8.743	5.178
Household head gender (1=male)	-0.495	0.316	-0.300	1.071	0.947
Household head age	0.003	0.010	-0.002	0.030	0.020
Household head marital status (1=married)	0.916***	-0.120	0.493	-0.071	-0.516
Household head education (years)	0.100*	0.016	0.068	0.023	-0.017
Household size	0.102	0.355***	0.174	1.471***	0.683***
Household size squared	0.007	-0.023***	-0.005	-0.087***	-0.049***
Number of dependents	-0.153	-0.018	-0.028	-0.255	0.053
Kompong Thom	0.686*	-0.155	0.898**	-0.810	-0.609
Pursat	1.654***	-0.373	2.061***	-2.597**	-1.086
Constant	-0.071	-3.965***	1.173	-8.980*	-5.133*
First stage:					
Adjusted R-squared	0.049	0.042	0.042	0.042	0.042
F-value	1.731	1.731	1.731	1.731	1.731
p-value	0.179	0.179	0.179	0.179	0.179
Over-identification Test					
Score chi2	0.003	0.535	0.007	1.388	0.002
p-value	0.952	0.464	0.929	0.238	0.963
Endogeneity Test					
Robust score chi2	1.497	6.577	4.826	5.842	7.180
p-value	0.221	0.010	0.028	0.001	0.007

Note: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent. Heteroscedasticity-robust standard errors are reported. Source: Authors' calculations

15 The first stage i.e. estimation of equation 3 is presented in Appendix Table A1.

Table 5: Determinants of Household Assets in 2010 (LIML)

Variable	Durable assets index	Livestock index	Farm equipment index	Cow & buffalo	Pull/plough animal
Irrigation	-3.093	3.001	-4.691	13.027	5.181
Household head gender (1=male)	-0.495	0.339	-0.301	1.311	0.947
Household head age	0.003	0.011	-0.002	0.043	0.020
Household head marital status (1=married)	0.916*	-0.139	0.493	-0.274	-0.516
Household head education (years)	0.100**	0.017	0.068	0.038	-0.017
Household size	0.102	0.364**	0.174	1.562**	0.683***
Household size squared	0.007	-0.024**	-0.005	-0.095**	-0.049***
Number of dependents	-0.153	-0.019	-0.028	-0.271	0.053
Kompong Thom	0.686*	-0.197	0.899**	-1.250	-0.610
Pursat	1.655***	-0.445	2.062***	-3.355*	-1.087
Constant	-0.069	-4.293**	1.181	-12.437	-5.136*

Note: * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent

Source: Authors' calculations

5 Conclusion

This study investigates the impacts of the presence of irrigation on the amount of household assets i.e. durable assets, livestock, farm equipment, cow and buffalo and pull/plough animal. Our descriptive analysis does not support the idea that irrigation substantially contributes to the amount of durable assets and farm equipment. We found that the amount of durable assets and farm equipment increased between 2008 and 2010 regardless of the status of irrigation infrastructure. The amount of durable assets and farm equipments however, of households with non-irrigated plots grew more rapidly than those of households with irrigated plots. The decrease in livestock holdings and cow/buffalo and pull/plough animal numbers in households with non-irrigated plots was often smaller than in households with irrigated plots. The Analysis of Variance test shows that there were no significant differences among the three household groups for most assets in both the survey years. Regression analysis also provides the same evidence, that irrigation had no impact on the abundance of household assets. Hence, our results, both descriptive and through econometric analysis, cannot confirm a positive correlation between irrigation and accumulation of household assets. However, our analysis does indicate that human capital contributes positively to the level of durable assets in households. Our results are consistent with the study of Jalilian and Weiss (2004), which shows that for developing countries, investment in human capital (e.g. education) increases poverty elasticity to a greater extent than investment in the development of new infrastructure.

These results may reflect the fact that irrigation systems in Cambodia do not function well enough to have a significant impact on improving livelihoods and household asset accumulation (Kim & Khiev 2007; CDRI 2010). Under such circumstances, investment in irrigation development should be focussed more on balancing the expansion of irrigation systems against improvements in irrigation efficiency that ensure availability of water in both wet and dry seasons, establish appropriate water levels and ensure equitable water allocation across the irrigation scheme areas. A combination of increased investment in human capital *and* infrastructure development/maintenance could have a strong impact on the accumulation of household assets and standard of living, as opposed to investment in infrastructure alone.

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Appendices

Table A1: The Determinants of Irrigation Accessibility (OLS)

	Coefficient	Standard error	t	P>t
Household head gender (1=male)	-0.067	0.09	-0.74	0.46
Household head age	-0.003	0.00	-1.40	0.16
Household head marital status (1=married)	0.055	0.09	0.59	0.56
Household head education (years)	-0.002	0.01	-0.21	0.83
Household size	-0.021	0.04	-0.52	0.61
Household size squared	0.002	0.00	0.63	0.53
Number of dependents	0.009	0.02	0.48	0.63
Kompong Thom	0.112	0.05	2.09	0.04
Pursat	0.185	0.06	3.32	0.00
Midstream	-0.026	0.05	-0.48	0.63
Downstream	-0.101	0.06	-1.79	0.08
Constant	0.821	0.17	4.85	0.00

Source: Authors' calculations

Table A2: Total Rice Harvested and Cultivated Areas

Province	Harvested area, 1000 ha			Irrigated area 1000 ha	Proportion of irrigated area
	Wet season	Dry season	Total		
Banteay Mean Chey	140.20	0.30	140.50	36.00	25.62
Battambang	168.57	1.20	169.77	52.00	30.63
Kandal	42.67	45.00	87.67	20.00	22.81
Koh Kong	7.27	–	7.27	0.60	8.25
Kompong Cham	167.24	30.00	197.24	30.00	15.21
Kompong Chhnang	83.07	9.90	92.97	22.00	23.66
Kompong Som	9.50	–	9.50	–	0.00
Kompong Speu	84.30	1.00	85.30	22.00	25.79
Kompong Thom	99.16	1.80	100.96	37.00	36.65
Kompot	133.11	2.50	135.61	19.30	14.23
Kratie	20.62	6.00	26.62	12.00	45.08
Mondulkiri	6.18	–	6.18	0.20	3.24
Phnom Penh	5.40	1.20	6.60	3.10	47.00
Preah Vihear	16.91	–	16.91	0.30	1.77
Prey Veng	240.23	57.00	297.23	40.00	13.46
Pursat	71.95	0.10	72.05	26.00	36.09
Ratanakiri	17.62	–	17.62	0.20	1.14
Siem Reap	181.08	10.00	191.08	25.50	13.35
Stung Treng	13.47	–	13.47	0.80	5.94
Svay Rieng	162.32	9.00	171.32	20.00	11.67
Takeo	173.13	58.00	231.13	40.00	17.31
Total	**1844.0**	**233.0**	**2077.0**	**407.00**	**19.60**

Source: FAO (2005)

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