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Sonali Senaratna Sellamuttu , Takeshi Aida , Ryuji Kasahara , Yasuyuki Sawada , and Deeptha Wijerathna

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JICA Research Institute

JICA Research Institute
10-5 Ichigaya Honmura-cho
Shinjuku-ku
Tokyo 162-8433, JAPAN
TEL: +81-3-3269-3374
FAX: +81-3-3269-2054

How Access to Irrigation Influences Poverty and Livelihoods:

A Case Study from Sri Lanka

Sonali Senaratna Sellamuttu[*], Takeshi Aida[†], Ryuji Kasahara[‡],
Yasuyuki Sawada[§], and Deeptha Wijerathna[**]

Abstract

This study combines a livelihoods approach with a regression approach to quantify the effectiveness of irrigation infrastructure investment on improving people's livelihood strategies. Using a unique dataset based on households in southern Sri Lanka, and a natural experimental setting, we estimate from a two stage income regression model to show that irrigation access has a positive effect on income through livelihood choices. We also show through qualitative approaches that factors not linked to irrigation infrastructure may contribute to changes in livelihood portfolios. In addition, we highlight factors that result in certain households being unable to move out of poverty despite access to the improved irrigation infrastructure.

Keywords: irrigation, poverty, livelihoods

[*] Corresponding author, International Water Management Institute (IWMI), Southeast Asia Regional Office, Lao PDR. (s.senaratnasellamuttu@cgiar.org)
[†] Graduate School of Economics, University of Tokyo, Japan.
[‡] Japan International Cooperation Agency, Bangladesh.
[§] Visiting Fellow, JICA Research Institute, and Professor, Faculty of Economics, University of Tokyo, Japan
[**] Yaso Udana Development Consultants, Sri Lanka.

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1. Introduction

Because investment in irrigation infrastructure continues to be substantial, governments and donor agencies need to know whether such infrastructure helps alleviate the poverty of those who have access to irrigation in the context of achieving the Millennium Development Goals. Indeed, recent empirical studies have started to focus on the role of infrastructure in reducing poverty directly (Datt and Ravallion 1998; Jacoby 2000; Gibson and Rozelle 2003; Jalan and Ravallion 2003; Lokshin and Yemtsov 2004, 2005; Jacoby and Minten 2008). Although existing empirical studies try to uncover the important causal influences of infrastructure on poverty reduction, the structure of poverty reduction in this regard remains largely unaddressed. In this paper, we thus aim to bridge this gap in the existing quantitative studies by combining the canonical empirical framework of income regression and the livelihoods approach of Ellis (1998, 1999) and Ellis and Freeman (2004) to analyse household selection, or the 'portfolio' of livelihood activities that generate significant income.

The concept of poverty is complex because it is both multidimensional and dynamic in nature. Although conventional poverty measures focus on income and consumption expenditure (World Bank 2001), an emerging body of research has argued that these measures only cover certain dimensions of poverty and lack the ability to indicate the actual meaning of poverty in the lives of those people who experience it (Brock 1999; Narayan et al. 2000; Fisher et al. 2005). The sustainable livelihoods approach is one method that looks into different dimensions of poverty such as environmental, social, economic, and political ones, in order to provide a better understanding of the complex driving forces and processes behind it (Davies 1996; Carney 1998; Scoones 1998).

Sustainable livelihoods approaches have evolved from three decades of changing perspectives on poverty (Chambers and Conway 1992; Chambers 1995; De Haan and Zoomers 2005). Since the 1990s, they have gained wide acceptance as useful means of understanding the

multiple aspects that shape poor people's lives and well-being rather than offering a narrow focus on how many people live on a purchasing power of $1 or $2 per day (Ashley and Carney 1999; Adato and Meinzen-Dick 2002).[1] The approaches are therefore valuable when considering the manifold factors that poor people in different contexts define as contributing to their situations of vulnerability, poverty, and well-being (Adato and Meinzen-Dick 2002). They have also often been applied to studying poverty in rural settings (Bird and Shepherd 2003; Chimhowu and Hulme 2006) and used in certain impact assessment studies, for example to study the impact of agricultural research on poverty. In this context, the approaches enable researchers to gain insights into influencing factors that have not been highlighted in traditional cost/benefit analyses or other such approaches (Meinzen-Dick and Adato 2001).

In this paper, we combine the canonical empirical framework of income regression with the livelihoods approach, with robustness checking through qualitative interviews. We show how access to irrigation influences poverty and livelihoods. More specifically, we first assess the impact of irrigation access on poverty alleviation by exploiting the natural experimental situation. Second, we estimate a multinomial logit model as a nonlinear difference-in-difference approach in order to show how a livelihood strategy changes according to the degree of irrigation access. In addition, we estimate a two stage income equation using the results of the livelihood choice and show the impact of irrigation access on income using a livelihood strategy. Finally, we investigate why the influences of irrigation investment may not be uniform across poor households, using the results of the in-depth interviews. For example, we address the reasons why certain households that have access to the improved irrigation infrastructure are still

1. Several leading development agencies use livelihoods approaches in their work and a brief overview that compares the different livelihoods approaches that they have adopted can be found in Carney et al. (1999). For example, the general livelihoods framework advocated by the UK Department of International Development (DFID) assists in explaining the different aspects of a community's livelihoods patterns and the factors that influence this. Five broad categories of livelihoods assets or 'capital' are recognised by the DFID livelihoods framework: human, social, physical, financial/economic, and natural capital (DFID 2001). In recent adaptations of the framework, the analyses of political factors and how they influence livelihoods are also incorporated as a sixth capital (for example, in the conceptual framework for the Assessment of Life Chances [Mayer 2003]).

poor. This qualitative method enables us to address multiple dimensions of the impact of irrigation, which quantitative approaches usually overlook.

The present study makes two important contributions to the body of knowledge on livelihoods approaches. First, we apply the sustainable livelihoods approach in the context of irrigation infrastructure. We estimate the effect of irrigation access on livelihood strategy by employing a nonlinear difference-in-difference approach. To our knowledge, no previous empirical study of program evaluation has applied a livelihoods approach specifically to an irrigation infrastructure investment project. Second, we combine an income regression approach with an endogenously selected livelihood strategy. Although Jansen et al. (2006) developed factor and cluster analysis to group households based on the use of their main livelihoods assets (capitals), our approach carefully integrates the canonical income regression approach with the livelihoods approach.

Our approach is closely related to the one developed by Hansen et al. (2011) and White (2011) which discusses that it is beneficial for policy makers to understand the selection mechanism as a possible causal mediation effect, especially in impact evaluation of infrastructure interventions. This means that estimating the direct impact of irrigation access on income is less informative, because the causal mechanism is ignored as a black box. Our empirical strategy is to break down the causal effects of irrigation access on income by employing the livelihood approach. This approach enables us to avoid self-selection bias between irrigation access and income, and to extract the pure causal mediation effect on endogenous livelihood choice. Our approach is effective because irrigation access does not directly lead to poverty alleviation. Rather, it involves the changes in livelihood choices from low productive ones to more productive ones such as cultivation of paddy or other commercial crops. Thus it is important and informative to show the causal effect of irrigation access on income through the changes in livelihood choice. Note that our research design is different from a simple mixed method combing qualitative and quantitative approaches; instead, our design of

combining livelihood approach and impact evaluation of infrastructure interventions is necessary in order to comprehend the endogeneity of livelihood choice rigorously. Also, we believe that this approach validates the robustness of the estimated impact of irrigation access. We define the following causal links between pre-irrigation characteristics, livelihood strategy, and income and poverty: Irrigation access enables farmers to cultivate paddy or other crops which require large amounts of water even during dry seasons, which in turn results in poverty reduction.[2]

The remainder of this paper is organised as follows. Section 2 explains the study site and its natural experimental setting. Sections 3 and 4 explore how irrigation access influences poverty alleviation and primary livelihood activity and income, respectively. Section 5 discusses the qualitative aspect to irrigation infrastructure development and supports the quantitative findings. The final section presents our overall conclusions.

2. Research Design

2.1 Study site

The present study focuses on the Walawe left bank irrigation system in the southern dry zone of Sri Lanka. This irrigation system is a part of the Uda Walawe irrigation and resettlement project, implemented to develop a land area of 32,000 ha in the dry zone of southern Sri Lanka for irrigated agriculture (Figure 1). The irrigation system, which draws water from the Uda Walawe reservoir, was built across the fifth largest river in Sri Lanka between 1963 and 1967, It supplies water to downstream areas through two main canals known as the right bank main canal, which is 42 km long, and the left bank main canal (LBMC), which is 31 km long (Hussain et al. 2002;

2. In other words, our position is that it would be difficult to presume that irrigation access directly leads to higher income without changing their livelihood choices.

Molle and Renwick 2005). The downstream area is divided into two main sections known as the right and left bank of the original Walawe river, which is currently flowing with drainage water from the developed area. During construction, the right bank got the priority. The left bank area was divided into five divisions or blocks known as Sevanagala block located upstream of the LBMC; Kirriibbanwewa block, located in the middle of the LBMC; Sooriyawewa block, located downstream of the LBMC; and the Mayurapura and Tissapura blocks which were implemented in different phases as a result of financial constraints. By 1997, irrigation water was only present up to the middle of the Sooriyawewa block.

The upgrading and extension of the Walawe left bank irrigation system was funded by the Japan Bank for International Cooperation in 1997.

2.2 Method and Sample

We drew upon the relevant aspects of the reviewed empirical studies in order to adopt a livelihoods approach that combines both qualitative and quantitative methods, since previous studies have clearly illustrated the value of using mixed methods (Carvalho and White 1997).

Data for this analysis was gathered from a series of surveys that we have carried out in this area from the year 2000. An initial evaluation study was commissioned between 2000 and 2002 to assess the impact of irrigation infrastructure on poverty alleviation (Hussain et al. 2002; Sawada et al. 2010; Sawada et al. 2012; Shoji et al. 2012). In 2005, a section of the project coverage area; i.e. Mayurapura block, that was not irrigated at the time of the first evaluation, was finally serviced, and a follow-up evaluation was then carried out between 2007 and 2008. By 2009, eight household surveys were conducted in this project,[3] but for this study, we used data from only the first seven surveys, which cover six cropping seasons. During the first five rounds of surveys, the Walawe left bank system was divisible into two areas: the first had

3. There were some inconsistencies in the survey method between the latest survey in 2009 and those of the previous ones. Thus, this study uses the first seven surveys.

adequate access to irrigation and the second was a rain-fed area with provisions for irrigation in the near future. When the sixth and seventh rounds of data were collected, the formerly rain-fed areas had been transformed into irrigated areas. Households who obtained plots in the north (head end) were able to have earlier access to irrigation than were households in the south (tail end). This situation provided us with important variations in access to irrigation infrastructure in order to evaluate the impact of irrigation infrastructure. Moreover, the type of farming in the study area varies from irrigated to rain-fed and *chena* (slash and burn) cultivation, and the project area shows considerable variability in terms of cropping patterns. Hence, these data are suitable for evaluating the role of infrastructure in improving livelihoods. For the livelihoods study, we utilised some of the data gathered during the first seven surveys in addition to information obtained through a set of in-depth interviews in order to determine how the improved irrigation infrastructure had influenced the livelihood dynamics and poverty levels in the described study site.

The survey instrument in all phases was a multi-topic questionnaire that included seven modules. The first module on basic information asked for the key characteristics of household (size, land ownership, and other household traits) and basic profiles of household members (age, schooling, employment, non-farm income). The second module on infrastructure got information on the operating environment of the household such as sources of water, irrigation infrastructure, cultivated area, operation and maintenance of infrastructure, and health facilities in the study area. The third module on agricultural production obtained information on the farming situation, farm assets, cost and value of agricultural production, household organizations, and marketing of inputs and produce. The fourth module on expenditure asked about household expenditure on food, clothing, medical care, transportation, education and other living expenses. The fifth module on credit collected information on loans, sources, repayment and problems in obtaining credit. The sixth module on risk coping asked questions about the household head's level of trust of others, support obtained from different sources, and his

sociability.[4] The last module on social capital included questions on support and benefits received from government and non-government institutions, and membership and active participation in people or community-based organizations.

For the quantitative analysis, panel data were used comprising seven household surveys (covering six cropping seasons), with five surveys conducted from October 2000 to September 2002 (Hussain et al. 2002), and two surveys from October 2006 to September 2007. The household sample consisted of 193 households, which was a sub-sample of 22 per cent of the original 858 household sample used by Hussain et al. (2002). This included 92 households from the irrigated and rain-fed blocks of Sevanagala, Kirriibbanwewa, and Sooriyawewa, and 101 households from the extension area of the irrigation project, comprising the Mayurapura and Tissapura blocks on the left bank. Prior to the inception of the irrigation scheme, this area was primarily rain-fed or under *chena* cultivation. Mayurapura, our treatment group, was comprised of 85 sample households and had access to improved irrigation from 2005. In contrast, Tissapura, which was comprised of 16 sample households, did not have access to the improved irrigation infrastructure in 2007 and therefore acted as a control group. Sevanagala (the irrigated area), Kirriibbanwewa, and Sooriyawewa, where irrigation was available for all six seasons, also acted as other control groups. Table 1 summarizes the sample size and irrigation accessibility at each time period. Note that the Sevanagala rain-fed block was excluded from the study because irrigation canals did not reach this area owing to topological constraints. Thus the total sample size is 184.

For the qualitative case studies, we utilised a poverty mobility score in identifying our purposive sample of households to conduct in-depth interviews. Based on the categories of poverty measures described in Section 3.3, a simple poverty mobility score was assigned to each household for the period under investigation. We adopted a method similar to one used in some

4. The 2001/2002 surveys also obtained the historical information (10 years prior) on production of main crops, yields and related problems as the original sixth module.

earlier empirical studies (Hettige and Mayer 2003; Fuenfgeld et al. 2004; Lawson et al. 2007; Senaratna 2007). We used this poverty mobility score to identify the households that represented outliers. This included households in the following mobility categories: those that had remained 'very poor' or 'better off' or had moved from 'very poor' to 'better off' between 2002 and 2007 (that is, after the irrigation infrastructure had been improved). Our purpose sample included households in the extension area that had access or no access to the improved irrigation infrastructure (that is, Mayurapura and Tissapura, respectively) as well as those in areas that had undergone earlier development (that is, Sevanagala, Sooriyawewa, and Kirriibbanwewa). The locations of the sample households in the study site are shown in Figure 1.

2.3 Extension of the irrigation system

Table 2 shows the land ownership and irrigation accessibility by year. The left hand column shows whether the household owns the irrigated land and the right hand column includes rented land. Although half of households had no irrigation access in 2001, 90 per cent had irrigation access by 2007. Even though irrigation access deteriorated slightly from 2001 to 2002, overall long run accessibility improved. This deterioration may reflect a temporal stop in the water supply because of the construction of irrigation canals. Furthermore, although some households moved from irrigation access to no access, excluding them has little effect on our results.

2.4 Natural experimental setting

Although the entire Walawe left bank area is agro-climatically and geographically similar, only half of households had access to irrigation in 2001. Yet, by the end of 2007, almost all households had gained irrigation access. During the construction program, the government provided farmers with 0.2 ha of land for residence as well as 1.0 ha of irrigated paddy fields or

0.8 ha of other field crops.[5] However, according to settlers' subjective assessments following this land allocation, approximately half of households could claim a preference for plot-level land (Aoyagi et al. 2010). Intriguingly, the government used lotteries to distribute land for 30 per cent of farmers, and thus, these households received plots for certain crops regardless of their preferences. Consequently, 35 per cent of households did not obtain their preferred lands (Aoyagi et al. 2010). Therefore, some community and household characteristics – such as the sizes of farmers' organisations, neighbourhood characteristics, irrigation access, distance to their plots, and so forth – were exogenously given in this setting. In fact, the econometric analysis by Aoyagi et al. (2010) finds supportive evidence that households were exogenously allocated to canal communities and within each distribution regardless of their observed characteristics. We thus conclude that sample selection errors are not serious with these data. Therefore, by using this natural experimental situation, a simple comparison of the outcomes between the irrigated and non-irrigated groups shows the unconditional impact of irrigation access on poverty alleviation.

We utilize this situation to show the connection between irrigation access and livelihood choice as a causal mediation effect in the impact evaluation of irrigation infrastructure intervention following the spirit of Hansen et al. (2011) and White (2011). By combining the livelihood "choice" approach and clean quantitative impact evaluation method, we extracted selection bias arising from endogeneous livelihood choice and evaluated the impact of irrigation access rigorously. Our approach is not a simple and mechanically mixed method of quantitative and qualitative analyses. Rather, our mixed approach is necessary to quantify the causal mediation effect using this natural experimental situation.

5. There are several definitions of other field crops, but for the purpose of the livelihoods analysis, we consider this category to include condiments (chilli and onion), grain legumes (mungbean, cowpea, blackgram, pigeon pea, and chickpea), oil seed crops (groundnut, soybean, sesame, and sunflower), and non-rice cereals (maize, sorghum, finger millet, and other minor millets), according to the definition used by the Department of Agriculture, Sri Lanka (http://www.agridept.gov.lk).

3. Poverty Dynamics

3.1 Average consumption by irrigation status

Table 3 shows the average monthly consumption level per adult including self-production. We can see that the consumption level of households that have irrigated land is higher compared with those that do not have irrigated land, except for food consumption in 2002. In particular, the consumption level of those who have irrigation access is higher than that of those without irrigation, and the difference is statistically significant in 2001 and 2002.

3.2 Poverty and irrigation

Table 4 shows the statistical poverty measure using the Foster-Greer-Thorbecke (FGT) poverty indices, which are calculated as follows:

$$P_{\alpha t} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{z_t - y_{it}}{z_t}\right)^{\alpha}$$

where $P_{\alpha t}$ is the headcount index ($\alpha = 0$), the poverty gap index ($\alpha = 1$), and the squared poverty gap index ($\alpha = 2$), z_t is the poverty line at time t, and y_{it} is the consumption level of household i at time t. Here, the poverty line is derived from the monthly poverty line suggested by the Department of Census and Statistics of Sri Lanka, namely Rs 1293 in 2001, Rs 1423 in 2002, and Rs 2233 in 2007.

We can see that all incidences of poverty declined over time. Although 76 per cent of households were below the poverty line in 2001, this declined to 31 per cent in 2007. In addition, all incidences of poverty were smaller for households that had irrigation access. Note that Table 4 shows the results of owned irrigated land only (including rented irrigated land has little effect on our results).

Table 5 shows the poverty head count ratio according to irrigation accessibility. Among households that had no irrigation access in 2002, the poverty headcount ratio decreased by 17 percentage points (0.45–0.28) by 2007 under the assumption that irrigation access is determined exogenously. We can see that the poverty head count ratio of households that had irrigation access is lower than that of households that did not. As mentioned before, some households had irrigated land in one year, but not in the next. However, because the number of these households was very small, this effect of 'losing' irrigated land is unclear from the sample.

Figure 2 displays the treatment effect on distribution by showing the cumulative distribution function of the log of expenditure. The difference between households that have irrigation access and those that do not highlights the impact of irrigation access on expenditure. The difference is larger for lower expenditure households, but it is unclear for higher expenditure ones. This means that irrigation access has a large impact on the poor, although it has hardly any impact on the better off.

3.3 Poverty transition

For all of the 184 households whose poverty statuses can be traced between 2001 and 2007, a poverty transition matrix was constructed (Table 6). By adopting a method similar to that proposed by Bird and Shepherd (2003), we defined four categories of poverty measures based on Sri Lanka's national official poverty line (NOPL): 'very poor' (average monthly consumption below 0.5 of NOPL); 'poor' (above 0.5 of NOPL but below NOPL); 'average' (above NOPL but below 1.5 of NOPL); and 'better off' (above 1.5 of NOPL). In order to compare the impact of access to irrigation, we separated the newly irrigated area (Block 5) from the rest. As Table 6 shows, the upper diagonal elements dominated the overall shares. While the shares of 'very poor' and 'poor' decreased dramatically from 2002 to 2007, the proportions of 'average' and 'better off' increased remarkably. This implies that households moved out of poverty during the survey

period. Intriguingly, transient poverty captured by the 'poor' category is still an important issue in this area.

4. Livelihood Dynamics

4.1 Categorisation of livelihood activities

According to the livelihoods framework, as livelihood activities are usually considered to generate an income (DFID 2001), for the purpose of the livelihoods assessment, the different livelihood activities engaged in by households were categorised. This categorisation was based on the breakdown of income sources that Hussain et al. (2002, 2007) applied, culminating in the following five categories: (i) paddy cultivation (rice crops), (ii) non-paddy cultivation (all non-rice crops grown on the site including sugarcane, banana, vegetables, and other field crops), (iii) natural resource related livelihoods (non-crop farm incomes from fishing and cattle rearing), (iv) labour work related to paddy cultivation (agricultural wages), and (v) all other non-farm livelihood activities (non-farm income from trade, services including the government sector, self-employment and shop keeping). As explained in Hussain et al. (2007), in a rural setting in Sri Lanka, as is typical to the one in this study, households engage in multiple livelihood activities, i.e., derive income from multiple sources that are both agricultural and non-agricultural. The broad categorisation of income sources as indicated above, were based on what was appropriate in the local context, and we followed a similar categorisation in our study to maintain consistency.

4.2 Defining primary livelihood activities

Empirical evidence suggests that in rural communities households often engage in more than one livelihood activity at a time (Ellis 1999; Bryceson 2000; Ellis et al. 2003). From the

selection of livelihood activities a household may undertake, we define the **primary livelihood activity** of the household as the activity that generates the highest proportion of the household's overall income. In addition, since we use a broad categorisation of livelihoods for our analysis, while some categories include more than one livelihood activity (for example, natural resource related livelihoods include fishing and livestock rearing), other categories include only one livelihood activity (for example, paddy cultivation). Each household was then categorised based on their primary livelihood activities in 2001, 2002, and 2007. These particular time periods were selected in order to determine the changes in primary livelihood activities that coincided with obtaining access to the improved irrigation infrastructure.

4.3 Livelihood strategies

The range and combination of livelihood activities and choices that people make in order to achieve their livelihood outcomes are termed **livelihood strategies**. This is a dynamic process, in which people combine livelihood activities in order to meet their various needs at different times (Scoones 1998; DFID et al. 2002). According to previous studies, people's access to different levels and combinations of assets (capitals) is a major influence on their choices of livelihood strategies (Scoones 1998). In other words, a household's choice of livelihood category is determined by fixed or slowly changing factors including its natural capital and human capital (Jansen et al. 2006).

We next investigated the relationships between the different portfolios of livelihood assets that households possessed (that is, human, social, physical, economic, and natural capital) and the determinants of livelihood strategies. We adopted a method similar to that described by Jansen et al. (2006), who grouped households based on the uses of their main livelihoods assets. The main difference from this study was that we used the five livelihood activity categories proposed by Hussain et al. (2002) in order to carry out the presented multinomial logit regression.

The regression was run for six cropping seasons (that is, Maha 2000, 01; Yala 2001; Maha 2001, 02; Yala 2002; Maha 2006, 07; and Yala 2007) with the livelihood categories as the dependent variable and the different capitals as the various explanatory variables.

4.4 Empirical analysis of livelihood choices

In the model, the human capital variables included household size, age, gender, and educational level of the head of household, and the number of workers. Under natural capital, we included the cross term of Mayurapura and dummy variable which takes one in year 2007. By controlling block dummies and season dummies, this cross term represents the difference-in-difference estimator in the multinomial logit model (Puhani 2012). Thus this variable shows the treatment effect of irrigation access on livelihood choice. The location capital variables we used were geographic location in terms of the irrigation block or stratum the household belonged to, distance to the nearest daily market and paved road, and the size of the cultivable plot owned (ha). In terms of physical capital, the total value of a household's agricultural assets in the previous period was included because farmers who go into farming would be expected to acquire farm equipment. Because of this, the observations in the first season (Maha 2001, 2002) are automatically dropped from this analysis. Under social capital, the variable included was being a member of a farmer's organisation.

As indicated by Jansen et al. (2006), these coefficients represent the effect of each explanatory variable on the probability of the household selecting the particular livelihood strategy relative to the probability of selecting the base category, which in this case was the agricultural wage livelihood strategy. We selected this livelihood category as the base because households without irrigated land tended to rely on this income source as explained in the following sections.

Table 7 shows the composition of livelihood activities. We use pooled data from six seasons, namely the Maha and Yala seasons in 2001, 2002, and 2007. The main livelihood activity in this area is paddy and non-paddy cultivation. In fact, few households had a livelihood activity that was natural resource related.

We conducted a quantitative analysis to show the impact of irrigation access on the choice of livelihood activities. The descriptive statistics are shown in Table 8. Because we do not have data on age, gender, and educational level in Yala in 2002, we replace them with those in Maha in 2002. We specify the multinomial logit model as follows:

$$\Pr(z_i = j) = \frac{\exp(\alpha_t + \beta_{block} + \gamma T \cdot 1(t \geq 5) + X_i\theta_j)}{\sum_j \exp(\alpha_t + \beta_{block} + \gamma T \cdot 1(t \geq 5) + X_i\theta_j)}, j=0,\ldots, 3,$$

where z_i is an indicator variable denoting the choice of livelihood for household i with respect to livelihood j, α_t is season fixed effect, β_{block} is block fixed effect, γ is the difference-in-difference parameter, which is a coefficient on the cross term of treatment group dummy, T, and year 2007 dummy (fifth and sixth season), i.e., $1(t \geq 5)$, X_i is a vector of household characteristics including human, physical, natural, social, or economic capital, θ_j is a vector of coefficients to be estimated, associated with choice $j \in$ {non-farm, agricultural wage employee, paddy cultivation, non-paddy cultivation}. We omitted the sample for the natural resource related livelihood category because it was too small for the estimation.

The results of the multinomial logit regression (Table 9) indicate that a household's choice of its primary livelihood strategy is determined by the combination of the biophysical and social variables that broadly fall within its livelihood assets or those it has access to. Importantly, household head's education level has significantly positive effect in all categories, implying that better educated household heads tend to choose these livelihoods relative to agricultural wage. Inversely, those with less education tend to choose the agricultural wage which is least profitable in our case.

Our main interest is the difference-in-difference parameter representing the treatment effect of irrigation access. As expected, the effect is significantly positive in paddy and non-paddy livelihood relative to agricultural wage category. In contrast, irrigation access does not affect the choice of non-farm related livelihood.

Based on Puhani (2012), the treatment effect on the probability of choosing paddy as the main livelihood is calculated as follows:

$$\frac{\exp(\alpha_t + \beta_{block} + \gamma T \cdot 1(t \geq 5) + \overline{X}_i\theta_j)}{\sum_j \exp(\alpha_t + \beta_{block} + \gamma T \cdot 1(t \geq 5) + \overline{X}_i\theta_j)} - \frac{\exp(\alpha_t + \beta_{block} + \overline{X}_i\theta_j)}{\sum_j \exp(\alpha_t + \beta_{block} + \overline{X}_i\theta_j)}$$

where $\overline{X}_i$ is the mean level of each household characteristics. Using the estimated coefficients above, this treatment effect is 0.210, which indicate that irrigation access increases the probability of choosing paddy category by 21% relative to agricultural wage category.

Our next concern is the exogeneity of the treatment. As mentioned above, our natural experimental setting may allow some systematic differences between already irrigated and newly irrigated areas. In order to confirm that endogeneity issue is not serious in our case, we show the conditional independence test, which is based on Imbens and Wooldridge (2012). This test implies that the outcomes in the treatment group are comparable with the control group conditional on observed household characteristics. This approach requires a group which does not have irrigation access for an exogenous reason. In our case, households in Tissapura serve as this control group because both Mayurapura and Tissapura are in the Extention area, and irrigation was not available in both areas until 2005.

This test employs samples of originally non-irrigated areas, i.e., Mayurapura and Tissapura. We are interested in whether there is a systematic difference in outcome between these two groups conditional on observed household characteristics, thus we estimate the following:

$$\Pr(z_i = j) = \frac{\exp(\alpha_t + \delta Tissapura + X_i\theta_j)}{\sum_j \exp(\alpha_t + \delta Tissapura + X_i\theta_j)}$$

Table 10 shows the results of this test. Tissapura dummy is not significant in all categories, implying that there is no systematic difference in livelihood choice between Mayurapura and Tissapura. Thus conditional independence holds in our case.

4.5 Poverty levels and livelihood strategies

Next, we integrate the canonical poverty dynamics framework and livelihoods approach using regression analysis. We conduct quantitative analyses at two stages using the multinomial logit regression results in the previous section as the first stage. In the second stage, we explore the nexus between each livelihood and income level. In doing so, we correct the self selection bias that arises from endogenously determined livelihood strategies.

Based on Kurosaki and Khan (2006), the correction term can be calculated using the predicted values estimated in the multinomial logit model as follows:

$$\hat{\lambda}_{ijt} = \frac{\phi[\Phi^{-1}[\hat{\Pr}(z_{it} = j)]]}{\hat{\Pr}(z_{it} = j)}$$

Where $\hat{\Pr}(z_{it} = j)$ is the predicted value of household *i* at time *t* that chooses livelihood *j*, and φ[・] and Φ[・] are the density and distribution functions for a standard normal variable. Using these correction terms, the second stage regression is estimated as follows:

$$\log(y_{it}^{P}) = \sum_{j} \beta_j 1(livelihood_{it} = j) + Z_{it}\delta + \sum_{j} \rho_j \hat{\lambda}_{ijt} + \alpha_i + \varepsilon_{ijt} \quad (1)$$

$$\log(y_{it}^{T}) = \sum_{j} \beta_j \log(income_{it} \mid incomesource_{it} = j) + Z_{it}\delta + \sum_{j} \rho_j \hat{\lambda}_{ijt} + \alpha_i + \varepsilon_{ijt} \quad (2)$$

Where y_{it}^{P} is household *i*'s income from its primary livelihood at time *t,* y_{it}^{T} is the total income of *i* at *t*, z_{it} is the set of covariates, and α_i is the household fixed effect. Note that the

irrigation dummy is included in the first stage only. The results of these estimations are shown in Table 11.[6]

Column 1 of Table 11 indicates the impact of each livelihood choice on the income from the primary livelihood. Standard errors are clustered at household level. The base category of livelihood dummies is agricultural wage. All of the livelihood dummies are significantly positive, indicating that agricultural wage is the least profitable livelihood. Together with the first stage results, households that have smaller plots of land or less educated heads tend to obtain a major part of their incomes from agriculture wage labour, rather than from paddy and/or non-paddy cultivation and thus they are more likely to remain poor. Of all the categories, non-paddy cultivation has the largest impact because the main crops other than paddy in this area are sugar cane and banana, and these are more profitable than paddy.

As before, the marginal effect of irrigation access on choosing the paddy crop as the livelihood strategy is 21%. Since the effect of choosing paddy on total income is 80.5%, we conclude that the impact of irrigation access through paddy cultivation is 17.85% compared with the base category, agricultural wage livelihood.

Column 2 indicates the effect of income from each source (agricultural wage, non-farm, natural resource related, and paddy and non-paddy cultivation) on total income. Because income from cultivation can be negative because of the large initial costs, the sample is smaller than that of column 1. Agricultural wage has the smallest effect on total income. This also indicates that the agricultural wage is not profitable in this area. Other income sources significantly affect total income. Note that the coefficient of non-farm income is the largest among the livelihood categories. This indicates that the increase in non-farm income has the largest effect on total income.

6. As noted in the previous section, we omit the natural resource related category because of the feasibility of the multinomial regression. However, we can predict the sample selection term by using the estimated coefficient vector. For this reason, we can include the natural resource related category in the second stage regression. We also estimated the second stage regression without the natural resource related category, but it has had little effect on our results.

In order to look into the transition of the effect of non-farm income, we include the cross term of non-farm income and the linear time trend. Column 3 shows that this cross term is significantly positive, indicating that the effect of non-farm income on total income has increased from 2001 to 2007. Considering that non-farm livelihood is not directly linked to the improvement of the irrigation infrastructure, this finding implies that other factors contribute to income growth.

Finally, we need to check the selection bias resulting from dropping households who report negative income from each livelihood. In order to handle this bias, we also estimate the Heckman-type canonical sample selection model (Heckman 1976). As we mentioned already, negative income represent large initial cost, which is often the case of banana or other farming crop cultivation. Since these crops require less water than paddy cultivation, non-irrigated land size positively affects introduction of these crops. Thus, non-irrigated land size serves as a key variable that is only included in the first stage selection equation. As shown in Table 12, the results are qualitatively unchanged. In addition, the coefficients on the inverse Mill's ratio are all insignificant statistically, confirming that the sample selection bias of dropping negative income households is not serious for our study.

5. Qualitative Analysis of Livelihood and Poverty

A semi-structured open ended questionnaire was used for the in-depth interviews, which covered some of the key livelihood 'capitals' described in the frameworks proposed by DFID (2001) and by Hettige and Mayer (2003). The qualitative livelihoods analysis provided some useful insights on why differences may still exist amongst households with seemingly similar irrigation conditions. Undertaking in-depth interviews with outliers from the panel survey data provided some useful insights into the factors causing the particular type of poverty mobility outlier

households were experiencing. For example, why are certain households that have access to the improved irrigation infrastructure still poor?

By comparing the key characteristics that emerged from these in-depth interviews, we gained a better understanding of certain common factors that appeared to emerge in households belonging to each of the poverty mobility groups (that is, those that remained poor; those that remained better off and those that moved from poor to better off between 2002 and 2007). For example, it was apparent that households that remained poor in the study period had exceptionally large families. By contrast, households that moved out of poverty or remained better off between 2002 and 2007 had average family sizes. These findings are similar to those reported in previous studies, where severe poverty has been associated with larger families and a greater number of children (Bird and Shepherd 2003).

While certain household characteristics such as being a female headed household are generally associated with a higher level of vulnerability and thereby poverty (Bibars 2001), our case studies, similar to other studies (Chant 2008), have illustrated that this is not necessarily always the case, and may vary depending on the overall circumstance of a household. For example, in our study, this appeared to be true when the number of dependents is high and when there are young school attending family members. By contrast, when the female head of household had lost her husband only after her children had completed their higher education and were receiving stable employment incomes, this did not cause them to fall into poverty. Therefore, the overall circumstances of the household play a role in determining poverty level, and these need to be assessed carefully in order to understand its particular requirements.

Some households that moved out of poverty between 2002 and 2007 showed the highest educational levels for both heads of households and spouses compared with poor or better off households. In these cases, a higher education might have helped motivate these individuals to engage in better paid income generating activities or more stable employment, and thereby move out of poverty. Furthermore, there seemed to be a higher dropout rate of school children in poor

households, whereas in the case of those who had managed to move out of poverty or remain better off, children had completed their primary, secondary and in one case even tertiary level education. Therefore, in these cases, the educational levels of the children seemed to be higher overall compared with those of their parents, providing them with a better chance of staying out of poverty.

Households in rural agricultural settings usually depended on informal social networks, especially family networks, to help undertake their daily activities and cope with any challenges that they may have faced (Warren et al. 2001). For various reasons, family networks seemed to be weak in the case of households that remained poor. There was a breakdown in relations with either immediate family members (for example, the female head of household who had been abandoned by her husband) or with extended family members. By contrast, family networks seemed to be strong overall for households that moved out of poverty and remained better off. Family members usually provided both financial support (contributions towards household expenses and purchases) and non-financial support (grandparents helped look after grandchildren, married children helped look after elderly parents, and so forth).

Although some of these relations and networks are intangible and thus difficult to measure, they seem to play an important role in enhancing poverty mobility, namely helping households or individuals move out of poverty or remain better off. This is the case in both those that had access to irrigation for many years (in Sevanagala, Sooriyawewa, and Kirriibbanwewa) and those who had enjoyed better irrigation access only more recently (in Mayurapura and Tissapura).

In terms of community level relations and networks, it seemed that poor households did not hold positions of influence within the community. For example, even if they were members of community based organisations (CBOs) such as farmer's organisations, they were unable to get some of their grievances listened to. By contrast, those belonging to the mobility category that had moved out of poverty held positions of responsibility in local CBOs and therefore

influenced the decision-making process. For example, this factor distinguished between households in Mayurapura that were able to move out of poverty after accessing improved irrigation and those that continued to remain in poverty. In better off households, individuals again held positions of influence and responsibility in local CBOs; in fact, some individuals in this category were also politically influential. Having a position of responsibility also seemed to be linked to how well established a family was within its community. For example, as expected, early settlers were usually better established than were those that had resettled more recently. However, in the case of poor households, even being an original settler did not seem to help them gain influence within their communities.

With regard to the livelihood strategies followed by the three poverty mobility groups, one common feature was their mutual adoption of 'livelihood diversification.' This included one family member engaging in more than one livelihood activity, several members engaging in different livelihood activities, or a combination of both. In the case of those households that remained poor between 2002 and 2007, livelihood activities usually comprised low income generating activities or unstable incomes that were perhaps seasonal. By contrast, in the case of those who experienced an upward mobility in terms of poverty, their livelihood activities seemed to be more stable and generated higher incomes. In some cases, however, households in this category were engaged in a combination of high and low income generating activities. Those who remained better off also seemed to engage in high income generating activities or enjoy more stable employment. There was also access to certain non-farm related income sources (such as state sector jobs) because of the relatively good educational levels of the second generation. Some households attributed their diversification into crop related livelihood activities such as paddy and non-paddy cultivation to their improved access to the irrigation system. Nevertheless, some households were still unable to move out of poverty, despite this because of other social conditions prevailing in the household as described earlier.

Another feature that emerged for both the households that moved out of poverty and those that were better off was that household members seemed to make a collective effort to make financial savings. It could be argued that this effort to save demonstrated that these households aspired to a better future and managed their finances accordingly. Households that remained poor, by contrast, did not save for the long term; in fact, many of these households described their difficulties in meeting their daily expenses. Once again, in the Mayurapura extension area, the ability shown by certain poor households to manage their finances in a prudent manner may have also provided them with the additional financial resources and necessary skills required to exploit the improved irrigation infrastructure, as opposed to those poor households that had access to improved irrigation but remained in the poor category.

In terms of political influence, those households that remained poor between 2002 and 2007 held little political clout and described themselves as being voiceless and discriminated against (in instances such as land distribution), even if they supported the 'correct' political party. By contrast, those who remained in the better off category carried considerable political influence at the community level, even including running for office in local elections. In terms of those that moved out of poverty, although some felt discriminated against based on their party affiliations, they did not feel that this had negatively affected them moving out of poverty.

6. Concluding Remarks

Having access to the improved irrigation infrastructure in the study area was a crucial factor that provided many households with the opportunity to diversify their livelihood activities and thereby increase their levels of income. The presented quantitative analysis shows that irrigation access is associated with declining poverty indices. We also find that the effect of irrigation access on consumption level is notable for the poor, although its effect is unclear for the better off.

The findings of both the quantitative (multinomial logit model) and qualitative (case studies) approaches presented here imply that households that were allocated cultivable land and irrigated water were able to grow their own crops as opposed to engaging in livelihood activities such as agricultural wage labour or depending on rain-fed cultivation. However, consistent with the trends reported in farming communities elsewhere in southern Asia (Ellis 1999; Otsuka et al. 2008), we find that an important share of income has long been derived from non-farm related livelihood activities across the entire study site.

This clearly illustrates that other factors that are not linked to improved irrigation infrastructure contribute to the discussed changes in livelihood portfolios. For example, through the in-depth interviews we learned that many of the younger generation from these areas were joining the armed forces or working in the garment industry. The former is as a result of the socio-political conflict in Sri Lanka that prevailed at the time of the study and the latter is a reflection of global market trends and preferential trade policies.

Furthermore, although some households remained poor throughout the study period, the overall trend shows a remarkable decline in the poverty indices. The case studies identified several factors or combinations of factors that may result in some households being unable to move out of poverty even in the presence of an improved irrigation infrastructure. In particular, belonging to more vulnerable groups such as female headed households that have many dependents and poor family support or being voiceless in the community with no position of influence are scenarios that appeared to be associated with higher poverty levels.

Therefore, although the importance of investing in irrigation development in order to alleviate poverty in rural communities is non-debatable, it is crucial that other suitable supporting investments must also be made. For example, certain targeted non-agricultural interventions could be introduced in order to offer alternative income generating livelihood activities to local residents, especially the more vulnerable groups. For such non-agricultural interventions, existing marketing networks (if any) should be identified and joined in order to

ensure their long term sustainability. These interventions could be targeted to help diversify the livelihood portfolios of households that have remained poor even in the presence of irrigation development.

Another important point that emerged from the presented findings is that improved educational levels of the second generation are associated with an ability to find stable, well paid employment outside the farming sector. These individuals therefore have the necessary human capital and skills to obtain employment that is more remunerative compared with agriculture. Two implications arise from this finding. The first is that it may be useful for integrated irrigation development projects to focus on enhancing educational or vocational training facilities in these rural areas in addition to investing in physical infrastructure development. The second is that, if the focus is poverty reduction, it is important to consider the net returns of irrigation investment compared with other options. This study found positive linkages between irrigation and poverty reduction. However, whether similar or greater reductions could have been achieved with the same or lower investment into other sectors is a broader question worthy of additional analysis and discussion.

From a methodological perspective, using a combination of quantitative and qualitative livelihoods approaches proved to be useful for several reasons. First, the qualitative case studies helped validate the results of the quantitative analysis. For instance, the biophysical and socio-economic variables that showed significant relationships with households' choices of livelihood strategies could be further explained by the qualitative information obtained through the case studies. One specific example is that households were likely to engage in paddy cultivation if they had access to improved irrigation and their own cultivable land, whereas they were likely to engage in agricultural wage labor if they did not. Second, the qualitative information helped explain some of the trends in the quantitative results. For example, the fact that many households increasingly derive parts of their incomes from engaging in livelihood activities outside the agricultural sector, was shown to be partly because at that time, many of the

younger generation were joining the armed forces or working in garment factories, as described in the in-depth interviews.

The qualitative case studies also highlighted some of the key factors that influence poverty at the household level that may be difficult to obtain from quantitative methods. For instance, we showed that holding positions of responsibility and having influence in the community enhances poverty mobility, whereas being voiceless within the community impedes it. Using this type of mixed methodology was thus valuable and it helped enhance the outcomes of the presented study.

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Figure 1. Map of the study site

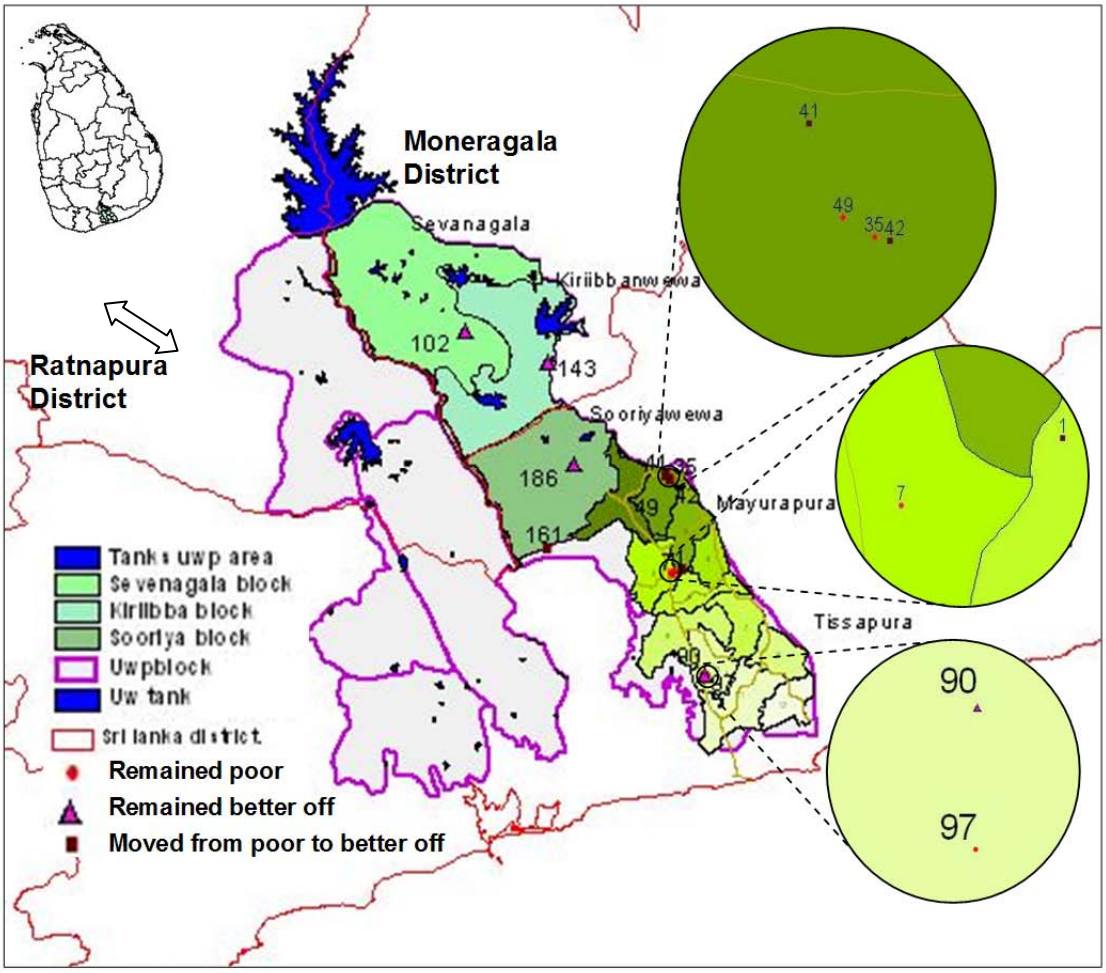

Table 1. Sample size and irrigation access of each block

	Sample size	Irrigation Access 2001 Maha/Yala	2002 Maha/Yala	2007 Maha/Yala
Control group 1				
Sevanagala (irrigated)	25	YES	YES	YES
Kirriibbanwewa	22	YES	YES	YES
Sooriyawewa	36	YES	YES	YES
Control group 2				
Tissapura	16	NO	NO	NO
Treatment group				
Mayurapura	85	NO	NO	YES
Ommited group				
Sevanagala (rain-fed)	9	NA	NA	NA

Table 2. Transition of irrigated landownership

Own land only		Own and rented land	
2001		2001	
Irrigated land (owned)	Percentage	Irrigated land	Percentage
NO	49.91	NO	46.47
YES	50.09	YES	53.53
Total	100	Total	100
2002		2002	
Irrigated land (owned)	Percentage	Irrigated land	Percentage
NO	54.35	NO	47.83
YES	45.65	YES	52.17
Total	100	Total	100
2007		2007	
Irrigated land (owned)	Percentage	Irrigated land	Percentage
NO	10.33	NO	7.07
YES	89.67	YES	92.93
Total	100	Total	100

Table 3. Average consumption level per adult (in Rs)

Irrigated land (owned)	Total	Food	Non-food
2001			
NO	1050.546	702.4789	348.067
YES	1184.773	728.4112	456.3616
t-value of the difference	-2.6607***	-1.5096	-2.5053**
2002			
NO	1155.531	812.6323	339.4695
YES	1312.214	772.5323	539.6821
t-value of the difference	-2.8998***	2.4272**	-4.2400***
2007			
NO	1711.497	1067.122	644.3749
YES	1970.624	1150.982	819.6415
t-value of the difference	-1.3026	-2.1134**	-0.9217

Note: We use the age-sex weights in Townsend (1994).
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 4. Statistical poverty measure

FGT poverty indices(a)				
		a=0	a=1	a=2
	2001	0.76132	0.32075	0.17045
	2002	0.72996	0.27889	0.13436
	2007	0.30661	0.07861	0.03014
Irrigated land (owned)		a=0	a=1	a=2
	2001			
Non-irrigated		0.80399	0.36175	0.20214
irrigated		0.71881	0.27991	0.13886
	2002			
Non-irrigated		0.76599	0.29102	0.14002
irrigated		0.6875	0.26461	0.12769
	2007			
Non-irrigated		0.41228	0.14371	0.06999
irrigated		0.29444	0.07112	0.02555

Table 5. Poverty head count ratio by the transition of irrigation accessibility

	Irrigated land (owned)	
2001		
Irrigated	0.8039927	
Non-irrigated	0.7188065	
2001–2002	Irrigated in 2002	Non-irrigated in 2002
Irrigated in 2001	0.6871981	0.7465278
Non-irrigated in 2001	0.7388889	0.7622222
2002–2007	Irrigated in 2007	Non-irrigated in 2007
Irrigated in 2002	0.296875	0.3958333
Non-irrigated in 2002	0.2760417	0.45

Figure 2. Treatment effect on distribution

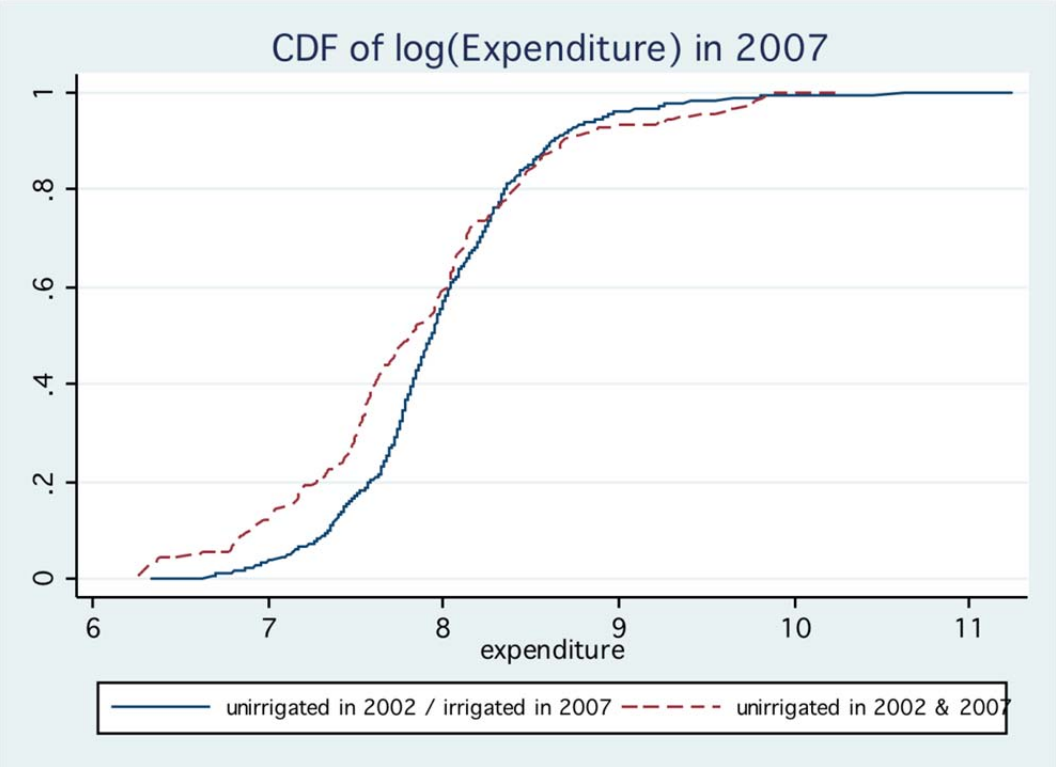

Table 6. Poverty transition matrix

Control group 1					
2002 ¥ 2007	very poor	poor	non-poor	better off	total
very poor	0%	2.41%	4.82%	1.20%	8.43%
poor	0%	7.23%	28.92%	10.84%	46.99%
non-poor	0%	2.41%	10.84%	15.66%	28.92%
better off	0%	1.20%	3.61%	10.84%	15.66%
Total	0%	13.25%	48.19%	38.55%	100%
Control group 2					
2002 ¥ 2007	very poor	poor	non-poor	better off	total
very poor	1.18%	2.35%	5.88%	3.53%	12.94%
poor	0%	12.94%	25.88%	21.18%	60%
non-poor	0%	3.53%	5.88%	10.59%	20%
better off	0%	0%	2.35%	4.71%	7.06%
Total	1.18%	18.82%	40%	40%	100%
Treatment group					
2002 ¥ 2007	very poor	poor	non-poor	better off	total
very poor	0%	6.25%	12.5%	0%	18.75%
poor	6.25%	12.5%	12.5%	12.5%	43.75%
non-poor	0%	0%	12.5%	12.5%	25%
better off	0%	0%	6.25%	6.25%	12.5%
Total	6.25%	18.75%	43.75%	31.25%	100%

Table 7. Composition of livelihood activities by primary livelihood

agri_wage (N=117)		
	Mean	Std. Dev
total income	709.3845	1644.146
agri_wage	764.8029	660.2521
nonfarm	181.5671	292.912
noncrop	22.57835	129.3005
paddy	4.853515	583.3283
non_paddy	-264.4173	1302.95
non-farm (N=371)		
	Mean	Std. Dev
total income	2764.928	4568.475
agri_wage	102.1348	231.5177
nonfarm	2523.718	4145.946
noncrop	64.99775	615.2561
paddy	231.3953	1019.23
non_paddy	-157.3179	2884.221
non-crop (N=48)		
	Mean	Std. Dev
total income	9760.963	13571.34
agri_wage	129.3837	388.019
nonfarm	1011.837	2000.042
noncrop	7820.793	11426.02
paddy	423.8421	1513.957
non_paddy	375.1071	2478.259
paddy (N=255)		
	Mean	Std. Dev
total income	6722.843	7346.606
agri_wage	148.5073	449.4281
nonfarm	817.1534	1230.735
noncrop	149.326	805.639
paddy	5466.335	5705.047
non_paddy	141.522	2720.978
non-paddy (N=328)		
	Mean	Std. Dev
total income	9264.393	12136.39
agri_wage	171.1168	401.8782
nonfarm	781.349	1624.802
noncrop	175.5744	1399.025
paddy	825.8642	2201.525
non_paddy	7310.488	10477.37

Table 8. Descriptive statistics of the variables used in the analyses

Variable	Unit	Obs.	Mean	Std. Dev.
First- and second-stage				
Size of household	#	1104	5.182367	1.844339
Age of household head	Year	1095	47.71689	11.83472
Male household head	Binary	1095	0.9324201	0.2511383
Schooling years of household head	Year	1093	5.511436	3.333577
Irrigated land holding (owned)	Binary	1104	0.634058	0.4819116
Sevanagala irrigated	Binary	(default category)		
Kirriibbanwewa	Binary	1104	0.1195652	0.3245995
Sooriyawewa	Binary	1104	0.1956522	0.3968817
extension	Binary	1104	0.548913	0.4978273
Land size	ha	1104	2.81653	1.492772
distance to daily market	km	1104	1.539839	2.631718
distance to paved road	km	1100	3.538927	21.67813
member of Farmer's Organization	Binary	1104	0.8508454	0.3478195
log(agricultural asset)		1104	2.114966	7.118592
maha2001	Binary	(default category)		
yala2001	Binary	1104	0.1666667	0.3728469
maha2002	Binary	1104	0.1666667	0.3728469
yala2002	Binary	1104	0.1666667	0.3728469
maha2007	Binary	1104	0.1666667	0.3728469
yala2007	Binary	1104	0.1666667	0.3728469
2nd Stage only				
log(income from primary livelihood)		1066	7.661144	1.298832
log(total income)		1035	7.721353	2.144174
agricultural wage livelihood	Binary	1104	0.0987319	0.2984369
natural resource-related livelihood	Binary	1104	0.0425725	0.2019827
paddy livelihood	Binary	1104	0.2273551	0.4193137
non_paddy livelihood	Binary	1104	0.2744565	0.4464422
Log(income from agricultural wage)		1104	-0.9960249	5.005858
Log(income from non-farm)		1104	4.089598	4.862254
Log(income from natural resource-related)		1104	-3.240645	3.727104
Log(income from paddy)		1064	0.7171861	6.132401
Log(income from non_paddy)		888	3.39199	5.565084

Note: We add 0.01 to compute logs

Table 9. First-stage estimation: the determinants of livelihood strategies

VARIABLES	(1) non-farm	(2) paddy	(3) non-paddy
Human Capital:			
Size of household	-0.00922	-0.0159	-0.0363
	(0.0807)	(0.0893)	(0.0811)
Age of household head	0.0295*	0.000176	-0.0100
	(0.0170)	(0.0181)	(0.0182)
Male household head	-0.279	0.471	0.206
	(0.639)	(0.689)	(0.675)
Schooling years of household head	0.143***	0.133**	0.105**
	(0.0527)	(0.0601)	(0.0512)
Natural Capital:			
Treatment effect of irrigation access	0.295	1.998***	1.714***
	(0.625)	(0.660)	(0.631)
Land size	0.354**	0.330*	0.379**
	(0.155)	(0.173)	(0.160)
Location Capital:			
Kirriibbanwewa	-0.864	-0.0736	-0.469
	(1.026)	(1.044)	(1.042)
Sooriyawewa	2.446**	2.129*	1.526
	(1.184)	(1.187)	(1.200)
Mayurapura	-1.165*	-3.380***	-2.888***
	(0.676)	(0.772)	(0.693)
Tissapura	-1.111	-2.330**	-2.211***
	(0.868)	(0.976)	(0.838)
distance to daily market	0.119*	0.0492	0.0911
	(0.0691)	(0.0789)	(0.0762)
distance to paved road	0.130*	0.136*	0.138*
	(0.0764)	(0.0764)	(0.0763)
Social Capital:			
member of Farmer's Organization	0.0454	1.722***	1.688***
	(0.427)	(0.503)	(0.470)
Physical Capital:			
log(agricultural asset)$_{t-1}$	0.0302	0.0883***	0.101***
	(0.0254)	(0.0269)	(0.0256)
Constant	-0.314	-0.502	-0.348
	(1.101)	(1.205)	(1.123)
Period fixed effect	YES	YES	YES
Observations	843	843	843

Standard errors in parentheses are clustered at household level. *** p < 0.01, ** p < 0.05, * p < 0.1

Table 10. Conditional Independence Test

VARIABLES	(1) non-farm	(2) paddy	(3) non-paddy
Human Capital:			
Size of household	0.0450	0.0253	0.0114
	(0.0869)	(0.110)	(0.0889)
Age of household head	0.0379*	0.0231	-0.0173
	(0.0197)	(0.0228)	(0.0213)
Male household head	-0.374	1.577	0.685
	(0.692)	(1.280)	(0.756)
Schooling years of household head	0.123**	0.158**	0.0315
	(0.0561)	(0.0699)	(0.0498)
Conditional Independence Test:			
Tissapura	-0.0537	-0.0453	0.0829
	(0.597)	(0.725)	(0.538)
Natural Capital:			
Land size	0.359**	0.466**	0.255
	(0.170)	(0.203)	(0.161)
Location Capital			
distance to daily market	0.147*	0.0567	0.147*
	(0.0817)	(0.0945)	(0.0862)
distance to paved road	0.116	0.124*	0.125*
	(0.0747)	(0.0749)	(0.0746)
Social Capital:			
member of Farmer's Organization	0.131	2.002*	1.538***
	(0.534)	(1.053)	(0.570)
Physical Capital:			
$\log(\text{agricultural asset})_{t-1}$	0.0356	0.0665**	0.0870***
	(0.0288)	(0.0333)	(0.0288)
Constant	-1.788	-5.330***	-1.067
	(1.394)	(2.012)	(1.449)
Period fixed effect	YES	YES	YES
Observations	447	447	447

Standard errors in parentheses are clustered at household level. *** p < 0.01, ** p < 0.05, * p < 0.1

Table 11. Livelihood strategies and incomes

VARIABLES	(1) Ln (income from livelihood)	(2) Ln (total income)	(3) Ln (total income)
non_farm livelihood	0.337**		
	(0.166)		
natural resource-related livelihood	0.903***		
	(0.221)		
Paddy livelihood	0.805***		
	(0.175)		
non_paddy livelihood	1.164***		
	(0.168)		
Log(income from agricultural wage)		0.0256**	0.0299**
		(0.0130)	(0.0127)
Log(income from non-farm)		0.134***	0.116***
		(0.0299)	(0.0297)
Log(income from non-farm)*season			2.43e-05***
			(4.51e-06)
Log(income from natural resource-related)		0.0888**	0.0914**
		(0.0381)	(0.0381)
Log(income from paddy)		0.100***	0.101***
		(0.0176)	(0.0178)
Log(income from non_paddy)		0.0769***	0.0721***
		(0.0105)	(0.0106)
Size of household	0.133***	0.0696	0.0636
	(0.0388)	(0.0864)	(0.0860)
Age of household head	0.0341**	0.00787	0.00521
	(0.0165)	(0.0285)	(0.0286)
Male household head	-1.429*	-1.083	-1.152
	(0.818)	(0.801)	(0.753)
Schooling years of household head	0.0523	-0.115	-0.120
	(0.0474)	(0.0725)	(0.0727)
Land size	0.0222	0.0176	0.0185
	(0.0901)	(0.0936)	(0.0945)
Distance to daily market	0.00258	0.0284	0.0172
	(0.0390)	(0.0550)	(0.0553)
Distance to paved road	-0.0182	-0.0168	-0.0139
	(0.0134)	(0.0143)	(0.0145)
member of Farmer's Organization	-0.649***	-0.787**	-0.690*
	(0.246)	(0.359)	(0.358)
log(agricultural asset)$_{t-1}$	-0.0580***	-0.0845***	-0.0742**
	(0.0161)	(0.0318)	(0.0321)
Constant	3.687**	7.933***	8.481***
	(1.595)	(2.976)	(3.007)
Correction terms	YES	YES	YES
Season fixed effect	YES	YES	YES
Observations	887	694	694
Number of household	184	179	179
R-squared	0.351	0.422	0.439

Standard errors in parentheses are clustered at household level. *** p < 0.01, ** p < 0.05, * p < 0.1

Table 12. Livelihood strategies and incomes
(Heckman selection model for negative income)

VARIABLES	(1) Ln (income from livelihood)	(2) Ln (total income)	(3) Ln (total income)
non_farm livelihood	0.337***		
	(0.128)		
natural resource-related livelihood	0.902***		
	(0.203)		
Paddy livelihood	0.805***		
	(0.144)		
non_paddy livelihood	1.163***		
	(0.134)		
Log(income from agricultural wage)		0.0295	0.0331
		(0.0231)	(0.0202)
Log(income from non-farm)		0.134***	0.116***
		(0.0209)	(0.0193)
Log(income from non-farm)*season			2.36e-05***
			(7.99e-06)
Log(income from natural resource-related)		0.0925***	0.0945***
		(0.0310)	(0.0271)
Log(income from paddy)		0.0991***	0.0998***
		(0.0193)	(0.0169)
Log(income from non_paddy)		**0.0771*** **	**0.0724*** **
		(0.0183)	(0.0161)
Size of household[1]	0.134***	0.115	0.103
	(0.0319)	(0.0962)	(0.0841)
Age of household head[1]	0.0344**	0.00951	0.00673
	(0.0143)	(0.0395)	(0.0346)
Male household head[1]	-1.430***	-0.801	-0.903
	(0.366)	(1.066)	(0.932)
Schooling years of household head[1]	0.0521	-0.150	-0.150*
	(0.0345)	(0.100)	(0.0876)
Land size[1]	0.0219	-0.102	-0.0858
	(0.0552)	(0.180)	(0.158)
Distance to daily market[1]	0.00283	-0.0306	-0.0340
	(0.0269)	(0.0848)	(0.0741)
Distance to paved road[1]	-0.0181**	-0.0194	-0.0163
	(0.00820)	(0.0224)	(0.0196)
member of Farmer's Organization[1]	-0.650***	-1.040*	-0.914*
	(0.196)	(0.588)	(0.516)
log(agricultural asset)$_{t-1}$[1]	-0.0579***	-0.0819**	-0.0723**
	(0.0127)	(0.0348)	(0.0306)
Constant	2.706*	6.564	7.319*
	(1.622)	(4.427)	(3.880)
Correction terms	YES	YES	YES
Season fixed effect	YES	YES	YES
Mills ratio	0.114	2.348	2.052
	(1.005)	(1.761)	(1.542)
Observations	906	906	906

Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1. Excluded instrument for the first stage is the unirrigated land size. [1]variables included in both first and second stage.

Abstract (in Japanese)

要約

本研究は生計アプローチと計量経済学的アプローチを組み合わせることにより、灌漑設備への投資が農村家計の生計改善に与えた影響を定量的に分析したものである。スリランカ南部の家計調査データと現地の自然実験的状況を利用し、２段階の回帰モデルによる所得決定要因の分析をすることで、灌漑へのアクセスが生計選択の変化を通じて所得にプラスの影響を与えていることを示した。また、質的アプローチを用いて、灌漑アクセスとは直接関係しない要因もまた生計手段の選択に影響を与えている可能性を示した。さらに、灌漑アクセスがあるにもかかわらず特定の家計が貧困から抜け出せない原因を明らかにした。

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