Poverty, Income Inequality, and Irrigation Development: Longitudinal Evidence from Palawan, Philippines

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ABSTRACT

We measure the impacts of irrigation development on poverty and income inequality in a frontier region of the Philippines. Using household panel data we measure changes in standard poverty measures and income inequality over the period 1995–2002. We make comparisons within the beneficiary community and between the beneficiary community and an adjacent community that, while not affected directly by irrigation services, was indirectly affected through expanded labor market opportunities arising from irrigation. Results of the analyses, including poverty and inequality decompositions, suggest lowland irrigation development led to reduced income inequality and lower rates of poverty in the lowland community, reduced inequality and lower rates of poverty for the group of upland households who participated in off-farm work on irrigated lowland farms, and higher overall income inequality between the lowland and upland communities.

Keywords: inequality, irrigation, Philippines, poverty decomposition, rice
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INTRODUCTION

Irrigation development is a key factor for improving agricultural incomes and facilitating rural wealth accumulation, particularly in the low-income tropics (Bhattarai, Sakthivadiel, and Hussain 2002). By contributing to land improvement, irrigation can speed up poverty reduction in areas where populations are directly dependent on land for livelihood (Balisacan 2001). Nevertheless, despite its favorable impact on agricultural incomes and poverty alleviation, irrigation has been shown to sometimes exacerbate income disparities within irrigated farming communities (Bhattarai, Sakthivadiel, and Hussain 2002; Sampath 1990; Adriano 1980). Dam-type irrigation systems have been shown to bring greater inequality in the distribution of benefits across irrigated farms than groundwater or lift irrigation systems (Sampath 1990; Shah 1998; Shah 2001). One reason is that farms that are distant from main water sources and irrigation canals typically have a less secure water supply (Bromley, Taylor, and Parker 1980; Adriano 1980). Another reason is that in such irrigated areas, larger landholdings frequently have more secure water supplies than smaller farms (Sampath 1990; Bromley, Taylor, and Parker 1980; Adriano 1980). Greater income inequality may perpetuate poverty and may also increase the incentives for governments to adopt policies and programs that reduce productive efficiency (Binswanger and Deininger 1997).

Numerous studies have examined the impact of irrigation at the aggregate level, either at the country or regional level (e.g., Hussain and Wijerathna 2004; Sampath 1990; Ramasamy, Paramasivam, and Otsuka 1992). David, Cordova, and Otsuka (1994) found that income inequality was less pronounced in irrigated areas than in rainfed areas. This is consistent with several studies from Asia suggesting improved income distributions in irrigated farming communities compared with rainfed areas (Bhattarai, Sakthivadiel, and Hussain 2002; Hossain, Gascon, and Marciano 2000). Micro-level investigations regarding the impacts of irrigation development have tended to focus on impacts either within beneficiary lowland farming communities (Thapa, Otsuka, and Barker 1992; Adriano 1980) or between beneficiaries and non-beneficiaries within the irrigated communities (David, Cordova, and Otsuka 1994). Most analysts have used household-level cross-section data sets. Although some authors have had access to longitudinal data (e.g., Hossain, Gascon, and Marciano 2000), multi-year studies remain scarce. Moreover, we are aware of no study to date that measures, over time, irrigation's off-site impacts on poverty and income inequality.

In this paper we seek to fill this gap in the literature using panel data from farm households in the southern district of Palawan, Philippines. We study two groups of farm households: those residing within a lowland irrigation catchment and those living on adjacent non-irrigated forested slopes. We evaluate the distributional and poverty impacts of irrigation within the beneficiary lowland community, within the upland community adjacent to the lowlands, and between these two communities. We are motivated by two questions: first, did irrigation development contribute to poverty alleviation at the study sites, and second, did development reduce income inequality?

METHODS

At the outset we note that researchers could observe poverty and income inequality changing for several reasons. First, irrigation could have made all farm households better off (or no worse off), but increased welfare disproportionately for a subset. Second, one group could have become better off and another group could have become worse off. And third, both groups could have become worse off, but one group could have become much worse off. Given these possibilities, the measurement of inequality cannot, in and of itself, be considered a measure of welfare (Deaton 1997). For this reason, we first measure the incidence of poverty in the study sites, decomposing selected poverty measures by specific categories of interest. To measure inequality and compare income distributions between and within groups of households we then turn to the use of Gini coefficients and Gini decompositions.

Throughout the analysis we use real income per capita, weighted by household size, and denominated in kilograms of rice to measure welfare. Income per capita is used instead of total income per household because it is difficult to attach meaning to household or family welfare without starting from the welfare of its members (Deaton 1997). Our approach is consistent with the method proposed in Yao (1999) and the methods discussed in Coulter (1989), Deaton (1997), and Sadoulet and de Janvry (1995). We use this approach not because rice production is our measure of welfare, but because total consumption is our best measure of welfare, and rice is a useful "basket" with which to form our own consumer price index (CPI). Welfare here is not judged on the basis of how much rice is produced by a household, but rather by how much rice the household's income (cash + value of non-marketed production) represents in a given year, based on prices in that year. This is a more accurate measure of welfare, in our opinion than a pure Philippine peso (PHP) measure because it more accurately reflects the household's purchasing power in each year. The price used to value rice is the average reported farm gate price of rice in the relevant survey year.

Poverty Indices and Decompositions

To examine poverty levels in the sample we focus on three measures proposed by Foster, Greer, and Thorbecke (1984). These are the headcount ratio, the poverty gap ratio, and the squared poverty gap ratio.

The headcount ratio (*H*) measures the prevalence of poverty and is calculated as the ratio of the number of poor individuals to the total number of individuals in the sample:

$$H = \frac{q}{n} \tag{1}$$

where q represents the number of poor individuals living below the absolute poverty line in the sample and n is the sample size. The headcount ratio reflects the incidence of poverty by indicating the proportion of individuals in the sample with an income per capita below the poverty threshold.

The poverty-gap (*P*) index measures poverty depth, and is defined as:

$$P = H \cdot I \tag{2}$$

where $I = \sum_{i=1}^{q} \frac{g_i}{z}$.

In Equation 2 I is the income gap ratio and g_i is the income shortfall of household i, and z is the absolute poverty line.[1] In evaluating the impact of a policy change or development initiative on poverty alleviation, P is considered a better measure than H because it is based on the aggregate income deficit of the poor, relative to a given poverty line. For this study, we use the absolute per capita poverty line for the province

1 The term g_i or income shortfall is g_i=z−y_i, where y_i is the income per capita of household *i*.

of Palawan as reported by the Philippine National Statistics Coordinating Board (NSCB).

The squared poverty gap (P^2) measures the severity of poverty. It is calculated as

$$P^2(y;z) = \frac{1}{n}\sum_{i=1}^{q}\left(\frac{g_i}{z}\right)^2 \qquad (3)$$

This measure is advantageous for comparing policies targeting the poorest segment of the population, but can be difficult to interpret (Ravallion 1992). Equation 3 can be used for poverty decomposition by population class, via:

$$P_\alpha^2(y;z) = \sum_{i=1}^{q}\frac{n_c}{n}P_\alpha^2(y_i;z) \qquad (4)$$

where $\frac{n_c}{n}$ is the population share of class *c* and

$\frac{n_c}{n}P_\alpha(y_i;z)$ is regarded as the total contribution of a class to overall poverty of the total sample, with y_i representing a vector of per capita incomes arranged in ascending order. The decomposition in Equation 4 allows one to assess the effect of changes in subgroup poverty on total poverty, both in quantitative and qualitative terms.

General Measures of Inequality

We report below six widely-used inequality measures: (1) relative mean deviation (RMD);[2] (2) the coefficient of variation (CV); (3) the standard deviation of logs; (4) the Gini coefficient (G); (5) the Theil index; and (6) the mean log deviation. Of these six inequality measures, we focus our discussion on the Gini coefficient because it satisfies the primary criteria of a good measure of income inequality.[3] That the Gini coefficient satisfies the criteria for population size independence is important for this study because we use unbalanced panel data.[4]

The Gini coefficient can be computed in several ways. We use Yao's (1999) formula:

$$G = 1 - \sum_{i=1}^{I} P_i\left(2\sum_{k=1}^{i} Q_i - w_i\right) \qquad (5)$$

where $Q_i = \sum_{k=1}^{i} w_i$, p_i is the relative share in the population frequency of household *i*, w_i is the income share of household *i*, and Q_i corresponds to the sum of the income shares, w_i. This formula for *G* also serves as the base for Gini decompositions.

Gini Decomposition

Inequality may be broken down along population lines, by income sources, or in other dimensions. Although early studies point out difficulties in computing and decomposing the Gini coefficient (Allison 1978; Braun 1988), Yao (1999) proposed a straightforward method of Gini decomposition, which we follow.

Gini decomposition generates three components: intra-class (within-group), inter-class (between-group), and overlap. Each component may take a value between zero and the total Gini coefficient. The sum of these three components equals the total Gini coefficient. If the within-group component is equal to zero, then there is no income inequality within each

2 The formula for this inequality measure is adopted from Schwartz and Winship (1980).

3 These are typically taken to be mean independence, population size independence, symmetry, Piguo-Dalton Transfer sensitivity, and decomposability.

4 Population size independence means that if the population were to change, the reported measure of inequality would not change (World Bank 2005).

class or group. If the between-group component is equal to zero, then the mean incomes of all classes or groups are identical. If the overlapped component is equal to zero, then the richest person in any income class is no better off than the person with the lowest income in the next highest income class. Gini decomposition by population classes discussed by Yao (1999), Yao and Liu (1996), and Pyatt (1976). Yao (1999) and Rao (1969) focus on Gini decomposition by income source.

The first decomposition we undertake is decomposition by population class. We decompose the sample by the two broad classes of interest (lowland if residing in the irrigated lowlands and upland if residing in the uplands). We also decompose the lowland sample into two landholding size categories (small if farm size is less than 3 hectares [ha], and large if 3 ha or more), and decompose the upland sample by participation in off-farm employment (with off-farm employment and without off-farm employment). Gini decompositions are based on the formula:

$$G_{DC} = 1 - \sum_{i=1}^{C} P_I \left(2 \sum_{k=1}^{C} Q_1 - W_I \right) \qquad (6)$$

where $Q_I = \sum_{K=1}^{I} w_K$, C represents the number of population classes, and w_I and p_I represent the income and population share of the Ith class (I = 1, 2, …, C) in the population. The sums of p_I and w_I from 1 to I are both equal to unity. Q_I is the cumulative income share of source I. Where the Gini coefficient is decomposed by income source, we use

$$G_{DS} = \sum_{h=1}^{H} w_h C_h \qquad (3)$$

where $C_h = 1 - \sum_{i=1}^{N} \theta_i 2(Q_{ih} - w_{ih})\,, Q_{ih} = \sum_{k=1}^{j} w_{ih}$ and where H represents the total number of income sources, w_h is the income share of source h, C_h is the concentration ratio of source h, θ_i is share of household i in the total number of individuals in the sample, w_{ih} is the income share of household i for source h, and Q_{ih} is the cumulative income share of household i for source h. Gini decomposition is via the approach of Yao (1999) and Fisher (2004).

Data

We use data from household surveys conducted in the southern district of Palawan, a fairly remote area of the Philippines. The panel (referred to below as the pooled sample) consists of 907 annual household data points collected during the survey years 1995, 1997, 1999, and 2002 in the lowland and upland communities. These data are summarized in Table 1. We also use two subsets of this dataset: the lowland sample (386 annual household observations) and the upland sample (521 annual household observations).

Table 1. Structure of the panel data sets, 1995–2002

Year	Pooled Sample		Lowland Sample		Upland Sample	
	Households	Individuals	Households	Individuals	Households	Individuals
1995	157	789	36	212	121	577
1997	214	1,079	112	592	102	487
1999	203	971	104	507	99	464
2002	333	1832	134	743	199	1,089
Total	907	4,671	386	2,054	521	2,617

Different observed years can be characterized by different physical conditions based on average yields observed. The year 1995 is our base year, during which no dam-type irrigation system existed at the study site. Having no operational irrigation facility in 1995, all lowland households produced only one crop in that year. In 1995, the average yield for lowland households was 2,585 kilograms per hectare (kg/ha). Average per capita household income for lowland households was PHP 10,619, the lowest among the four observed years.

Irrigation development at the study sites occurred in 1997. Years 1997, 1999, and 2002 are classified as favorable, unfavorable, and typical, respectively, from the perspective of growing conditions and observed yields and incomes. Average lowland yields in these years were 3,375; 2,558; and 2,899 kg/ha, respectively, with an average number of 2.1 croppings per year. In 1999 an El Niño weather pattern adversely affected crop yields at the study sites. The other years did not have prolonged drought spells. Although weather is undoubtedly a driver of the patterns observed, a limitation of our approach is that we cannot remove the effects of weather from the results.

As indicated above, we express real income per capita in the form of kilograms of rice equivalents. These grain-equivalent measures are derived by deflating the household's nominal income per capita (including imputed values of rice retained for home consumption) by the average rice price observed in each sample year. Although we have consumer price indexes for the province of Palawan for the given period, we elect to use the average price of milled rice as our deflator since the price of milled rice has greater local precision and because rice accounts for a major portion of household budgets in our sample. All reported figures, unless noted otherwise, are based on per capita weighting for each household.[5]

Within the overall context of the Philippines, the lowland and upland households in our sample can be considered low income. Nevertheless, the lowland group is relatively better off. Lowland households derive most of their income from the sale of agricultural crops, using relatively modern farming systems that include modern seeds, mechanization, chemical fertilizer, and pest control. Upland households operate along the forest margins they inhabit, in an ecosystem that is considerably different from the lowland ecosystem. Upland agricultural production is characterized by minimal use of purchased inputs, traditional hand cultivation techniques, and low yields. The lowland and upland samples are discussed in greater detail by Shively and Pagiola (2004) and Shively and Fisher (2004). A precondition for development of the irrigation scheme was that lowland farmers become part of an irrigators association. At the time of the post-irrigation surveys, all farmers participated in this association.

RESULTS

Poverty Findings

The poverty line used for this analysis was taken from Poverty Statistics published by NSCB. This publication reports that, in 1997, the annual per capita poverty threshold level in Palawan was PHP 9,511 (approximately USD 190) (NSCB 2005). This absolute poverty line is computed by the NSCB from a triennial Family Income and Expenditure Survey. We employ the

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5 Unweighted measures of inequality generate patterns similar to those reported here.

1997 poverty line since it corresponds to one of the four observed years in our sample. The nominal provincial poverty line was converted by the average price of paddy rice of PHP 6 per kg in 1997 to generate a poverty line of 1,585 kg of rice equivalents per person per year. We use this value as our absolute poverty line for all observed years.

Poverty Indices

The municipalities studied here are among the lowest income municipalities in the Philippines. Poverty indices of the three samples are presented in Table 2. Headcount ratios indicate a very high incidence of poverty in the study sites, particularly for the upland group. In 1997, the overall poverty incidence in the sample was 56 percent. This is about 24 percentage points higher than the province-wide poverty incidence of 32 percent reported by NSCB for the same year. The headcount ratios for the pooled sample exhibit a pattern of lower poverty incidence in the years following irrigation development. The poverty gaps per person also reveal a pattern of lower poverty depth in the years with irrigation development. This indicates that, overall, irrigation has likely reduced the incidence and extent of poverty in the study sites.

Focusing only on the lowland sample, the headcount ratios show that the poverty incidence was highest in the year with no irrigation. The post-irrigation years had lower incidences of poverty. In 1997, the headcount ratio for the lowland sample was 0.24, 0.08 percentage points lower than the provincial headcount ratio of 0.32. The poverty gap per person also decreased in 1997 to only 90 kg of rice equivalents—a seven-fold reduction from 1995's gap of 664 kg. This very low poverty gap for lowland households in 1997 largely reflects the confluence of irrigation and favorable growing conditions in the lowlands. In 1999,

Table 2. Poverty indices for the sample, 1995–2002

	1995	1997	1999	2002
All farms				
Headcount ratio (%)	88.5	56.4	80.2	79.5
Aggregate poverty gap*	797,977	571,462	880,340	1,754,816
Poverty gap per person*	1,011	530	907	958
Poverty gap ratio (%)	63.8	33.4	57.2	60.4
Income gap ratio (%)	72.1	59.2	71.3	76.0
Lowland farms				
Headcount ratio (%)	72.2	24.6	67.1	52.5
Aggregate poverty gap*	140,837	53,159	338,602	336,518
Poverty gap per person*	664	90	668	453
Poverty gap ratio (%)	41.9	5.7	42.1	28.6
Income gap ratio (%)	58.1	23.5	62.8	24.4
Upland farms				
Headcount ratio (%)	94.5	95.7	94.6	98.0
Aggregate poverty gap*	657,139	518,303	541,738	1,418,298
Poverty gap per person*	1,139	1,064	1,168	1,302
Poverty gap ratio (%)	71.9	67.1	73.7	82.2
Income gap ratio (%)	76.1	70.2	77.9	83.9

Note: * in kg of rice equivalents

a relatively unfavorable year for agriculture production in the lowlands, the lowland sample had a lower poverty incidence but a higher poverty depth. This can be traced to extremely low incomes in several lowland households. The poorest individuals in the sample fell very far below the poverty line, resulting in a poverty gap per capita of 668 kg of rice equivalents.

In terms of the upland sample, the headcount and poverty gap ratios do not show clear patterns of decreasing poverty incidence or poverty depth. In 1997, poverty incidence slightly increased while the poverty gap ratio slightly decreased. This scenario was reversed in 1999. Record high poverty incidence and poverty depth (98% and 82%, respectively) were recorded for 2002. This seems to indicate that the upland community, as a whole, has become worse off in absolute terms. Such a pattern is consistent with observations that upland farming is "unsustainable" with widespread nutrient mining, poor fertility management, and a general shortage of viable alternatives to traditional forms of cultivation.

Poverty Decomposition

To better understand how lowland irrigation might have impacted upland households, we turn now to poverty decomposition for the upland sample. The general poverty indices from the full upland sample do not reveal a strong pattern of poverty reduction. This would seem to suggest that the upland households did not benefit from irrigation development in the lowlands. However, decomposing upland poverty by labor force participation reveals a reduction in poverty share for the group with off-farm employment in the years following irrigation development. These decompositions are reported in Table 3. In general, the upland households with off-farm employment tend to be poorer than those without, largely because these households have extremely limited agricultural capacity to begin with, which precipitates their labor market participation. In 1995, the population share of 0.59 for upland individuals with off-farm work corresponded to a poverty share of 0.64 (using the squared poverty gap). However, in the years following irrigation development, particularly in 1997 and 1999, the poverty share measures were lower compared to the population shares. Only in 2002 (an agronomically unfavorable year in the uplands) was the poverty share slightly higher than the population share. In the post-irrigation years the poverty share for those with off-farm employment was consistently lower than for those without. Although households with off-farm work had smaller mean incomes than those without, the difference between the two groups in 2002 was not as large as in 1995. We conclude that, in an extremely harsh setting, those with off-farm work benefited from irrigation in the lowlands and tended to fare better in relative terms, than those without off-farm work.

Inequality Findings

Inequality Indices

Measures of income inequality in the sample are reported in Table 4. Inequality measures do not exhibit a consistent pattern of income distribution over time. The coefficients of variation, the Theil indices, and the mean log deviations for the pooled sample exhibit similar patterns suggesting that the overall income distribution narrowed between 1995 and 1997, almost remained constant between 1997 and 1999, and widened between 1999 and 2002. In contrast, the Gini coefficients for the pooled

Table 3. Poverty indices for upland farms, 1995–2002

	1995		1997		1999		2002	
	w/o off	**w/ off**	**w/o off**	**w/ off**	**w/o off**	**w/ off**	**w/o off**	**w/ off**
Mean income								
All farms	557	435	451	574	384	525	401	274
Poorest group	440	340	363	504	325	367	269	251
FGT Index								
Headcount	0.92	0.96	0.94	0.96	0.97	0.93	0.96	0.99
Poverty gap	0.67	0.75	0.72	0.66	0.78	0.71	0.80	0.83
Squared gap	0.53	0.63	0.59	0.49	0.65	0.59	0.70	0.72
Poverty share								
Headcount	0.40	0.60	0.22	0.78	0.38	0.62	0.27	0.73
Poverty gap	0.38	0.62	0.24	0.76	0.39	0.61	0.27	0.73
Squared gap	0.36	0.64	0.26	0.74	0.39	0.61	0.27	0.73
Poverty risk								
Headcount	0.98	1.02	0.98	1.01	1.03	0.98	0.98	1.01
Poverty gap	0.93	1.05	1.07	0.98	1.05	0.97	0.97	1.01
Squared gap	0.90	1.07	1.14	0.96	1.07	0.96	0.98	1.01
Population share	0.40	0.59	0.22	0.78	0.37	0.63	0.28	0.72

Table 4. Measures of income inequality in the sample, 1995–2002

	1995	**1997**	**1999**	**2002**	**All**
Pooled Lowland and Upland Sample					
Relative mean deviation	0.47	0.46	0.48	0.53	0.52
Coefficient of variation	1.62	1.46	1.53	1.80	1.82
Standard deviation of logs	1.23	1.35	1.39	1.55	1.50
Gini coefficient	0.62	0.62	0.64	0.68	0.68
Theil index (GE(a), a = 1)	0.74	0.69	0.72	0.89	0.88
Mean log deviation (GE(a), a = 0)	0.75	0.82	0.71	1.01	0.97
Number of households	157	214	203	333	907
Number of individuals	789	1,079	971	1,832	4,671
Lowland Sample					
Relative mean deviation	0.43	0.36	0.42	0.37	0.40
Coefficient of variation	1.26	1.02	1.28	1.17	1.28
Standard deviation of logs	1.13	0.85	1.10	0.96	1.09
Gini coefficient	0.57	0.46	0.58	0.51	0.55
Theil index (GE(a), a = 1)	0.58	0.38	0.57	0.47	0.54
Mean log deviation (GE(a), a = 0)	0.57	0.37	0.42	0.38	0.49
Number of households	36	112	104	134	386
Number of individuals	212	592	507	743	2,054
Upland Sample					
Relative mean deviation	0.42	0.31	0.41	0.44	0.41
Coefficient of variation	1.20	0.94	1.32	1.73	1.34
Standard deviation of logs	1.10	0.85	1.29	1.17	1.18
Gini coefficient	0.54	0.43	0.56	0.58	0.55
Theil index (GE(a), a = 1)	0.52	0.32	0.57	0.67	0.56
Mean log deviation (GE(a), a = 0)	0.57	0.34	0.66	0.66	0.61
Number of households	121	102	99	199	521
Number of individuals	577	487	464	1,089	2,617

sample were relatively stable over the sample period.[6] The Gini coefficients for the pooled sample remained the same between 1995 and 1997, increased by four percentage points in 1999, and increased by another four percentage points in 2002. Considering the available data, it would appear that during the transition from rainfed to irrigated conditions, the overall income distribution in the lowlands widened.

In the lowland and upland samples all income inequality measures exhibit similar, somewhat uneven patterns, suggesting a narrowing in income distribution following irrigation but a widening in 1999, in parallel with the full capacity operation of irrigation facilities. In the lowlands, the income distribution appeared narrower in 2002 than in 1995, while in the uplands, the income distribution was wider. We now turn to Gini decompositions to further understand these patterns.

Gini Decompositions

For the pooled sample, we decompose Gini coefficients by site. These are reported in the top panel of Table 5. For all the observed years, the average real income per capita in the lowlands was significantly higher than in the uplands. The statistical significance of this difference is higher during the favorable and average years compared to the rainfed and unfavorable years. Our Gini decomposition shows that, in 1995 and 1997, Gini coefficients were slightly larger in the lowlands than in the uplands. This pattern was reversed in 1999 and 2002 when Gini coefficients fell in the lowlands, suggesting irrigation may have narrowed the lowland income distribution.

The between-group component of the Gini coefficient measures the mean difference in real income per capita between the two groups. This component accounts for the highest share in the Gini coefficient in 1995, 1997, and 2002. From 47 percent in 1995, the percentage contribution of this component rose to 59 percent in 1997, fell to 43 percent in 1999, and rose again to 63 percent in 2002. In part, we believe underlying agronomic conditions drive these patterns: the relatively higher percentages in 1997 and 2002 indicate a widening income disparity between lowland and upland communities under favorable growing conditions.

The within-group component measures the contribution to income inequality within the two groups. The percentage contribution to the Gini coefficient of this component was close to the between group component in 1995, 1997, and 1999 but not in 2002. This indicates that, from 1995 to 1999, income inequality within the groups was fairly high, contributing a relatively high amount of inequality to the overall Gini coefficient. However, in 2002, the income gap between the lowland and upland individuals increased markedly. This might have contributed to the reduction in the percentage contribution of the within-group component of the Gini coefficient for the pooled sample.

The overlap components were high in 1995 and in 1999 (corresponding to the rainfed year and the year in which a prolonged drought adversely affected irrigation operation). This indicates that crop failures due to lack of irrigation and an unfavorable climatic condition pulled down incomes for a number of lowland individuals to the point where their income per capita was similar to or was even lower than that

6 Braun (1988), suggests the Gini coefficient exhibits greater stability over long periods of time than other inequality measures, largely because the Gini coefficient is more responsive to changes in income in the middle of the distribution than to changes in the tails of the distribution (Allison 1978).

Table 5. Gini decompositions for the sample

	1995		1997		1999		2002	
	Index	%	Index	%	Index	%	Index	%
By site, all farms								
Between-group component	0.29	46.6	0.36	59.0	0.26	43.2	0.43	63.1
Overlap component	0.07	11.2	0.00	0.5	0.07	11.8	0.03	3.8
Within-group component	0.26	42.2	0.25	40.5	0.27	44.9	0.22	33.0
Total Gini	0.62	100.0	0.62	100.0	0.60	100.0	0.67	100.0
Decomposed Gini								
Upland farms	0.54	0.43	0.56	0.58				
Lowland farms	0.56	0.46	0.52	0.49				
By farm size, lowland sample								
Between-group component	0.03	5.0	0.20	44.0	0.10	18.6	0.17	31.6
Overlap component	0.23	40.6	0.07	15.1	0.11	21.2	0.12	22.4
Within-group component	0.31	54.4	0.19	40.9	0.31	60.2	0.24	46.1
Total Gini	0.56	100.0	0.46	100.0	0.52	100.0	0.49	100
Decomposed Gini								
Small farms	0.65	0.35	0.50	0.43				
Large farms	0.50	0.45	0.47	0.49				
By employment status, upland sample								
Between-group component	0.06	11.1	0.04	9.0	0.07	12.5	0.08	14.2
Overlap component	0.21	39.2	0.11	25.7	0.18	32.7	0.20	34.1
Within-group component	0.27	49.7	0.28	65.4	0.31	54.9	0.30	51.7
Total Gini	0.54	100.0	0.43	100	0.56	100	0.58	100
Decomposed Gini								
With off-farm work	0.51	0.48	0.55	0.70				
No off-farm work	0.55	0.42	0.55	0.50				

of the upland individuals. On the other hand, during the favorable years 1997 and 2002, the overlap components were smaller. This might indicate that yield variability fell in the lowlands during the favorable growing conditions, thereby reducing the overlap in income per capita.

For the lowland sample, the Gini coefficient decompositions by landholding size are reported in the middle panel of Table 5. We assume, for reasons discussed at the outset, that large and small farms might be affected differently by irrigation development. The median farm size in the lowland sample, across all years, was 3 ha. A farm smaller than 3 ha is considered small while a farm that is 3 ha and above is considered large.

In contrast to the pooled sample, where the between-group component of the Gini coefficient often contributes the most to the total Gini coefficient, the within-group component of the lowland sample gave the highest percentage contribution to the Gini coefficient in 1995, 1999, and 2002. This indicates that within the small and large farm groups, income is significantly unequal. The between-group component in 1995 accounted for only 5 percent of the Gini coefficient, but this increased as much as eight-fold in the years following irrigation development. This might indicate that irrigation development enhanced income inequality between small and large farms.

Furthermore, this rise in inequality accompanied a reduction in the percentage contribution of the overlap component. Under rainfed conditions, the overlap component accounted for about 41 percent of the Gini coefficient, but this share fell to 15 percent, 21 percent, and 22 percent in 1997, 1999, and 2002, respectively.

The decomposed lowland Gini coefficients are lower for both large and small farms in the years following irrigation development. This indicates that, over time, irrigation development has improved, or at least not worsened, the income distribution for both large and small farms in the lowlands. Interestingly, lowland small farms had a relatively greater reduction in inequality than lowland large farms. In 1999 smaller farms seemed to be more adversely affected by the climatic disturbance, with this group's Gini coefficient rising to 0.50. The Gini coefficient for large farms increased slightly to 0.47. The analysis reveals that, in 2002 (considered a normal year, weather-wise), small lowland farms had a more equal distribution of income than large farms, perhaps because smaller farms are relatively easier to manage, leading to reduced yield variability.

Gini coefficient decompositions for the upland sample are reported in the lower panel of Table 5. Participation in off-farm work, over time, seems to have stabilized the upland income distribution. In 1995, the group with off-farm employment had slightly greater income inequality than those without employment. This scenario was reversed in 1997, when the group with off-farm work had less inequality. In 1999 (considered a favorable year for the uplands), the Gini coefficient for both groups increased to 0.55. But in 2002 (an unfavorable year in the uplands) the Gini coefficient of the group without off-farm income increased to 0.70 while those with off-farm work declined to 0.50. A possible explanation for this large inequality for those without off-farm income is that some of the households were able to specialize in generating income from other sources (e.g., making handicrafts or minor forest product extraction) while some were not able to diversify, and depended mainly on on-farm production.

The group with off-farm work had a significantly lower income, on average, but their income distribution was narrower. It seems that off-farm employment at a fixed wage provided them with much lower income risk. For this reason, income inequality for this group—while still high with a Gini coefficient of 0.50—was relatively lower than for the group without off-farm income.

The overall Gini coefficients for the upland sample (reported in Table 4) do not demonstrate clear patterns of change in inequality over time. However, results from a Gini decomposition by income source cast light on how irrigation development in the adjacent lowlands may have contributed to improved income distribution in the uplands. These decompositions are reported in Table 6. They indicate that among the four major sources of income in the uplands, the proportion of income from off-farm work contributes the least to income inequality. This is exhibited by the values of the concentration ratios of off-farm income. These are lowest in 1995, 1997, and 2002. The Gini decomposition by income source allows the calculation of the Gini coefficient for each source of income. Results in Table 6 show that the Gini coefficient for off-farm income declined from a high of 0.77 in 1995 to 0.50, 0.70, and 0.70 in 1997, 1999, and 2002, respectively. A possible reason for this decline is that irrigation development in the lowlands contributed to an increase in off-farm participation by upland households, allowing the entire sample to both increase the income share from off-farm work and increase

Table 6. Income inequality decomposition by income source, upland sample (1995–2002)

	Agricultural Production	Off-farm Employment	Forest Products	Other Sources	Total
1995 sample (n=121)					
Gini coefficient	0.56	0.77	0.86	0.85	0.54
Share in Gini coefficient	0.63	0.02	0.26	0.09	1.00
Concentration ratio (C_i)	0.52	0.24	0.65	0.64	---
Mean household income	1533	98	496	183	2310
Mean per capita income	357	26	136	46	565
Share in total income (w_i)	0.66	0.04	0.21	0.08	1.00
w_iC_i	0.34	0.01	0.14	0.05	0.54
1997 sample (n=102)					
Gini coefficient	0.59	0.50	0.76	0.88	0.43
Share in Gini coefficient	0.64	0.07	0.20	0.10	1.00
Concentration ratio (C_i)	0.52	0.18	0.39	0.49	---
Mean household income	1397	420	565	226	2608
Mean per capita income	334	120	141	47	642
Share in total income (w_i)	0.54	0.16	0.22	0.09	1.00
w_iC_i	0.28	0.03	0.09	0.04	0.43
1999 sample (n=99)					
Gini coefficient	0.61	0.70	0.83	0.98	0.56
Share in Gini coefficient	0.87	0.08	0.03	0.02	1.00
Concentration ratio (C_i)	0.61	0.34	0.26	0.80	---
Mean household income	1762	279	142	37	2219
Mean per capita income	408	79	38	10	534
Share in total income (w_i)	0.79	0.13	0.06	0.02	1.00
w_iC_i	0.49	0.04	0.02	0.01	0.56
2002 sample (n=199)					
Gini coefficient	0.63	0.70	0.87	1.00	0.58
Share in Gini coefficient	0.70	0.15	0.08	0.07	1.00
Concentration ratio (C_i)	0.61	0.44	0.54	0.93	---
Mean household income	1138	343	140	73	1694
Mean per capita income	261	78	32	58	430
Share in total income (w_i)	0.67	0.20	0.08	0.04	1.00
w_iC_i	0.41	0.09	0.04	0.04	0.58

mean real income from off-farm work (by a factor of three in the years following irrigation development).

Despite the large Gini coefficients for income from forest products and other sources in all the years, their respective shares in the overall Gini coefficient are always lower than that of agricultural income. This can be explained by their relatively small share in overall income. The ratio of off-farm work income to total income has at least tripled in the years following irrigation development. This contributes to its rising share in the overall Gini coefficient, although the magnitude of its contribution remains low compared to the contribution of agricultural production.

Income inequality measures for the upland sample, grouped by those with and without off-farm income are reported in Table 7. All inequality measures are higher in the without off-farm work sample. This indicates that off-farm income contributes to a reduction in income inequality in the uplands. The percentage point difference of the Gini coefficients between the two samples indicates that off-farm employment had already improved the income distribution, even prior to irrigation. In the years following irrigation development the role of off-farm income in reducing inequality increased in importance, and was sustained over time.

CONCLUSIONS AND POLICY IMPLICATIONS

Our findings point to two key patterns. The first is that lowland irrigation development contributed to poverty alleviation in the study communities. This is true, and largely unambiguous in the lowland community, where the poverty gap index fell from 42 percent in 1995 to 29 percent in 2002. The results therefore extend and confirm previous work on irrigation highlighting improvements in income distribution in beneficiary communities (Balisacan 2001; Hussain and Wijerathna

Table 7. Inequality measures for upland households without off-farm employment

	1995	1997	1999	2002	All Years
Upland farms with off-farm employment					
Relative mean deviation	0.42	0.31	0.41	0.44	0.41
Coefficient of variation	1.20	0.94	1.32	1.73	1.34
Standard deviation of logs	1.10	0.85	1.29	1.17	1.18
Gini coefficient	0.54	0.43	0.56	0.58	0.55
Theil index (GE(a), a=1)	0.52	0.32	0.57	0.67	0.56
Mean Log Deviation (GE(a), a=0)	0.57	0.34	0.66	0.66	0.61
Upland farms without off-farm employment					
Relative mean deviation	0.43	0.36	0.45	0.49	0.46
Coefficient of variation	1.23	1.07	1.48	2.08	1.51
Standard deviation of logs	1.15	1.08	1.48	1.32	1.34
Gini coefficient	0.56	0.50	0.60	0.64	0.60
Theil index (GE(a), a=1)	0.55	0.43	0.68	0.85	0.67
Mean Log Deviation (GE(a), a=0)	0.62	0.47	0.83	0.82	0.75
Percentage point difference of the Gini coefficients between the two samples (%)	2	7	4	6	5

2004; Hossain, Gascon, and Marciano 2000). It is worth pointing out, however, that we find support for the view that irrigation is poverty-reducing only during relatively favorable cropping conditions. During the least favorable cropping year observed, the poverty gap ratio was actually higher with irrigation than in the pre-irrigation period. This might indicate that lowland households faced greater income risk in the presence of irrigation, suggesting a need for a mechanism to help mitigate the consequences of a negative production shock, such as that which accompanied El Niño. Although lowland irrigation development did not uniformly contribute to poverty alleviation in the uplands, and overall income for upland households fell throughout the study period, real income from wages from off-farm work rose by roughly 57 percent, benefiting the upland households that participated in off-farm employment on lowland farms. Considering that irrigation development is mainly intended to benefit lowland farming communities, it is encouraging that some poverty-alleviating benefits of irrigation accrued to members of the adjacent upland community, in this case via off-farm employment.

Our second main finding is that irrigation had an ambiguous impact on income inequality in the study site. In the lowland farming community, inequality fell in conjunction with irrigation development. Irrigation helped to stabilize yields and this, in turn, tended to compress the income distribution in the lowlands. But lowland irrigation development occurred in parallel with an increase in income inequality in the adjacent upland communities, largely because those who took advantage of off-farm employment opportunities had substantially larger income gains. Added to this, of course, is that income inequality between the observed lowland and upland communities increased with irrigation development: both upland and lowland communities benefited from irrigation development, but the lowland community benefited far more.

To conclude, we find a pattern of falling poverty and somewhat moderating inequality in the study site. At the same time, evidence underscores the importance of off-farm work in reducing income inequality and poverty. Off-farm employment of upland households, in the long-run, may be a very important channel to help upland households glean the developmental benefits from irrigation development in the adjacent lowland communities. To secure these benefits, opportunities and incentives must be in place for upland households to participate in off-farm employment. Where low-skill labor is found in abundance, rural development projects must be designed to absorb labor. At the same time, parallel investments must be made in human capital, through improvements in health and education. This will ensure that those who might engage in off-farm employment can fully and fruitfully participate in the rural labor market.

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