Local Economy-wide Impact Evaluation of the Kalangala Oil Palm Project

Draft Final Report

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1. Introduction

In July 1998 Uganda's Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), in collaboration with the International Fund for Agricultural Development (IFAD), launched the Vegetable Oil Development Project (VODP). The Kalangala oil palm development project, which is part of VODP, represents a prototype for projects to increase income and improve livelihoods of poor rural households in geographic areas suitable for oil palm development. The project employs a vertically integrated processor-nucleus-estate-smallholder model. Planting of palms started in 2005, and harvests of palm fruit began approximately five years later.

Researchers from the University of California, Davis, collaborated with MAAIF, IFAD, the VODP team and the Kalangala Oil Palm Growers Trust (KOPGT) to document the economic impact of the oil palm project on Kalangala residents. Extensive surveys of households and businesses were conducted to construct a local-economy wide impact evaluation (LEWIE) model for the Kalangala economy. The model was used to simulate the impacts of changes in oil palm acreage, productivity, and prices on the welfare of palm farmers, palm workers, and other Kalangala residents; on non-palm production activities; and on employment. The LEWIE model was designed to uncover the indirect impacts of oil palm production, or spillovers, in Kalangala, as well as the distribution of impacts across households.

Oil palm development has both direct and indirect impacts on the livelihoods of Kalangala residents. Direct impacts consist mostly of increased income to farmers who participate in the project. Indirect impacts include the wages paid to workers on small-scale oil palm plantations, the nucleus estate, and the palm oil processor. They also include income spillovers to households that do not grow palm but benefit from an increase in the demand for goods and services in Kalangala. Markets transmit the impacts of oil palm development from palm farmers to other production activities and households.

Our simulations reveal that each additional acre of mature oil palm adds 2.2 million UGX annually to the Kalangala economy (1.9 million if we adjust for price inflation). Of this, 800,000 UGX goes to households that do not participate in oil palm production. An additional acre in oil palm creates 127 person-days of employment in Kalangala, 95.9 of which are in households that do not grow or work in oil palm. All sectors of the economy expand, with the exception of fishing. A 1% (108.7 acre) expansion in oil palm plantations raises total cash income in Kalangala by 242 million UGX and total real income by 210.1 million UGX. A 10% increase in oil palm productivity increases total cash income in Kalangala by nearly 5 billion UGX annually, with nearly half of the income gain going to non-oil-palm-producing households.

Our simulations reveal that the entire Kalangala economy is now vulnerable to oil palm price shocks. Market linkages magnify the impacts of both positive and negative price shocks. Positive price shocks stimulate production, employment, and incomes throughout Kalangala. Negative shocks, on the other hand, have a disproportionately large negative impact on local incomes. Both positive and negative price shocks affect employment much more in non-palm producing households than in palm farmer or palm worker households.

This analysis underlines the importance of using an economy-wide approach to evaluate the impacts of development programs. The relative geographical isolation of Kalangala District helps shape local-economy impacts of oil palm. Barriers to trade, including reliance on ferries and long transportation times, effectively trap a good proportion of the economic spillover effects of palm development in Kalangala. Virtually all wages paid and most household purchases are within the local economy of Kalangala. This helps explain why the impacts on total Kalangala income far exceed the direct benefits of the project.

The rest of this report is structured as follows: Section 2 provides background on the oil palm project in Kalangala and a description of the household and business surveys that were carried out to support this local economy-wide impact evaluation. Section 3 draws from survey data to present a statistical overview of Kalangala households, including socio-demographics, incomes, and expenditures. Section 4 focuses on oil palm growers in Kalangala, documenting differences between adopters and non-adopters and productivity and other challenges that farmers face. Section 5 uses retrospective data from the survey together with information on oil palm plantings to show the correlation between oil palm expansion and new business development in Kalangala. Section 6 describes the LEWIE methodology and model construction, and Section 7 presents the simulation results. We conclude with a discussion of some of the policy implications of our findings.

2. Project Site and Survey Design

Kalangala district is located in southern central Uganda and is comprised of a series of islands situated on Lake Victoria. The estimated population in 2016 was 56,900 individuals, with the vast majority of residents located on Bugala Island, the largest island accounting for 63.2 percent of total dry land in the district. Historically, the primary income-generating activities on the islands have consisted of fishing, tourism, and agriculture.

Since the inception of the oil palm project in 2005, in the form of a private-public partnership between the government of Uganda and BIDCO Uganda Limited (operating as Oil Palm Uganda Limited, or OPUL), cultivation of oil palm has steadily become a key economic activity within the district. Under the umbrella of the VDOP, promotion of oil palm production has been seen as a strategic effort to address high poverty rates and reduce Uganda’s dependency on oil imports by increasing domestic production. At the time of the survey, roughly 10,000 hectares of palm oil had been planted, with 6,500 hectares operated by OPUL in the form of a nucleus estate. The remaining 3,500 hectares belong to 1,800 individual smallholders whom sell their fresh fruit bunches (FFBs) to one of two local mills operated by OPUL.

As part of the project, the government of Uganda and IFAD established the KOPGT, which enables farmers to access credit; current loans total 13 million USD to smallholder growers. In addition to loans and extension services, KOPGT also acts as an intermediary between smallholders and OPUL by collecting FFBs from individual farmers and processing payments.

It is evident that the livelihoods of local residents have been transformed as a result of the oil palm project. While the number of smallholder growers is relatively small, oil palm production and processing activities provide jobs for more than 3,000 workers, including employment with plantations, mills, and refining. Previous surveys indicate that the largest source of income on Bugala Island was the sale of palm oil, at 30% of total income (MOA, 2017). In addition, the project has drastically improved transportation and utility services on Bugala Island, developing over 250 kilometers of roads and providing continuous electricity to the majority of villages.

2.1 Survey and Field Work Design

The LEWIE framework was the basis to design questionnaires for surveys of resident households, Oil Palm Uganda Ltd (OPUL) employee households, and business on the main Kalangala island of Bugala. Further information on the oil palm estate and mill was gathered from administrative records.

During the data collection process, the enumeration team visited 18 randomly selected villages over a course of 4 weeks, from a total of 39 villages. Two of the selected villages where then used as pre-test sites, with their information omitted from the finalized sample. From each randomly selected village, a maximum of 40 households were then randomly chosen from two lists, one of oil palm growers and one of non-growers. In the case where a village had fewer than 20 oil palm growing households, all oil palm households were approached for interviewing to ensure that a substantial number of oil-palm growing households appeared in our sample. In addition to business information captured within the household surveys, a supplementary business survey was administered; information was collected on sales, employment, and input purchases by business operation within and around villages. Business survey timing was staggered with that of the household survey to ensure no businesses were counted twice in our sample. Lacking a master list of businesses on Bugala Island, enumerators were instructed to survey all businesses which consented to the interview.[1] Administrative records from Kalangala Oil Palm Growers Trust (KOPGT) were merged with the survey data to obtain more detailed information regarding oil palm growers' sales and input usage.

The resulting sample contains 513 households, including 156 oil palm growers, 113 oil palm employee households and 244 non-oil palm growing residents. Combining businesses from the

[1] While a strategy of skipping every other business was initially implemented, this proved infeasible for collection of a substantial sample as villages often did not have enough businesses.

household survey and the separate business survey, we obtained a total sample of 284 individual business operations, capturing a wide range of entrepreneurial activities on Bugala Island.

3. Descriptive Statistics from Survey Data

Table 1 summarizes key household demographics for Kalangala residents and oil palm worker households. Local residents include palm and non-palm growers. Local residents, both oil palm growers and non-growers, actively participate in various production activities. Estate worker households tend to be employment oriented, working solely on the Nucleus Estate plantation.

3.1 Household Socio-demographics

Most of the Kalangala population (half of those in palm and non-palm households, 69% of those in palm worker households) was born outside of Kalangala. The majority of oil palm workers are migrants from other regions of Uganda (81.6%) and reside in dormitories provided by the estate. In comparison to residents, oil palm workers have smaller household sizes, younger heads of household and less dependents living under the same roof.[2] Estate worker households are relatively small, often only comprised of immediate family, and their heads of household are significantly better educated. One plausible explanation for the difference in household head education is the positive link between schooling and migration, well established in the development economics and migration literature (Taylor and Martin 2001). This results in a positive selection effect on educational attainment of estate workers.

Table 1. Household Socio-demographics

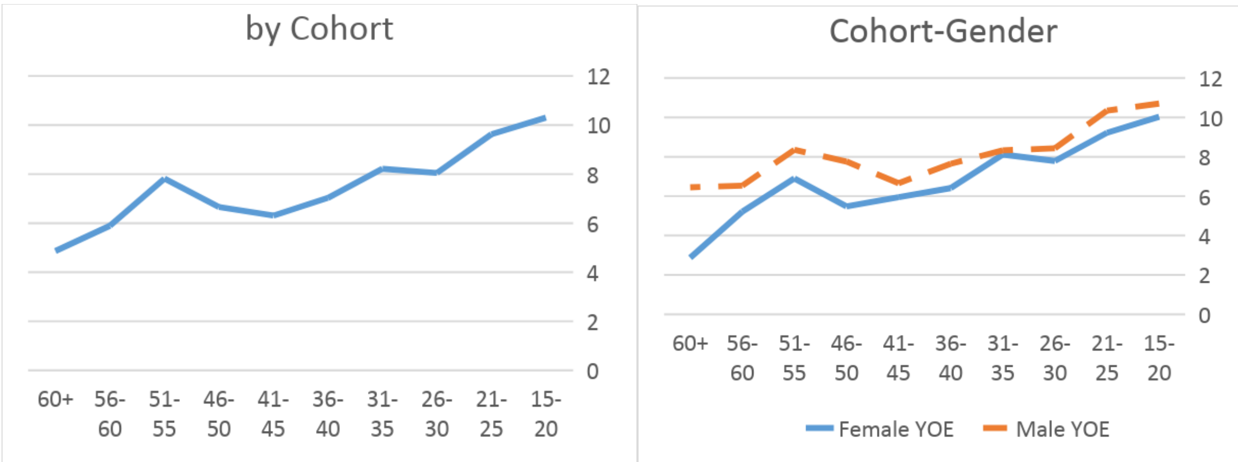
Statistic	Household Size	Share Born in Kalangala	Age		% female	Dependency Ratio	Education	
			Head of HH	Average		(<=16)	Head of HH	Average
	Palm and Non-palm Households							
Mean	4.38	0.5	41.3	21.1	0.51	0.4	7.5	6.4
Std. Dev	(2.44)	(0.50)	(12.6)	(16.6)	(0.5)	(0.26)	(4.4)	(4.6)
N	391	1713	391	1713	1713	391	391	1561
	Palm Worker Households							
Mean	2.87	0.31	33.1	21.1	0.43	0.24	8.9	6.9
Std. Dev	(2.18)	(0.46)	(10.9)	(14.5)	(0.5)	(0.26)	(4.1)	(4.5)
N	120	344	120	344	344	120	120	310

Source: 2017 Kalangala Survey

Looking at the educational attainment of local residents, we find that the average education level is higher for younger cohorts, indicating an increase over time of educational attainment for locals. Interestingly, we also observe a narrowing of the educational gap between male and female students over time. Figure 1 illustrates trends in educational attainment overall and

[2] In the survey we define individuals living under the same roof and eating together for at least 6 months in the past year as members of a household.

between males and females. The most recent cohorts (age 15-25) display a substantial increase in the average number of years of schooling (see figure on left). There is some evidence that the gender gap in educational attainment has narrowed over time; the average years of education for female residents is increasing at a higher rate than that of their male counterparts.



Source: 2017 Kalangala Survey

Figure 1. Educational attainment by age-cohort and age-gender-cohort

3.2 Household Expenditures

Using total annual expenditure as a measure of permanent income (or welfare), Table 2 below summarizes expenditure levels for the two household categories and the proportion of total expenditures made outside Kalangala. Despite demographic differences between long-term and estate worker households, per-capita expenditures of both groups easily exceed the average per-capita income of Uganda. Per-capita annual total expenditures are UGX 3.3 million (approximately 908 USD) for long-term residents and UGX 2.8 million (778 USD) for oil palm worker households. The average per-capita GDP for all Uganda was US $615.30 in 2016 (World Bank).

Table 2. Expenditures and Income

	Total Expenditure	Per Capita Expenditure	% Expenditure Outside Kalangala
	Palm and Non-palm Households		
Mean	11,000,000	3,270,000	0.18
Std Dev	15000000	5100000	0.21
N	391	391	391

	Palm Worker Households		
Mean	5,600,000	2,800,000	0.18
Std Dev	4990000	2900000	0.21
N	120	120	120

Source: 2017 Kalangala Survey

Due to geographical constraints, residents spend most of their money close to home: 82% of total household expenditures are on-island. This reflects convenience, subsistence production (we count home-produced food as an implicit expenditure), the importance of non-tradable goods (e.g., prepared meals) and services (e.g., construction and haircuts), and relatively high transaction costs in terms of money and time associated with purchasing off-island. A high on-island expenditure share contributes to larger local income spillovers as a larger proportion of increases to income/expenditure remains in Kalangala.

Table 3. Household Budget Shares by On-island Activity and Off-island

	On-island Expenditures, All Households					Off Island
	Agriculture	**Livestock**	**Fish**	**Retail**	**Non-ag**	
Mean	0.108	0.070	0.068	0.306	0.262	0.186
SD	0.103	0.081	0.096	0.181	0.166	N/A
	Palm and Non-palm Households					
Mean	0.095	0.072	0.065	0.308	0.275	0.185
SD	0.093	0.079	0.094	0.187	0.166	N/A
	Palm Worker Households					
Mean	0.150	0.065	0.075	0.301	0.224	0.186
SD	0.118	0.086	0.102	0.166	0.162	N/A

Source: 2017 Kalangala Survey

Table 3 provides a breakdown of household expenditures across island activities and off-island. The largest average budget shares are in retail purchases (0.31) and other non-agricultural activities, including services (0.26). Expenditure shares are fairly similar between residents and oil palm workers, with the exception that oil palm workers spend a slightly larger share of their budget on purchasing agricultural goods due to lacking the ability to consume from their own production.

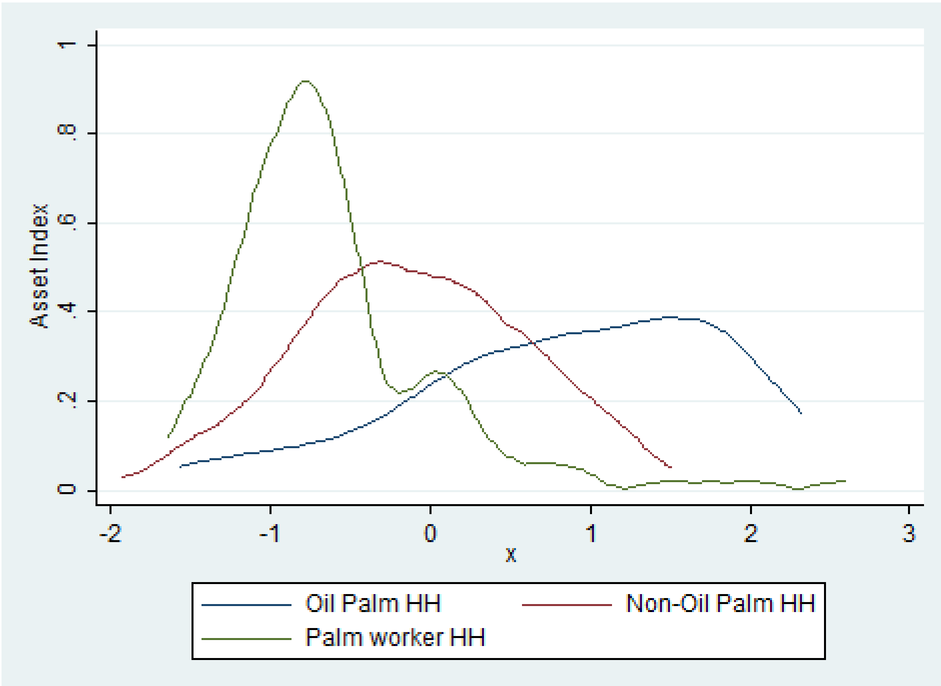


Figure 2. Asset Index by household category

As an alternative measure of overall household welfare, the survey collected information on household ownership of assets (bicycles, ratios etc.) to construct an asset index using principal component analysis. It is clear in Figure 2 that both the asset index and its variance are lowest for palm worker households, higher for non-palm producing households, and highest for palm households. Oil palm growers have, on average, the most durable assets, while oil palm worker households have the least durable assets. Landholdings were excluded from this index to avoid having it reflect differences in land requirements between oil palm and other crops.

3.3 Household Income and Production Activities

Kalangala households participate in a diversity of livelihood activities. Table 4 reports the shares of households in our sample which engaged in each of the six main income activities available in Kalangala: Oil palm, crop production, livestock production, fishing, wage work, and business activities. While just over 10% of households on Kalangala participate in oil-palm production, palm growers represent close to a third of households in our sample, due to our sampling strategy. Roughly two-thirds of resident households participate in agricultural production and livestock rearing. One in five fish or have local employment, and 40% of households have some form of business activity. All of these shares are considerably lower for oil palm workers, who tend to focus on employment at the mill. Unsurprisingly, oil palm worker households have little in the way of outside income and derive most of their income stream from wage work. Only 7% grow their own oil palm, 13% grow other crops, 15% have livestock, 3% fish and 9% run a business. In comparison, local residents have a substantially more diversified set of activities.

Table 4. Household Production and Income Activities

	Oil Palm	Agriculture	Livestock	Fishing	Wage work	Business
	Oil Palm Grower Households					
Mean	1	0.82	0.74	0.15	0.13	0.21
Std Dev	0	0.38	0.43	0.36	0.34	0.41
N	125	125	125	125	125	125
	Non-palm Households					
Mean	0	0.6	0.64	0.23	0.23	0.5
Std Dev	0	0.49	0.48	0.43	0.43	0.5
N	266	266	266	266	266	266
	Palm Worker Households					
Mean	0.07	0.13	0.15	0.03	1	0.09
Std Dev	0.25	0.33	0.36	0.16	0	0.29
N	120	120	120	120	120	120

Source: 2017 Kalangala Survey

Table 5 provides summary findings on agricultural production and income (excluding oil palm production), using data from the first growing season of 2017. The average (cultivatable) landholding of Kalangala households is small, around 1.36 acres, with the two primary staple crops of cassava and potatoes accounting for 55.3% of all cultivated area. The total value of agricultural output per household averaged 737,000 UGX, or 541,912 UGX per acre. Households on Kalangala partially consume their own output, but are not entirely subsistence, 41% of crops are sold onto local markets (by value). Fertilizer and pesticide usage tends to be low at 16% and 27%, respectively.

Table 5. Crop Activity and Income, Kalangala Residents (First season 2017)

	Landholding (acres)	Agricultural Output (in UGX)	Proportion Sold	Input Usage: Fertilizer	Input Usage: Pesticides	Input Usage: Hired Labor
Mean	1.36	737,000	0.41	0.16	0.27	0.14
Std Dev	(3.51)	(747,000)	(0.37)	(0.36)	(0.45)	(0.35)
N	391	218	211	218	218	218

Source: 2017 Kalangala Survey

2.

Livestock, fishing and employment also play an important role in the economic lives of Kalangala residents (Table 6a-6c). Sixty-two percent of all Kalangala residents own livestock, and these have an average herd value of UGX 1.66 million (US$ 460). Ninety-six percent of all livestock purchases are in Kalangala, and 73% are direct purchases from other households. The primary

Table 6a. Livestock Holdings and Transactions for Kalangala Residents (Annual 2017)

	Livestock Growers	Livestock Value*	Livestock Purchases^	
			% purchased on island	% from other HH's
Mean	0.62	1,657,000	0.96	0.73
Std Dev	(0.49)	2,600,000	(0.20)	(0.45)
N	391	242	144	144

** Livestock Value calculated for households with positive livestock holdings*

^Table only displays % on island and % from HH's conditional on a transaction occurring

Source: 2017 Kalangala Survey

Despite increased regulation on equipment and practices at the time of survey, fishing remains an important income generating activity for many residents. In recent years, several packing and shipping centers have opened in Kalangala, purchasing from local fisherman and exporting the catch, creating a relatively stable buyer for their output. Table 6B below summarizes key statistics for fisherman. Fishing is a lucrative (though risky) endeavor and is performed almost entirely by males. While the average monthly earnings are substantial, there is a lot of uncertainty in earnings due to the nature of the activity, the average fisherman makes just under 1.8 million UGX monthly, selling over 70% of their catch. Startup costs for fishing can be high as the average asset value of fishing equipment is over 17 million UGX, while nets and boats require constant maintenance, further adding to this cost.

Table 6b. Fishing Income and Assets

	Catch Value (Monthly, UGX)	Proportion Sold	Asset Value (UGX)
Mean	1,778,000	0.71	17,200,000
Std Dev	(4,700,000)	(0.28)	(70,000,000)
N	51	43	51

Source: 2017 Kalangala Survey

In addition to their current conditions, the survey also records retroactive recall data at the individual level for historical fishing activity, dating back to 2003 (prior to introduction of oil palm in Kalangala). Enumerators were instructed to guide recall for fishing activities in both the extensive (whether a fisherman did any commercial fishing in a given year) and intensive margin (whether a fisherman fished for more than 3 months commercially in that year). Figure 3 graphs the trends in fishing activity. The first vertical line indicates the year oil palm was introduced to the island (2005) and the second vertical line denotes when the palm groves began to bear fruit four years later.

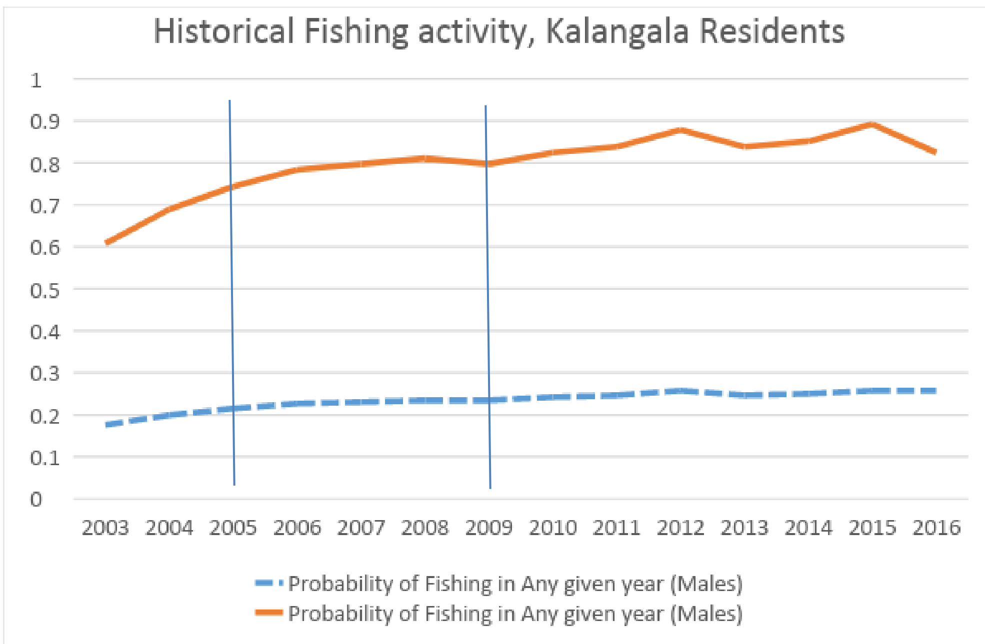


Figure 3. Kalangala Residents' Fishing Activity, 2003-2016

A statistical analysis of the correlation between fishing and oil palm cultivation indicates a 28.8% reduction in the likelihood of an individual participating in fishing activities once his or her household begins to harvest from oil palm groves (4 years after planting). Limitations to retroactive recall data include recall error, and a potentially selective sample, i.e., fishermen who switched over to other activities and left Kalangala are not captured in the survey.

Table 6c. Employment

	Months Worked	Net Income (Annual, UGX)	Wage (daily, UGX)
	Palm and Non-palm Households		
Mean	9.5	1,516,000	7552

Std Dev	(3.7)	(1,309,500)	(7132)
N	51	47	47
		Palm Worker Households	
Mean	10.7	2,046,000	8293
Std Dev	(2.7)	(1,203,000)	(4792)
N	121	120	120

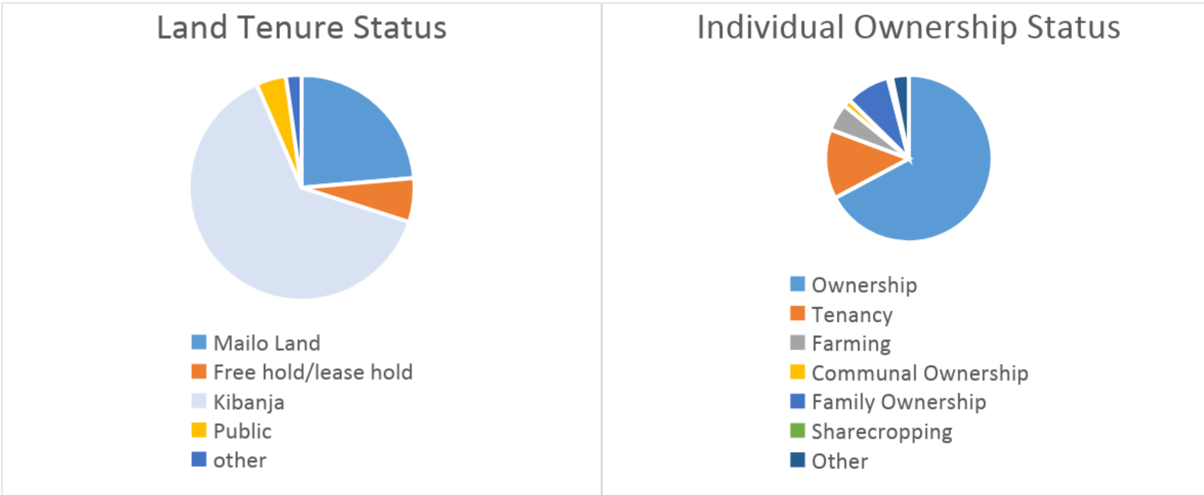
Source: 2017 Kalangala Survey

Wage employment opportunities are scarce in Kalangala (excluding odd jobs), and only around 20% of the population have some form of wage work. However, those who do find work tend to work full time, the average Kalangala resident who is employed works over 9 months out of the year. Daily wages are estimated to be around 7500 UGX per day for residents and 8300 UGX for oil palm workers.

4. Land and Oil Palm

There are two levels of land tenure status in Uganda, as illustrated in Figures 4a and 4b. The first (Figure 4a) concerns the status of the land itself: officially registered land owned by an individual or organization (Mailo and Freehold/Lease hold); tenant rights land (Kibanja); or publicly owned land. While Kibanja, or tenant rights, are technically informal, in practice tenancy on private land is secure, with owners having to offer compensation when evicting residents from their land.

A second level of tenure status (Figure 4b) concerns the ownership status of the individuals residing upon the land itself, and is broadly composed of mixed ownership (individual ownership, family/communal ownership) and rental, including sharecropping arrangements.



Figures 4a-b: Distributions of land tenure status and individual ownership status.
Source: 2017 Kalangala Survey

Table 7 summarizes land ownership and land in oil palm production. Sixty-nine percent of households own land, with an average holding of 3.51 acres. Thirty percent grow oil palm, with an average of 2.62 acres in oil palm. The variation in oil palm acreage is high, with a standard deviation (7.41) nearly three times the mean acreage.

Table 7. Land Ownership and Oil Palm Acreage in Sample

	Land Ownership	**Landholding (acres)**	**Fraction of Oil Palm Growers**	**Area in Oil Palm (acres)**
Mean	0.69	3.51	0.3	2.62
Std Dev	(0.46)	(8.22)	(0.46)	(7.41)
N	391	391	391	391

Source: 2017 Kalangala Survey

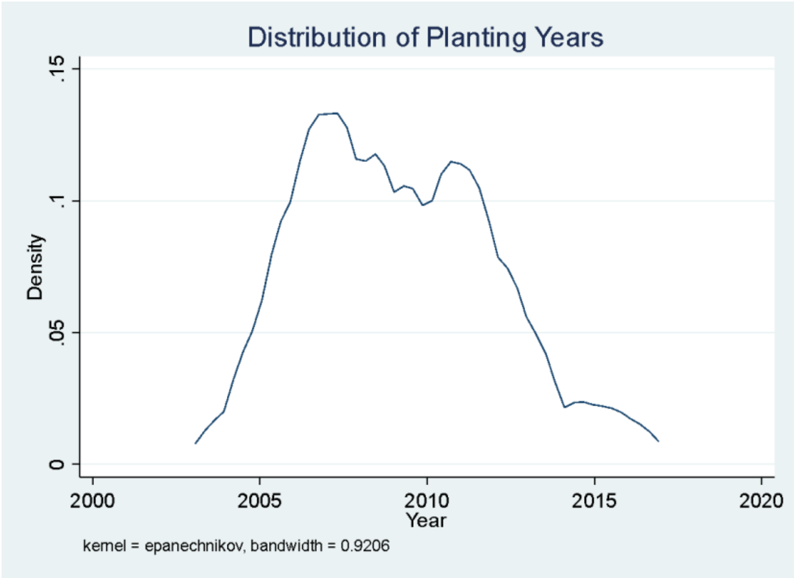


Figure 5. Year distribution of oil palm plantings.
Source: 2017 Kalangala Survey

Figure 5 shows the distribution of initial oil palm plantings. Almost none of the oil palm plantings predate 2004. Plantings rise sharply between 2004 and 2006, tapering off quickly after 2012.[3]

The average size of an oil palm plot is 5.58 acres (Table 8). It yielded an average of UGX 27,800 in output per acre over the three months prior to the survey, with a very high standard deviation (180,000). The average total sales value per oil palm farm was UGX 2.07 million over the three months prior to the survey. Twenty-three percent of the acreage in oil palm involves mixed cropping, usually with cassava. Most plots (73%) have fertilizer applied, and just under half (45%) are treated with pesticides. The high variance of yields, together with the finding that more than one-fourth of plots receive no fertilizer, suggest that there is room to increase productivity in oil palm.

Table 8. Oil Palm Summary Statistics (plot level)

	Size of plot (acres)	Yield per acre (UGX, last 3 months)	Percent lost	Sales Value	Mixed Cropping	Inputs (Share of Plots Using…)	
						Pesticide	Fertilizer

[3] According to Bennett et al. (2015), as of 2014 there are 1610 out growers producing on a total of 3,900 hectares of oil palm plantation. As of September 2017 there were just over 1800 out growers. Scaling up from the survey data we get approximately 4400 hectares in out-grower oil palm production.

Mean	5.58	27800	0.045	2,070,000	0.23	0.45	0.73
Std Dev	(7.63)	(180000)	(0.13)	(5,030,000)	(0.42)	(0.50)	(0.45)
N	159	144	143	159	162	162	162

Source: 2017 Kalangala Survey

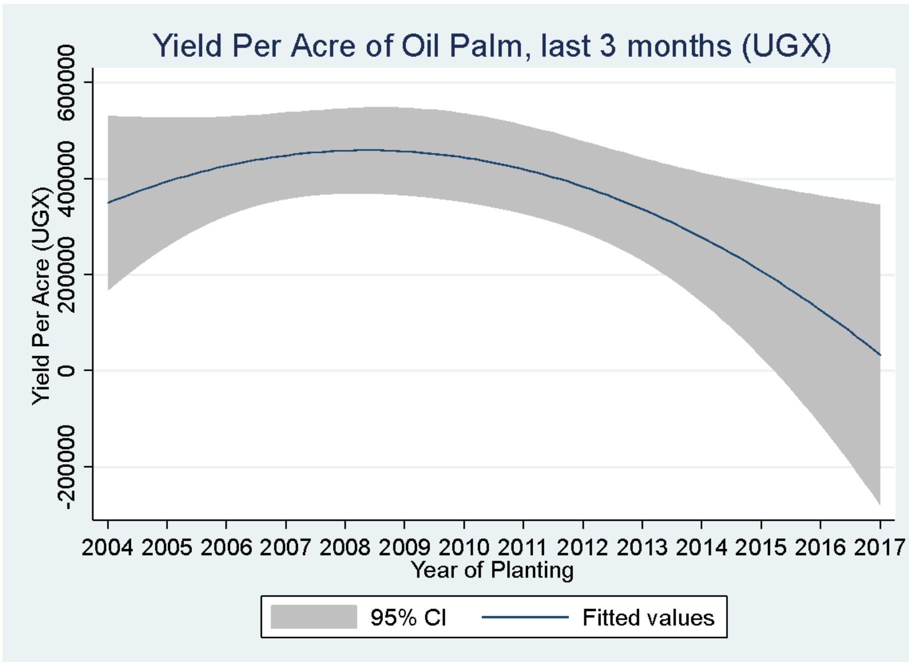


Figure 6. The survey data show an inverted-U shaped relationship between time since planting and yield per acre. Source: 2017 Kalangala Survey

Figure 6 shows that the oil palm fruit yield per acre displays a quadratic trend over time. In the first two years of planting (i.e., palm planted between 2015 and 2017), palm fields net no significant yields as seedlings are still growing. Over time (moving leftward in the figure), yields increase and reach a maximum level after roughly 8 years, when plants have reached maturity, at which point yields start to fall. In the figure, the highest yields observed in our 2017 survey were from palms planted around 2009. Yields are lower on palms planted prior to that.

We used the survey data to compare selected characteristics of oil palm adopters and non-adopters as well as early versus late adopters. The results appear in Tables 9a-b. The most striking differences are between oil palm adopters and non-adopters (Table 9a). Adopters have significantly larger average land area (7.3 acres for adopters, compared with 1.3 acres for all residents who are non-adopters and 2.3 acres if we limit the comparison group to land owners). Oil palm growers' average land area (Table 9a) is greater on average than the average size of oil palm plots (Table 8) inasmuch as some farmers grow palm on more than one plot. Oil palm farmers also have larger households, suggesting more labor availability (4.9 versus 4.1 members on average) and older household heads (46 versus 39 years of age, on average). These differences are all statistically significant at well above the 99% level. There are no significant differences in terms of household dependency ratios or the education or gender of household heads. Early adopters (those first planting oil palm in 2004-2008) have larger land holdings and are older than late adopters, who first planted after 2009 (Table 9b). There are no other significant differences between early and late adopters among the variables in the tables.

Table 9a. Comparison of Characteristics (Balance Test) between Oil Palm Adopters and Non-adopters

Balance test for Oil-palm vs non Oil-palm HH's (residents)

	Adopter	Non-Adopters	t-test
Land Area (acres) All residents	7.32 (0.59)	1.33 (0.31)	9.92***
Land Area (acres) Land owners*	7.32 (0.59)	2.34 (0.53)	6.86***
HH size	4.93 (0.24)	4.13 (0.14)	3.03***
Dependency Ratio	0.40 (0.02)	0.40 (0.02)	-0.11
HH Head Age	46.3 (1.3)	39.0 (0.7)	5.52***
HH Head Schooling	7.8 (0.4)	7.3 (0.3)	0.97
HH Head Female	0.25 (0.04)	0.26 (0.03)	-0.28

** Excludes all residents who did not own or operate land in past year*

Source: Analysis of 2017 Kalangala Survey data

Table 9b. Comparison of Characteristics (Balance Test) between Early Oil Palm Adopters (2004-2008) and Late (After 2009) Adopters

Balance test for early vs. late oil-palm adopting HH's (residents)

	Early (2004-2008)	Late (2009+)	t-test
Land Area (acres) All residents	9.32 (0.99)	6.40 (0.64)	2.49***
HH size	5.33 (0.39)	4.56 (0.31)	1.54
Dependency Ratio	0.39 (0.04)	0.40 (0.03)	-0.1

HH Head Age	51.0 (1.9)	41.6 (1.6)	3.86***
HH Head Educ	7.8 (0.7)	8.5 (0.5)	-0.82
HH Head Female	0.21 (0.05)	0.29 (0.06)	-0.96

Source: Analysis of 2017 Kalangala Survey data

Since there seem to be systematic differences in household characteristics between early and late adopters, regression analysis to examine the correlation between per acre yields and household characteristics are documented in Table 10 below.

Table 10. ln(Yield) and HH characteristics

Land Size	-0.04** (0.02)
HH Size	-0.01 (0.07)
HH Head Age	0.01 (0.01)
HH Head Educ	0.02 (0.03)
HH Head Female	-0.62** (0.31)
Dependency Ratio	0.27 (0.64)
Growing Experience	0.14** (0.06)

Robust SE’s in Parentheses, village dummies included

We find a slight negative relationship between total land size (in oil palm) and per acre yields, an inverse relationship well documented in the development economics literature. We find no correlation between yields and the educational attainment or age of the head of household. Having a female-headed household, however, does have a significant negative impact on predicted yields. This may be indicative of more vulnerable (e.g., widowed) household heads’ inability to summon the sufficient labor/capital resources to obtain higher yields on their oil palm crop. Finally, we find a positive relationship between the number of years of experience growing oil palm and yields.

4.1 Stochastic Frontier Analysis of Residents' Oil Palm production

To understand how efficiently farmers are cultivating oil palm, we conducted a stochastic frontier analysis (SFA) using the oil palm production function. By measuring how close each farmer's production is to the production frontier, we can gain insight into which farmers produce efficiently and which do not—and the factors shaping efficiency. In SFA, the residuals from a production function regression are transformed into a measure of production efficiency. We regressed this efficiency measure for each farmer on variables related to oil palm production and other income activities as well as a vector of household characteristics. The results are shown in the table below.

Larger households are more efficient in oil palm production. Farmers with older oil palm plantings are also more efficient. Households that engage in fishing or wage work are more efficient than those dedicating their time exclusively to palm production. This might reflect a higher opportunity cost of time for those with other income-earning possibilities. It might also reflect access to cash from occasional wage work or fishing that can be invested in raising palm productivity. However, households that engage in activities other than fishing or wage work, including competing household production activities, are generally less efficient. The negative relationship between dependency ratio and efficiency reflects a tradeoff in allocation of time spent caring for household members versus time improving productive efficiency.

Table 10. Determinants of Oil palm production efficiency

VARIABLES	Dep. Var. = efficiency
HH size	0.023*
	(0.013)
Age of oil palm on plot (years)	0.031**
	(0.012)
HH fishes or engages in wage work	0.150**
	(0.065)
Share of oil palm in total income	0.169
	(0.102)
HH activity diversity	-0.070**
	(0.034)
Total land under oil palm	0.001
	(0.003)
Dependency ratio	-0.209*
	(0.118)
Observations	115
R-squared	0.198

Robust standard errors in parentheses

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

5. Business Formation and Its Correlation with Oil Palm Expansion

The rate of new business formation provides a vivid illustration of economic growth in the wake of oil palm expansion in Kalangala. Business operations are ubiquitous on Kalangala. Of the resident households who grow oil palm, 20% also operate at least one small business in Kalangala, and that figure is higher, 50%, for non-palm growers.

Table 11. Small Business Summary Statistics

	Age of Business	Months Operated	Asset Value (UGX)	Rental	Revenue	Profit
Mean	5.2	10.3	10,500,000	0.41	2,917,000	974,000
Std Dev	(5.5)	(3.0)	(30,400,000)	(0.49)	(11,000,000)	(5,339,000)
N	269	275	274	279	272	269

Table 11 summarizes characteristics of businesses interviewed in our household and business surveys.[4] The average age of businesses within our sample is 5.2 years, and the average number of months the business is in operation stands at 10.3 months. Businesses in our sample tend to hold a substantial amount of assets—just over 10 million UGX—and just over 40% of businesses pay rent to local land/property owners. In a typical month, the average business brings in close to 3 million UGX in revenue and just under 1 million UGX in profits.

Figure 7 shows the distribution of Kalangala businesses by startup year. Few businesses were set up prior to the oil palm project, but business formation increased steeply after 2007 and especially after 2010. More than 40% of businesses in Kalangala were initiated after 2012, with the highest percentage (22%) starting up in 2016. Part of this increase could be an artifact of high failure rates in the first few years of new businesses. We do not have information on business failure rates, and it is impossible to rule out this possibility without having matched panel data on businesses. Nevertheless, the trend in Figure 7 is consistent with an expansion in economic activity in the wake of oil palm development.

[4] The same business module was used in the business survey and in surveying households that reported having a business. The distribution of business assets is log normal, so large standard deviations reported in the table are a result of long right tails in the (non logged) distribution.

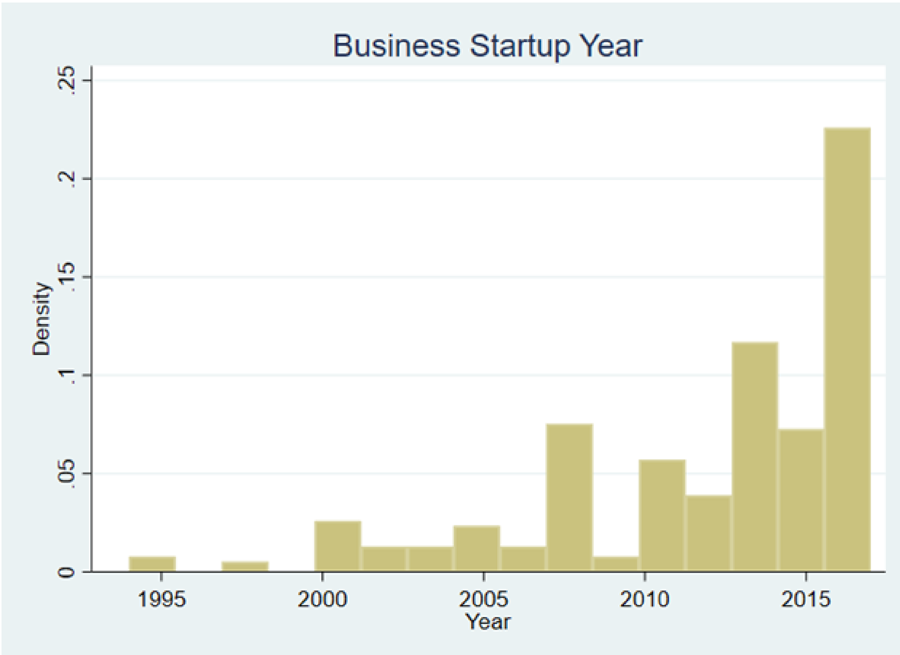


Figure 7. Kalangala Business Formation, by Startup Year
Source: 2017 Kalangala Survey

Figure 8 shows trends in both new business formation and the cumulative acreage in oil palm in our sample. Total oil palm acreage is nil prior to 2004, after which it rises gradually and then jumps sharply to 560 acres in 2010. The expansion tapers off after 2010, topping out at just under 785 acres at the time of the survey in 2017. The rate of new business creation in the sample is less than 10 per year prior to the start of the oil palm development program, but it increases sharply after that, rising to 49 in 2016, the year prior to the survey. The patterns in this figure are consistent with oil palm development providing a catalyst for new business development in Kalangala. The continuation of new business formation even after oil palm expansion tapers off suggests that this new activity may have set in motion a self-sustaining business development dynamic.

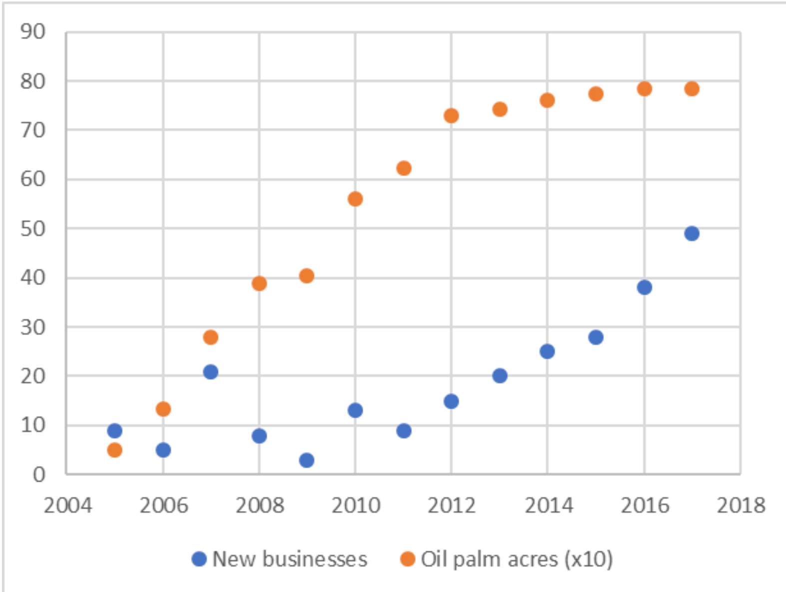


Figure 8. New business formation increases with acreage in oil palm.

We used an autoregressive distributed lag model to estimate the correlation between new business development and mature oil palm acreage (that is, acreage in plantations 5 or more years old). The results (not shown) reveal that, other things being equal, a 100-acre increase in mature oil palm plantations is associated with the creation of 1.2 new businesses in Kalangala ($t = 2.78$). Controlling for mature palm acreage, there is not a significant relationship between new business development at times t and $t-1$. Total palm acreage (including plantations that do not yet yield fruit) does not have a statistically significant relationship with new business development—only mature palm acreage does. It appears that, in order to simulate business growth, plantations have to be of productive age—just as one would expect.

6. Local Economy-wide Impact Evaluation

The high correlation between oil palm acreage and new business formation in Kalangala suggests that indirect effects, or spillovers, should be taken into account when evaluating project benefits. Quantifying spillovers requires a local general-equilibrium perspective. In theory, experiments could be designed to estimate income and production spillovers from development interventions. However, it is not possible to do this for the Kalangala oil palm project, because there is no randomized treatment or control group for both beneficiaries and non-beneficiaries. Moreover, experiments provide reduced-form estimates of impacts. A structural approach is needed if one goal of this evaluation is to inform the design of complementary interventions to enhance project impacts (or counteract possible adverse impacts).

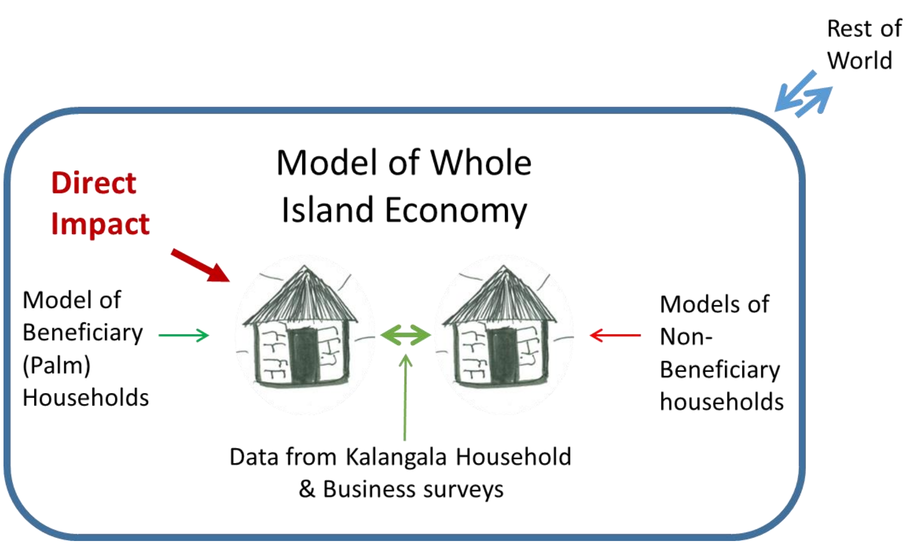
Local economy-wide impact evaluation (LEWIE) offers a viable alternative by simulating project impacts on incomes and welfare of project beneficiaries as well as non-beneficiaries, local production activities, employment, and other outcomes of interest and construct confidence intervals around simulated impacts. LEWIE models are constructed from an econometric analysis of micro-survey data. In Kalangala, where the required microdata do not currently exist, this required carrying out surveys of a random sample of households and businesses.

6.1 LEWIE Methodology

The Kalangala oil palm LEWIE was designed to evaluate the impact of oil-palm production on incomes, welfare, and production activities of project beneficiaries (the oil palm farmer households) as well as non-beneficiaries in the district of Kalangala. The design of the Kalangala oil palm LEWIE is based on the general LEWIE modelling approach in Taylor and Filipski (2014).

Figure 9 illustrates how the LEWIE model was constructed using micro-data from surveys. First, we carried out econometric analysis of the survey data to construct separate models of project beneficiary households (i.e., the palm-growing households directly "treated" by the project) and non-beneficiary households (non-palm-growing households). Non-beneficiaries are not to be confused with control households in a conventional experiment. In an experimental analysis, control households, like beneficiaries, are eligible for the treatment, but they do not receive it because they reside in control sites. In our analysis, the non-beneficiaries are part of the island economy treated by the project, but they are ineligible to receive the treatment because they are not (or have not become) palm growers. We draw from a rich tradition in development economics of using survey data to construct agricultural household models (e.g., see Singh, Squire and Strauss, 1986, and Taylor and Adelman, 2003).

Figure 9. Illustration of LEWIE Model



Once we construct separate models of beneficiary and non-beneficiary households, we combine them into a model of the whole Kalangala economy. For this, we draw from another rich tradition in development economics—applied general-equilibrium (GE) modeling. Computable general equilibrium models usually are built for country economies using aggregate data. LEWIE is unique in using GE methods to integrate micro household models into models of local economies, in the present case, the Kalangala LEWIE model.

6.2 Household and Activity Taxonomies

A practical household and activity taxonomy is needed in order to carry out simulations and compare outcomes across beneficiary and non-beneficiary household groups as well as across production activities. Groupings should reflect the characteristics of households and activities as well as the priorities of the evaluation. Project impact evaluation requires at least two groups: the treated group (in the present case, the palm growers who are beneficiaries of the project) and the non-treated group (households that do not grow palm and de facto are ineligible for the program). In practice, the LEWIE model may include multiple treated as well as non-treated household groups and many different production activities. However, there must be sufficient data to estimate production and expenditure parameters for each group.

Our household taxonomy for the LEWIE model includes three household groups: oil palm cultivating households, palm worker households, and all other households in Kalangala. The LEWIE methodology requires defining production activities in ways that are likely to reflect similar production technologies and/or interests of the study. Each household group may participate in one or more of these production activities, and it also may purchase output (or implicitly purchase output from itself, in the case of subsistence production) from each of the activities. Our classification reflects the oil palm focus of the study. The activities include oil palm, other crop activities, livestock production, fishing, retail, and other non-crop activities. Non-crop activities include services and non-crop production, including food processing. The nucleus estate and mill play a central role in the Kalangala economy as well as in the oil palm project. We give each its own production activity account in the model. The nucleus estate produces oil palm fruit, hiring labor from households on the Bugala Island and making other expenditures that may create linkages in the local economy. The mill processes fruit from the estate plantation as well as fruit purchased from small farmers who are beneficiaries of the project, sending the crude oil off-island.

6.3 Estimation of Model Parameters

We estimated the model parameters econometrically, using microdata from our surveys of households and businesses in Kalangala. Econometric estimation always requires making some assumptions about functional forms. Cobb-Douglas production functions are by far the most widely used in economics to represent technological relationships between inputs and outputs. They allow for nonlinearities, including diminishing marginal returns to inputs, and they can be estimated with the data from our household and business surveys.

Table 12 reports the production function estimates. The parameter on each factor represents the elasticity of output with respect to the factor. This elasticity is also the factor's share in the activity's total value-added. Labor value-added shares range from 0.14 (crops, retail, and other production) to 0.56 in small-scale livestock activities. The highest capital share (0.27) is in the production of livestock and livestock products (it corresponds to the animal stock itself). Land value-added shares are high in oil palm (0.54) and other crops (0.77). Purchased input shares in value-added are high for retail (0.68) and non-agricultural production (0.72) but relatively low in agricultural and livestock production.

Table 12. Cobb-Douglas Production Function Estimates by Activity

	Agricultural Production			**Fishing**	**Business**	
	Oil Palm	**Crops**	**Livestock**		**Retail**	**Other**
Labor	0.41	0.14	0.56	0.33	0.14	0.14
se	(0.17)	(0.05)	(0.08)	(0.10)	(0.08)	(0.05)
Land	0.54	0.77	0.07	0.67	-	-
se	(0.16)	(0.05)	(0.03)	(0.10)	-	-
Inputs	0.05	0.10	0.10	-	0.68	0.72
se	(0.03)	(0.03)	(0.05)	-	(0.10)	(0.07)
Capital	-	-	0.27	-	0.17	0.14
se	-	-	(0.06)	-	(0.07)	(0.08)
Constant	2.5	11.5	7.7	1.7	7.0	8.0
se	(1.9)	(0.35)	(0.78)	(1.17)	(1.08)	(0.89)
N	98	129	248	53	114	129

Note: All variables transformed using inverse hyperbolic sine (ln(x)=ln(x+(x^2+1)^0.5), which makes it possible to include activities with zero use of some inputs), White's Robust standard errors in parantheses. Labor, Input and Capital are measured in value (UGX), land in acres. Regressions constrained to have constant returns to scale.

The linkages created by production activities in Kalangala depend on the production functions as well as on whether inputs are purchased on- or off-island. Table 13 summarizes the shares of inputs each activity purchases on and off of Kalangala. The first row in this table shows that the on-island input demand relative to total revenue is highest for livestock (0.65) and non-agricultural activities (excluding retail; 0.60). It is slightly lower (0.53) in agriculture, reflecting the demand for fertilizer, seed, and other intermediate inputs purchased off-island. It is lowest (0.46) for retail, because most of the goods on Kalangala's store shelves come from off-island sources. Fishing uses almost no purchased inputs from off island, so its local input share (not shown) is close to 1.0.

Table 13: On-and Off-island Input Purchases as Share of Activity Gross Revenues

Input shares	**Ag**	**Livestock**	**Retail**	**Non-ag**

On-island	mean	0.528	0.650	0.461	0.601
	sd	0.374	0.317	0.352	0.382
Off-island	mean	0.472	0.350	0.539	0.399
	sd	0.374	0.317	0.352	0.382

On the consumption side, we assume linear expenditure functions without subsistence minima, implying Cobb-Douglas utility. We estimated a separate system of demand equations for each household group, yielding the group-specific marginal budget shares shown in Table 3 and discussed earlier. Table 3 shows that the households spend the largest share of their marginal income on retail and other non-agricultural activities, followed by crops, livestock, and fishing. More than 80% of household expenditures are in Kalangala.

Estimating income spillovers from palm production is a key objective of the LEWIE analysis. Income spillovers depend not only on the share of income spent in Kalangala, but also on which goods and services households spend their income on, as well as where these activities, in turn, obtain inputs. Real income multipliers also depend on the local supply response to increases in demand, which influences prices and thus the purchasing power of cash in Kalangala. The more elastic the response, the larger the real-income impact, and the smaller the inflationary impact. If households' budget share on goods and services from a given activity—say, retail—is large, but the activity spends a large share of its revenue on inputs obtained off-island, the impact on island income might be limited. On the other hand, large budget shares combined with high on-island activity input shares can translate into large island income multipliers.

Supply elasticities depend, in part, on the elasticity of factor input supplies. Labor is an important input for all activities. Very few reliable estimates of labor supply elasticities exist in the development economics literature, and these elasticities are not estimable from cross-section data. We assume an elastic labor supply in Kalangala. We believe this assumption is justified for two reasons. First, the Kalangala economy, like that of the rest of Uganda, is characterized by high unemployment. This implies that additional workers can readily be induced to supply their labor as the labor demand expands. Second, most of the population on Bugala Island was born outside of Kalangala. This implies a very open demographic system that can readily bring new workers to the island as the demand for labor increases. A high labor-supply elasticity keeps wage increases in check as the local demand for labor rises. The Kalangala labor market adjusts to changes in labor demand via the supply of workers rather than through wage changes.

7. Simulations and Results

The model was used to simulate the Kalangala economy-wide impacts of: (1) an additional acre in oil palm production; (2) a 1% increase in land in oil palm production; (3) – (4) a 1% increase and 1% decrease, respectively, in the farmgate price per FFB of oil palm fruit; and (5) a 10% increase in total factor productivity in oil palm production. Table 14 reports impacts on total nominal (cash) and real income (the Kalangala GDP), the income of each household group (including households that do not grow oil palm), and total sales in each Kalangala production activity. For simulations (2) – (5), Table 15 presents average per-household impacts.[5] The simulation results appear in Columns (1) – (5) in Table 14 and (2) – (5) in Table 15. In both tables, the top panel describes the simulation. In Table 14, the second panel reports impacts on total income, the third, impacts on income by household group, and the bottom panel, impacts on production and employment. All impacts are in millions of UGX, except for employment, which is in person-days. Standard errors generated using the Monte Carlo method in Taylor and Filipski (2014) appear in parentheses underneath total income impacts.

7.1. Impact of Additional Acreage in Oil Palm

Columns (1) and (2) report impacts of an additional acre and a 1% increase in acreage of mature (fruit-bearing) oil palm. The direct impact of increasing acreage in oil palm is to increase production of oil palm fruit; a 1-acre expansion increases the value of oil palm output by 1.77 million UGX annually (see bottom panel of Table 14). This creates new income for palm-cultivating households while increasing the demand for labor and other inputs. Employment in oil palm rises by approximately 31 additional worker-days (13 in palm-cultivating households and 18 in oil palm worker households; see bottom panel of Table 14). Higher wage labor demand transmits impacts to wage labourer households. Rising income in palm-producer and wage labourer households stimulates the local demand for goods and services, as these households spend their cash. Production to satisfy this demand creates new demand for labor and other inputs across the spectrum of production activities, and this unleashes multiple new rounds of income, demand, and production gains, creating production and income spillovers.

Once this process settles down into a new equilibrium, all production sectors in Kalangala expand as a result of the new acreage in oil palm. The largest production impact is on the retail sector, whose sales increase by 660,000 UGX. This is not surprising given the large share of household budgets spent on retail (see Table 3). Other non-agricultural production also expands significantly (by 490,000 UGX). Kalangala's agricultural and livestock output rise by 70,000 UGX each. Fish output drops slightly, as fishing (a declining activity, given overfishing of Lake Victoria) must compete with other activities for inputs, particularly labor.

Total wage income in Kalangala rises by 960,000 UGX, which translates into approximately 127 worker-days at the prevailing wage of 7552 UGX per day. Most of this total employment impact (96 worker days) is in households that do not produce oil palm.

The additional acre in oil palm increases total Kalangala income by considerably more than the increase in value of oil palm production. Cash income increases by 2.23 million UGX per additional acre in mature oil palm plantings. Higher demand has a slight inflationary effect, reducing the purchasing power of cash in Kalangala. Adjusting for inflation, the increase in total real income is 1.93 million UGX.

[5] We do not report average per-household impacts of simulation (1), because the impact of an additional acre in oil palm, spread across the island's 16,791 households, logically is small.

Table 14. Kalangala Oil Palm LEWIE Simulation Results: Total Kalangala Impacts

	Impacts on Total Income (Annual in million UGX)				
	(1)	(2)	(3)	(4)	(5)
	Increasing Oil Palm land by 1 acre	**Increasing Oil Palm land by 1% of total acreage**	**Price of Oil Palm FFB rises by 1%**	**Price of Oil Palm FFB drops by 1%**	**TFP goes up by 10%**
Description of Simulated Impact	Land area in mature oil palm increases by 0.89 million UGX, the monetized value of an acre (in rental rates, annual)	Land area in mature oil palm increases by 1% (108.7 acres, monetized value = 97.14 million UGX)	Farmgate price of oil palm fruit increases by 1%	Farmgate price of oil palm fruit decreases by 1%	Total factor productivity in oil palm increases by 10%
Change in Total Island Income					
Nominal Income (Cash)	2.23	242.05	472.20	-466.73	4,975.49
Real Income (Kalangala Island GDP)	1.93	210.16	409.94	-405.43	4,307.07
Standard Error	(0.59)	(63.65)	(126.66)	(120.49)	(1,593.50)
Confidence Interval: 5% Lower Bound	1.30	141.19	274.33	-594.79	2,785.82
Confidence Interval: 5% Upper Bound	2.85	309.58	606.39	-273.36	6,600.83
Change in Household Incomes (Real)					
Oil Palm	1.02	110.36	215.10	-213.10	2,241.62
Standard Error	(.06)	(7.02)	(14.46)	(12.83)	(228.22)
Non-Oil Palm	.80	87.49	170.81	-168.61	1,810.84
Standard Error	(.45)	(48.71)	(96.51)	(92.58)	(1,176.51)
Opul Worker	.11	12.31	24.03	-23.72	254.61
Standard Error	(.07)	(7.96)	(15.75)	(15.15)	(189.48)
Production Effects (In Monetary Value)					
Local Crops	.07	7.81	15.22	-15.09	158.11
Standard Error	(.02)	(2.43)	(4.82)	(4.64)	(57.45)
Local Meat	.07	7.42	14.48	-14.31	152.53
Standard Error	(.03)	(3.03)	(6.00)	(5.76)	(72.24)
Fish	-.01	-.93	-1.82	1.80	-18.95
Standard Error	(.00)	(.54)	(1.06)	(1.03)	(12.09)
Oil Palm	1.77	192.73	185.73	-185.10	3,960.58
Standard Error	(.53)	(57.93)	(114.19)	(110.63)	(1,464.99)
Local Retail	.66	72.20	140.84	-139.28	1,480.19
Standard Error	(.20)	(21.42)	(42.62)	(40.53)	(538.06)
Local Services	.49	53.67	104.72	-103.51	1,102.94
Standard Error	(.18)	(19.19)	(38.09)	(36.40)	(470.39)
Employment (Person-days)					
All households	127.06	13,815.11	26,973.94	-26,618.67	286,378.27
Standard Error	(74.15)	(8,036.61)	(15,921.61)	(15,271.45)	(194,580.24)
Oil Palm	13.06	1,407.08	2,747.32	-2,711.14	29,166.51
Standard Error	(7.94)	(818.53)	(1,622.09)	(1,555.88)	(19,817.27)
Non-Oil Palm	95.87	10,456.46	20,416.18	-20,147.27	216,759.34
Standard Error	(55.61)	(6,082.80)	(12,051.11)	(11,558.53)	(147,277.54)
Opul Worker	18.13	1,951.57	3,810.44	-3,760.26	40,452.42
Standard Error	(10.59)	(1,135.28)	(2,248.41)	(2,157.04)	(27,485.43)

Source: Kalangala LEWIE Simulations

Not surprisingly, the largest income gain goes to the palm-producing households. They benefit both directly, by cultivating slightly more land, and indirectly, by receiving some of the income spillovers resulting from increased economic activity in Kalangala. (For example, some palm-producing households have members who own non-palm businesses or work for others who do.) Their real income rises by 1.02 million UGX per additional acre in palm. Nevertheless, real income in households that do not cultivate palm increases by 800,000, and oil palm worker household incomes increase by 110,000. These numbers reflect the considerable income spillovers that oil palm production creates in Kalangala.

A 1% increase in mature oil palm acreage (simulation 2) has impacts that are similar to those from the 1-acre increase, but they are scaled up considerably. (A 1% increase is equivalent to 108.7 additional acres in mature oil palm.) Total real income in Kalangala rises by 210 million UGX. Table 15 reveals that the 1% expansion in oil palm increases household income in Kalangala by an average of 14,415 UGX (cash) and 12,516 (real). (The average household income effects in Table 15 are the total income effects spread evenly across Bugala Island's 16,791 households.)

Table 15. Kalangala Oil Palm LEWIE Simulation Results: Average Per-household Impacts

	Per-household Income Impacts (Annual in UGX)			
	(2) **Land in mature Oil Palm increases by 1%**	**(3)** **Price of Oil Palm FFB rises by 1%**	**(4)** **Price of Oil Palm FFB drops by 1%**	**(5)** **TFP goes up by 10%**
Description of Simulated Impact	Land area in mature oil palm increases by 1% (108.7 acres, monetized value = 97.14 million UGX)	Farmgate price of oil palm fruit increases by 1%	Farmgate price of oil palm fruit decreases by 1%	Total factor productivity in oil palm increases by 10%
Change in Total Income Per Household				
All Households, Nominal (Cash)	14,415.19	28,122.29	-27,796.60	296,318.60
All Households, Real	12,516.37	24,414.55	-24,145.86	256,510.81
Real Income Change By Household Group				
Oil Palm	61,311.32	119,499.89	-118,389.08	1,245,344.01
Standard Error	(3,899.85)	(8,033.33)	(7,127.78)	(126,788.89)
Non-Oil Palm	6,734.98	13,148.60	-12,978.96	139,392.16
Standard Error	(3,749.52)	(7,428.99)	(7,126.47)	(90,563.47)
Opul Worker	6,153.93	12,015.72	-11,861.55	127,305.11
Standard Error	(3,979.61)	(7,875.00)	(7,575.00)	(94,740.00)

Source: Kalangala LEWIE Simulations

7.2 Impacts of Oil Palm Price Shocks

While generating income for Kalangala households, oil palm production exposes producers as well as the Kalangala economy as a whole to swings in market prices for oil palm fruit. Market linkages transmit the impacts of palm-fruit price shocks throughout the Kalangala economy. They magnify the benefits from positive price shocks, but also the adverse effects of negative shocks. They are considerably larger than the impacts of a 1-acre increase in palm area, because a change in the farmgate FFB price affects the profitability of every acre in oil palm in Kalangala.

The FFB price change directly affects palm producers. As their incomes change, so do their expenditures on goods and services sold by other households in Kalangala. Palm producers also may alter their demand for labor and other inputs. Changes in palm households' consumption and input demands transmit the impacts of the price shock throughout the Kalangala economy.

A 1% price increase raises the value of oil palm fruit production by 185.7 million UGX. This results in a 472 million UGX increase in Kalangala's total cash income and a 410 million UGX increase in real income. These translate into average cash and real income gains per household of 28,122 and 24,415 UGX, respectively.

The positive price shock stimulates production in all sectors except fish. Kalangala retail sales rise by 141 million UGX; crop and livestock production increase by 15 and 14 million UGX, respectively; and other production in Kalangala increases by 105 million UGX. Total Kalangala employment rises by just under 27,000 person days. Most of the employment gain (20,416) is in non-palm producing households.

The impacts of a 1% decrease in FFB price are similar in magnitude to the above, only negative. The value of oil palm fruit production falls by 185.1 million UGX. This results in a 467 million UGX decrease in Kalangala's total cash income and a 405 million UGX drop in real income. These translate into average cash and real income losses per household of 27,797 and 24,146 UGX, respectively.

A negative FFB price shock causes a contraction in all production sectors except fish. Kalangala retail sales fall by 139 million UGX; crop and livestock production fall by 15 and 14 million UGX, respectively; and other production in Kalangala decreases by 103 million UGX. Total Kalangala employment contracts by 26,619 person days. Most of the employment loss (20,147 person days) is in non-palm producing households.

7.3 Impacts of Increased Productivity on Oil Palm Plantations

Productivity on Kalangala's small-scale palm plantations is significantly lower than on the OPUL estate plantation, and Figure 4 illustrates a decline in productivity over time. Declining productivity potentially has adverse effects on the Kalangala economy as well as on the livelihoods of palm farmers. We simulated the Kalangala economy-wide impact of a 10% increase in oil palm productivity <u>for smallholder farmers</u>. The findings appear in Column (5) of tables 14 and 15.

Increased productivity impacts palm households directly, by increasing FFB output. This boosts profits from palm cultivation while increasing palm farmers' demand for labor and other inputs. The bottom panel of Table 14 shows that employment increases by 29,167 person-days in oil palm households and by 40,452 in palm worker households. Higher wage labor demand transmits impacts to wage labourer households. Rising income in palm-producer and wage labourer households stimulates the demand for goods and services in Kalangala, as these households spend their cash. Production to satisfy this demand creates new demand for labor and other inputs across the spectrum of production activities, and this unleashes multiple new rounds of income, demand, and production gains, creating production and income spillovers. Total employment in Kalangala increases by 286,378 person days, considerably more than the employment gains in palm-grower and palm-worker households.

As markets transmit the influences of higher palm productivity through the economy, all sectors expand. Total output value rises by 158 million UGX in crops, 153 million UGX in livestock, 1.5 billion UGX in retail, and 1.1 billion UGX in other production activities.

The 10% increase in palm productivity raises total cash income in Kalangala by 4.97 million UGX. Adjusting for inflation, real income increases by 4.3 billion UGX. Non-oil-palm producing households gain nearly as much in real income (1.8 billion UGX) as palm-farming households (2.2 billion UGX). Palm worker households also benefit from higher productivity on oil palm plantations (255 million UGX). Averaged across all 16,791 households in Kalangala, the 10% increase in palm productivity raises income by 296.3 million UGX (256.5 million UGX in real terms).

8. Conclusions

Our analysis of survey data and LEWIE simulations reveal the importance of oil palm cultivation not only for palm farmers but for the Kalangala economy as a whole. As oil palm acreage expands, so does palm farmers' demand for labor and other inputs. Payments to workers spread benefits to palm worker households. As profits increase in palm farmer households and wages rise in worker households, these households' expenditures on goods and services supplied by other households and businesses in Kalangala increase. Market linkages spread the benefits of oil palm production through the entire Kalangala economy. Our simulations offer insight into how the Kalangala economy has grown in tandem with oil palm expansion, and why there is a high correlation between acreage in oil palm and new business formation.

Increases in oil palm acreage, oil palm productivity, or FFB prices benefit oil palm farmer and worker households. But our simulations show that the impact on total Kalangala income is substantially greater than the impact on oil palm farmer and worker households. Each additional acre of mature oil palm adds 2.2 million UGX annually to the Kalangala economy (1.9 million if we adjust for price inflation). Of this, 800,000 UGX goes to households that do not participate in oil palm production. An additional acre in oil palm creates 127 person-days of employment in Kalangala, 95.9 of which are in households that do not grow or work in oil palm. All sectors of the economy expand, with the exception of fishing, which appears to compete with oil palm for island labor. A 1% (108.7 acre) expansion in oil palm plantations raises total cash income in Kalangala by 242 million UGX and total real income by 210.1 million UGX.

Our simulations suggest that interventions that raise productivity on oil palm plantations and insure palm farmers against price shocks could provide large benefits for palm farmers and workers as well as for the entire Kalangala economy. Average productivity is low on small-scale palm plantations, and it appears to be declining over time. Based on our simulations, a 10% increase in oil palm productivity would raise total cash income in Kalangala by nearly 5 billion UGX annually. Non-oil-palm-producing households would capture nearly half of this income gain, and all production sectors except fishing would expand. A 10% increase in palm productivity would add more than 286,000 person-days of new employment to the Kalangala economy, of which nearly 217,000 would be in non-palm-producing households.

Palm households' livelihoods are intimately linked to global oil palm prices. So is the livelihood of the Kalangala economy as a whole. Our simulations show that when oil palm fruit price shocks hit producers, the effects ripple through the entire Kalangala economy. Negative FFB price shocks reduce employment much more in non-palm producing households than in palm farmer or palm worker households. This finding suggests that measures to protect small-scale palm farmers from adverse price shocks would create benefits for non-palm households. For example, an intervention that provides palm farmers with insurance against FFB price shocks would also insure the Kalangala economy as a whole.

This analysis underlines the importance of using an economy-wide approach to evaluate the impacts of development programs. It reveals that oil palm cultivation creates large production, income, and employment spillovers in Kalangala. By ignoring these spillovers, we miss many or even most of the income and employment impacts of oil palm production. Production, employment and income spillovers offer an explanation for the rapid expansion of the Kalangala economy following the introduction of oil palm. They also raise concerns about the Kalangala economy's sensitivity to oil palm fruit price shocks and declining productivity on palm plantations. A local-economy impact evaluation approach can be a basis for designing interventions that benefit small-scale oil palm farmers, workers, and the entire economy of which they are part.

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Appendix: Equations in the Kalangala LEWIE Model

Households engage in production activities and also may supply wage labour to local production activities, and they purchase goods and services locally or outside the zone, as in Taylor and Filipski (2014). For each good and factor, closure rules determine where markets clear and prices or wages are determined.

We assume that household capital and land endowments are fixed and neither capital nor land can be reallocated quickly between activities. These are reasonable assumptions, particularly in the short run, given our choice of activity aggregation: Crop cultivation implements are of little use in livestock or service activities, especially when markets are thin, and land cannot readily be converted from other uses to mature palm plantations. Thus, the rental rates on capital and land are household-specific shadow values.

Labour is tradable within the zone, but the supply of labor is elastic and the zone can freely 'import' wage workers from other parts of the country. We assume a nearly perfectly elastic labour supply (=100).

Oil palm fruit and fish are assumed to be tradable, with prices determined outside the zone. Oil palm fruit prices are determined exogenously, using a formula based on global prices. Households consume more fresh and dried fish than is produced on the island, even as local fish takes decrease due to overfishing in Lake Victoria. This implies outside trade in fish.

Thus, the model distinguishes among three levels of market closure: the household, the regional market, and outside the region. Monte Carlo simulations (Taylor and Filipski, 2014) were used to test the sensitivity of our simulation results to model parameters.

Table A1. Set, Subset and Mapping Names Used in Model Statement

SETS		Subsets	
g	Commodities	gtv	Goods locally tradable
		gtz	Goods traded in outside markets
f	Factors		
h or hh	households	gp	Locally produced goods
		gag	Agricultural goods
		gnag	Nonagricultural goods
		fk	Fixed factors
		ft	Locally tradable factors
		ftw	Factors traded in outside markets
		fpurch	Purchased variable inputs

Table A2. Commodities, Factors, Households, and Camps

Commodities and Activities	
Oil Palm	Local oil palm fruit production
Crop	Local crops: produced and consumed within the cluster
Livestock	Local livestock, produced and consumed within the cluster
Fishing	Local fishing from Lake Victoria
Retail	Local retailers in the cluster
Other	Other nonagricultural production
Outside good	Any commodity purchased outside the local economy
Factors	
Labor	Labor (family and hired receiving wage in cash or kind)
Land	Land
Capital	Capital
Input	Purchased inputs
Households	
A	Oil palm producing households
B	Non-palm households
C	Palm worker households
Sites	Bugala Island, Uganda

Table A3. Variable Names Used in Model Statement

VARIABLES			
Values		**Consumption and income**	
PV(g,v)	price of a good at the local level	QC(g,h)	quantity of g consumed by h
PZ(g)	price of a good at the regional level	Y(h)	nominal household income
PH(g,h)	price as seen by household h (=PV or PZ)	RY(h)	real household income
PVA(g,h)	price of value added net of intermediate inputs	CPI(h)	consumer price index
R(g,f,h)	rent for fixed factors	TROUT(h)	transfers given by a household of others
WV(f,v)	wage at the local level	SAV(h)	household savings
WZ(f)	wage at the regional level	EXPROC(h)	household expenditures outside the region
Production		**Trade**	
QP(g,h)	quantity produced of a good by a household	HMS(g,h)	household marketed surplus of good g
FD(g,f,h)	factor demand of f in production of g	VMS(g,v)	cluster marketed surplus of good g
ID(g,gg,h)	intermediate demand for production of g	ZMS(g)	Regional marketed surplus of a good
QVA(g,h)	quantity of value added created	HFMS(f,h)	factor marketed surplus from the household
HFD(f,h)	factor demand in the household	VFMS(f,v)	factor marketed surplus out of the cluster
HFSUP(f,h)	labor supply from the household (elastic endowment)	ZFMS(f)	factor marketed surplus out of the region

Table A4. Parameter Names Used in Model Statement (GAMS)

PARAMETERS Production		Consumption	
a(g,h)	Shift parameter in CD production function	alpha(g,h)	consumption share parameters in the LES
beta(g,f,h)	Factor share parameters (CD exponents)	cmin(g,h)	minimal consumption in the LES
vash(g,h)	Value-added share of output	exinc(h)	exogenous income of household
idsh(gg,g,h)	Intermediate input share	vmsfix(g,v)	fixed marketed surplus at the village level
fixfac(g,f,h)	Fixed factor endowments	Transfers	
vfmsfix(f,v)	Factors fixed at the local level (family, hired labor)	troutsh(h)	share of transfers in household expenditures
		exprocsh(h)	share of expenditures outside SCTPP zone
endow(f,h)	Household factor endowments	savsh(h)	share of income saved
hfsupzero(f,h)	Initial labor supply	trinsh(h)	share of total transfers received by a given household
hfsupel(f,h)	Factor supply elasticity		
pibudget(g,h)	Liquidity constraint on inputs		
pibsh(g,h)	Share of pibudget to good g		

Table A5. Equation Definitions

Equation Name	Description
*** prices**	
EQ_PVA(g,h)	prive value added equation
EQ_PH(g,h)	market price as seen from household h
*** production**	
EQ_FDCOBB(g,f,h)	factor demands Cobb Douglas
EQ_FDPURCH(g,f,h)	factor demands for purchased inputs - constrained or not
EQ_QVACOBB(g,h)	quantity VA produced Cobb Douglas
EQ_QP(g,h)	quantity produced from QVA and ID
EQ_ID(gg,g,h)	quantity of ID needed for QP
*** consumption**	
EQ_QC(g,h)	quantity consumed
*** income**	
EQ_Y(h)	full income constraint for the household
EQ_CPI(h)	consumer price index equation
EQ_RY(h)	real household income equation
*** transfers**	
EQ_TRIN(h)	inter household transfers in (received)
EQ_TROUT(h)	interhousehold transfers out (given)
*** exogenous expenditures**	
EQ_SAV(h)	savings (exogenous rate)
EQ_EXPROC(h)	expenditures outside of the zoi (exogenous rate)
*** goods market**	

clearing	
EQ_HMKT(g,h)	qty clearing in each household
EQ_VMKT(g,v)	market clearing within Kalangala
EQ_ZMKT(g)	market clearing in the region
EQ_VMKTfix(g,v)	price definition (zone+sourroundings)
EQ_ZMKTfix(g)	price definition (Kalangala)
*** factor market clearing**	
EQ_HFD(f,h)	total household demand for a given factor
EQ_FCSTR(g,f,h)	fixed factors constraint
EQ_HFSUP(f,h)	household elastic supply
EQ_HFMKT(f,h)	tradable factor clearing in the household
EQ_VFMKT(f,v)	tradable factors clearing in the village
EQ_ZFMKT(f)	tradable factor clearing in Kalangala (same as previous)
EQ_VFMKTfix(f,v)	wage determination for tradable factors clearing locally
EQ_ZFMKTfix(f)	wage determination for tradable factors
*** In case of nlp solve**	
EQ_USELESS	trick to make GAMS think it's maximizing something (optimization is already implicit in the model's equations, so GAMS does not have to maximize or minimize anything to solve the LEWIE model)

Table A6. Equations in the Model

Name	Equation
1) HOUSEHOLD EQUATIONS	
Price Block	
EQ_PH(g,h)..	$PH_{g,h} = [PZ_g]_{g \in gtz \cup gtw} + \left[\sum_{v \mid maphv(h,v)} PV_{g,v}\right]_{g \in gtv}$
EQ_PVA(g,h)..	$PVA_{g,h} = PH_{g,h} - \sum_{ga} idsh_{ga,g,h} \times PH_{ga,h}$
Production Block	
EQ_QVACOBB(g,h)..	$QVA_{g,h} = a_{g,h} \times \prod_{f} (FD_{g,f,h})^{\beta_{g,f,h}}$
EQ_FDCOBB(g,f,h)	$[R_{g,f,h}]_{f \in fk} + [WZ_f]_{f \in ftz} + \left[\sum_{v \mid maphv(h,v)} WV_{f,v}\right]_{f \in ftv} = \frac{PVA_{g,h} \times QP_{g,h} \times \beta_{g,f,h}}{FD_{g,f,h}}$
EQ_QP(g,h)	$QP_{g,h} = QVA_{g,h}/vash_{g,h}$
EQ_ID(gg,g,h)..	$ID_{ga,g,h} = QP_{g,h} \times idsh_{ga,g,h}$
Consumption and income block	
EQ_QC(g,h)..	$QC_{g,h} = \frac{\alpha_{g,h}}{PH_{g,h}} \times \left(Y_h - TROUT_h - SAV_h - EXPROC_h - \sum_{ga} PH_{ga,h} \times cmin_{ga,h}\right) + cmin_{g,h}$
EQ_Y(h)..	$Y_h = \sum_{g,fk} (R_{g,fk,h} \times FD_{g,fk,h}) + \sum_{g,ftz} WZ_{ftz} \times HFSUP_{ftz,h} + \sum_{ftv} \sum_{v \mid maphv(h,v)} WV_{ftv,v} \times HFSUP_{ftv,h} + \sum_{ftw} WZ_{ftw} \times HFSUP_{ftw,h}$

EQ_TROUT(h)..	$$TROUT_h = troutsh_h \times Y_h$$
EQ_EXPROC(h)..	$EXPROC_h = exprocsh_h \times Y_h$
EQ_SAV(h)..	$SAV_h = savsh_h \times Y_h$
EQ_CPI(h)..	$$CPI_h = \sum_g PH_{g,h} \times \alpha_{g,h}$$
EQ_RY(h)..	$$RY_h = \frac{Y_h}{CPI_h}$$
2) MARKET CLOSURE:	
Market clearing block for commodities	
EQ_HMKT(g,h)..	$$HMS_{g,h} = QP_{g,h} - QC_{g,h} - \sum_{ga} ID_{g,ga,h}$$
EQ_VMKT(g,v)..	$$VMS_{g,v} = \sum_{h\|maphv(h,v)} HMS_{g,h} + packsold_g$$
EQ_ZMKT(g)..	$$ZMS_{g,v} = \sum_v VMS_{g,v}$$
EQ_VMKTfix(gtv,v)..	$$VMS_{gtv,v} = vmsfix_{gtv,v}$$
EQ_ZMKTfix(gtz)..	$$ZMS_{gtz} = zmsfix_{gtz}$$
Market clearing block for factors	
EQ_HFV(f,h)..	$$HFD_{f,h} = \sum_g FD_{g,f,h}$$
EQ_FCSTR(g,f	$$FD_{g,fk,h} = fixfac_{g,fk,h}$$

k,h)..	
EQ_HFMKT(ft, h)..	$HFMS_{ft,h} = HFSUP_{ft,h} - \sum_g FD_{g,ft,h}$
EQ_HFSUP(ft, h)..	$\frac{HFSUP_{ft,h}}{hfsup^0_{ft,h} + hfsnewref_{ft,h}} = \left[\sum_{d\|maphd(h,d)} \left(WD_{ft,d}\right)^{\zeta_{ft,h}}\right]_{f \in ftd} + \left[\left(WZ_{ft,d}\right)^{\zeta_{ft,h}}\right]_{f \in ftz \cup ftw}$
EQ_VFMKT(ft, v)..	$DFMS_{g,d} = \sum_{h\|maphd(h,d)} HFMS_{g,h}$
EQ_ZFMKT(ft) ..	$ZFMS_{ft} = \sum_v VFMS_{ft,v}$
EQ_VFMKTFIX(ftv,v)..	$VFMS_{ftd,d} = vfmsfix_{ftv,v}$
EQ_ZFMKTFIX(ftz)..	$ZFMS_{ftz} = zfmsfix_{ftz}$
For simulations with a budget constraint	
EQ_FDCOBB(g,f,h) (only for purchased factors)	$FD_{g,f,h} \times WZ_f = pibudget_{g,h}$