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ORIGINAL PAPER

Potential effect of aquaculture promotion on poverty reduction in Sub-Saharan Africa

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Abstract There is a policy of increased support of aquaculture development in Sub-Saharan Africa. In the region, aquaculture expansion has the potential to create new jobs and improve food security among poor households. Three computable general equilibrium models were used to estimate the effects of aquaculture expansion and increased input productivity on poverty reduction in Ghana, Kenya, and Tanzania. The results suggest that there will be positive effects on per capita income for all households in Ghana and Kenya. In Tanzania some rich households will experience income loss, because of resource shift from other sectors to aquaculture. Because of reduction in poverty associated with price reductions, and increases in minimum income associated with income expansion, the poverty gap decreased in all household groups. Because of high sectoral linkages, aquaculture development is a potential candidate for sector-specific policy support to address poverty reduction in Sub-Saharan Africa.

Keywords Aquaculture · CGE · Economic effects · Poverty reduction

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Introduction

Aquaculture in Sub-Saharan Africa is currently undergoing growth with support from policy makers. A 2005 four-day summit on the future of African fisheries in Abuja, Nigeria, organized under the auspices of the New Partnership for Africa's Development (NEPAD), was a culmination of aquaculture policy support in Sub-Saharan Africa. The Abuja Declaration on Sustainable Fisheries and Aquaculture called for increased fish production focusing more on aquaculture promotion and development. Aquaculture was observed to be the only logical means of increasing fish supply without depleting wild stocks and maintaining low-priced fish affordable by poor households.

Aquaculture can be integrated into existing farming systems to enhance rural employment and income as a result of additional and off-seasonal production activity, improved food security and nutrition, and reduced risk as a result of diversification (USAID 1995). Aquaculture can also improve water availability and nutrient recycling and environmental benefits as a result of enhanced resource flows and sustainability (Tacon 2001; Edwards 2000). To have a noticeable effect in Sub-Saharan Africa, Muir et al. (2005) suggest that aquaculture must grow by more than 10% annually in the next 15 years, to meet projected demand, and that annual production must increase from approximately 700,000 metric tons to more than 3 million metric tons. This growth requires annual additional investment of more than $200 million (Muir et al. 2005). A well-planned aquaculture development program has the potential to create jobs, smoothen income flow, and increase farm efficiency (Simba 2001; Edwards 2000).

In most Sub-Saharan countries there is potential to increase aquaculture production activity and productivity growth in intermediate inputs and primary factors. Aquaculture expansion will involve increasing the number of fishponds and optimizing the use of available natural resources. Although pond culture is the main production system in most of Sub-Saharan Africa, there are possibilities for utilizing a wider range of production systems for fish farming, for example cage culture, recirculating systems, raceways, and integrated aquaculture production systems. Computable general equilibrium (CGE) models have been used to examine the potential economic effects of aquaculture expansion in Sub-Saharan Africa using Ghana, Kenya, and Tanzania as case studies. The three countries participated in the Aquaculture Collaborative Research Program (A/CRSP) funded by USAID. The primary data needed to create the aquaculture sector were collected during implementation of this project.

The model of each country was based on the standard neoclassical specification of trade-focused CGE models. The potential effect of aquaculture expansion in these countries is obtained by simulating models to account for possible expansion of aquaculture production activity and increased productivity in intermediate inputs and primary factors, mainly capital and labor that are used in aquaculture production. Changes in household income are then used to estimate the number of households that move out of poverty. The objective is to use these case studies to demonstrate and quantify the potential of aquaculture promotion and development in terms of poverty reduction in Sub-Saharan Africa. In the following section, data, the basic structure of the models, and poverty analysis in a CGE framework are summarized. Results and policy implications of aquaculture promotion are presented in the other two sections.

Materials and methods

Data description

CGE models are usually modeled using social accounting matrix (SAM) data (Cohen 1988). A SAM is the baseline data that contains a static account of all economic transactions in a base year of a particular country, presented in a square matrix form. The rows of the SAM contain receipts accounts of production activities, factors of production, institutions (households, government, and firms), investment and saving, import and export that account for purchased inputs for production activities, and commodities for consumption. The column elements represent expenditure made by these accounts. The matrix tracks how national outputs are produced and how household income is generated and distributed (Kehoe 1996). In this study, the database included SAMs for Ghana, Kenya, and Tanzania. The Ghana SAM was modified from Basin and Annim (2005) and the base year was 1999. The Kenya and Tanzania SAMs were obtained from the International Food Policy Research Institute and the base year was 2001. The structure of the Kenyan SAM is documented in Wobst and Schraven (2004) and for Tanzania is documented in Thurlow and Wobst (2003).

On the basis of the original SAMs the data were aggregated to levels consistent with the objectives of this study. This was achieved in two steps. The first step involved aggregating the original SAMs to create fewer accounts. For Ghana, the exercise resulted in a SAM containing seven accounts. Two accounts were for activity and commodity—agriculture, manufacturing and services; one account was for factors of production disaggregated into labor and capital. The household account included five types of household (agricultural farmers, public sector employees, private sector employees, non-farm self-employed, and miscellaneous households that earned income from different sources). The other two accounts included investment and trade with the rest of the world.

The Kenya SAM had two additional accounts, the marketing margin and tax accounts. The activities were divided into crop production, livestock operation, fishing, manufacturing and services. Households were divided into rural and urban groups. Each group has six representative households—three for female-headed households and three for male-headed households, each constituting ultra-poor, poor and non-poor households. Factors of production were divided into agricultural and non-agricultural wage labor and capital.

Compared with Kenya, the Tanzania SAM had an additional account for enterprise. Primary factors of production included: subsistence factor, labor, agricultural capital, non-agricultural capital, and agricultural land. The subsistence factor accounts for the household's subsistence production (Thurow and Wobst 2003). Labor supply was divided into child, female, and male labor sub-groups. Child labor supply is for participants aged 10–14. Female and male labor supply is for participants aged above 14 years and grouped into those without formal education, those with some primary education, those with some secondary education, and those who have completed secondary or higher education. The household account was divided into urban and rural households. In each category, households are organized into six groups that include households below the poverty line, between food and basic needs poverty lines, non-poor head with no education, non-poor head with some primary education, non-poor head with some secondary education, and non-poor head with completed secondary education.

In the original SAMs the aquaculture sector was combined with the crop sector for Ghana and with the fishing sector for Kenya and Tanzania. Consequently, the respective sectors in each country were split to create the aquaculture sector. Data for production,

exports, and imports in the aquaculture sector were obtained from the Food and Agricultural Organization of the United Nations (FAO) database. Marketing margins and tax payments were estimated using tax rates on outputs from the original SAM. Sub-matrices related to households, government, and enterprise commodity and investment demand and income distribution among households were estimated using proportion techniques. Intermediate input demand and value added were estimated using data from aquaculture farm surveys conducted in the respective countries between January and April 2005. These were purposeful surveys conducted in each country under the A/CRSP. Because aquaculture production is in its infancy, the objective was to cover all farms located in major aquaculture regions. The survey covered 124 farms in southern Ghana, 138 in central, eastern, and western Kenya, and 148 farms in northern and southern Tanzania. The major objective of the survey was to collect information about management practices and input–output data for feasibility analysis of small-scale aquaculture enterprises. This study used data collected under the input–output subsection to create the aquaculture sector's input–output matrix. To avoid errors that may have been introduced in the new SAM, a cross entropy difference method was used to balance the new SAM (Robinson et al. 2001a, b; Golan et al. 1996). The balanced aggregated 2001 macro SAMs for Ghana, Kenya, and Tanzania, after creating the aquaculture sector, are presented in Tables 1, 2, and 3, respectively. As shown in Table 1, a square SAM is balanced when the sum of rows equal the sum of columns to satisfy the zero profit and market clearing conditions.

CGE Model structure

Techniques for formulating SAM-CGE based models are detailed in Abbink et al. (1995), Bautista et al. (1999) and Vargas et al. 1999). Löfgren et al. (2001) present a procedure for constructing an algebraic standard CGE model in the general algebra modeling system (GAMS) software (Brooke et al. 1992). Rutherford presents a simplified implementation of the same model using GAMS/MPSGE language (Rutherford 1998), which was used in this study. A non-technical discussion of a basic CGE model for developing economies can be found in Wahrheim and Wobst (2005). The underlying principle for CGE models is that prices and production or demand for factors of production are determined within the economic system. At equilibrium, four major market characteristics must be fulfilled. First, the total market demand equals the total market supply for every factor and output.

Table 1 Structure and aggregate SAM for Ghana—1999 (trillion Ghana cedi, GHC)

	A	C	F	H	G	X	IN	Total
Activities (A)	–	13,159	–	–	–	–	–	13,159
Commodities (C)	5,480	–	–	3,346	1,309	4,550	901	15,586
Factors (F)	7,679	–	–	–	–	–	–	7,679
Households (H)	–	–	3,492	–	30	–	–	3,522
Government (G)	–	816	580	176	–	518	–	2,089
Savings/investment (X)	–	–	551	1	750	–	3,766	5,068
Rest of the world (IN)	–	1,611	3,056	–	–	–	–	4,667
Total	13,159	15,586	7,679	3,522	2,089	5,068	4,667	

Source: Modified from Basin and Annim (2005)

Table 2 Structure and aggregate SAM for Kenya—2001 (billion Kenya shillings, KES)

	A	C	M	F	H	T	G	X	IN	Total
Activities (A)	–	1,621	–	–	136	–	–	–	–	1,758
Commodities (C)	985	–	99	–	556	–	150	114	233	2,138
Marketing margins (M)	–	99	–	–	–	–	–	–	–	99
Factors (F)	773	–	–	–	–	–	–	–	–	773
Households (H)	–	–	–	773	–	–	37	–	–	809
Taxes (T)	–	107	–	–	103	–	–	–	–	210
Government (G)	–	–	–	–	–	210	–	–	–	210
Saving/investment (X)	–	–	–	–	15	–	23	–	76	114
Rest of the world (IN)	–	309	–	–	–	–	–	–	–	309
Total	1,758	2,138	99	773	809	210	210	114	309	

Source: Adapted from Wobst and Scharaven (2004)

Table 3 Structure and aggregate SAM for Tanzania—2001 (billion Tanzania shillings, TZS)

	A	C	M	F	H	E	G	T	X	IN	Total
Activities (A)	–	11,989	–	–	1,932	–	–	–	–	–	13,921
Commodities (C)	6,382	–	355	–	4,917	–	511	–	1,306	1,294	14,765
Marketing margins (M)	–	355	–	–	–	–	–	–	–	–	355
Factors (F)	7,515	–	–	–	–	–	–	–	–	–	7,515
Households (H)	–	–	–	5,226	–	2,150	61	–	–	399	7,837
Enterprise (E)	–	–	–	2,245	–	–	–	–	–	–	2,245
Government (G)	–	–	–	–	–	1	–	662	–	–	663
Taxes (T)	24	432	–	18	94	94	–	–	–	–	662
Saving/investment (X)	–	–	–	–	894	–	91	–	–	321	1,306
Rest of the world (IN)	–	1,988	–	26	–	–	–	–	–	–	2,014
Total	13,921	14,765	355	7,515	7,837	2,245	663	662	1,306	2,014	

Source: Adapted from Thurlow and Wobst (2003)

Second, prices are set so that equilibrium profits of firms are zero with all rents accruing to factors. Third, household income equals household expenditure. Fourth, government tax revenues equal expenditure. Thus, the CGE model contains a complete specification of the optimization problems facing all sectors of the economy. It is, therefore, possible to trace welfare changes for each specific agent in the economy. This characteristic makes the models useful and realistic tools for ex-ante poverty analysis.

The CGE models of all three countries were developed in accordance with Devarajan et al. (1997). Each sector produces a composite commodity that is transformed according to a constant elasticity of transformation (CET) function into a commodity sold on the domestic market, consumed at home or exported. Output is produced according to a constant elasticity of substitution (CES) production function in primary factors and fixed input–output coefficients for intermediate inputs. Commodities produced for home consumption, private consumption, intermediate demand, enterprise, government, and investments are the five components of domestic demand. Consumer demand is based on the Cobb–Douglas utility functions that generate fixed expenditure shares. Households pay

income taxes to the government and save a proportion of their income. Real government demand and real investment are fixed exogenously.

There are three macro balances in the model: the government deficit, aggregate investment and savings, and the balance of trade. Government savings is the difference between revenue and spending, with real spending fixed exogenously and revenue depending on a variety of tax instruments. Taxes include direct taxes on domestic institutions, import tariff, export taxes, value-added or activity taxes, indirect or sales taxes, and factor taxes. The government deficit is, therefore, determined endogenously. Real investment is set exogenously and aggregate private savings is determined residually to achieve the nominal savings–investment balance. The balance of trade foreign savings is set exogenously and valued in world prices. The model solves for the relative domestic prices and factor returns that clear the factor and product markets. In equilibrium there is exogenous aggregate trade balance in the model, and real exchange rate brings aggregate export supply and import demand into balance. The circular flow of income is captured by tracing the flow from producers to households, government, enterprises, and investors, and finally back to demand for goods and services in the product markets.

Model simulation or experimentation is focused on aquaculture production activity expansion and productivity growth in intermediate inputs and primary factors. Exogenously increasing the size of aquaculture production sector by 10% and imposing productivity growth of intermediate inputs, labor, and capital by 10% achieves this objective. To account for rigidities common in factors and commodity markets in developing countries, lower elasticities of substitution and transformations of supply and demand functions were used.

Poverty analysis in a CGE framework

Different definitions and concepts exist for what constitutes poverty. This study focuses on what is typically referred to as incidence of poverty and poverty vulnerability. Incidence of poverty indicates whether a household possesses enough resources or abilities to meet their current needs (Coudouel et al 2002). This definition is based on comparison of household income or consumption with some defined threshold below which households are considered poor in that particular attribute. Two steps are involved in measurement of the incidence of poverty. The first step involves estimating the poverty equivalent scale. The second step involves estimating the poverty line. The standard means of determining whether a household is poor involves comparison of its estimated poverty equivalent scale to the poverty line.

In the literature there are two kinds of poverty line—an absolute poverty line and a relative poverty line. The absolute poverty line is based on a basket of quantities of commodities reflecting basic needs or minimum consumption requirements for each individual member of the population (Ravallion 1994). With this approach, the value of the basket is determined using prevailing prices, which are used to estimate a minimum per capita income poverty line. Relative poverty lines are used to define the poor relative to the average living standards in a given country. A relative poverty line is determined in relation to a certain percentage of the mean, mode, or median per capita expenditure or income within the country. Although the minimum basket of goods may remain the same, neither line is fixed, because the monetary value of the basket will change with inflation and the relative poverty line will change with average expenditure or income levels (Decaluwé et al. 1991).

Poverty vulnerability is the probability of a household falling below the poverty line in the near future or the probability of falling into poverty at some point in the future. Vulnerability is a key dimension of poverty, because it affects household behavior in terms of investment, production patterns, and coping strategies and their perception of their own situation. Poverty vulnerability is, therefore, a stochastic dimension of poverty. Whereas incidence of poverty measures ex-ante poverty (poverty reduction), vulnerability to poverty is an ex-post concept (measures impact of poverty-reduction programs). The most popular money-metric measure of incidence of poverty is that of Foster et al. (1984), defined as:

$$P_\rho = \int_{y_{\min}}^{z} \left[\frac{z - y_i}{z}\right]^\rho = \frac{1}{N}\sum_{i=1}^{M}\left[\frac{z - y_i}{z}\right]^\rho \quad (1)$$

In Eq. 1, z is the poverty line or poverty threshold and ρ is the poverty aversion term or a measure of inequality term, y_i is the welfare measure by group i, N is the number of people in the sample population, and M is the number of poor people in the group. When $\rho = 0$, Eq. 1 reduces to M/N, the number of poor people in the population divided by the number of people in the sample population or the headcount ratio. When $\rho = 1$ the measure shows how far the poor people are from the poverty line (i.e. poverty gap index) and is used as an indicator of the minimum cost of eliminating poverty using perfectly targeted transfers. When $\rho = 2$ the index measures the severity (or intensity) of poverty and gives more weight to the poorest of the poor. A percentage change in a poverty gap is a crude measure of changes in poverty vulnerability (Decaluwé et al. 1999).

In 1999 the monetary poverty line for Ghana was 665,300 GHC (or $261) per person per year (Basin and Annim 2005). This is based on a basket for the bottom 20% on the national consumption distribution. The basket provided 2,900 kilocalories per adult equivalent per day for all final demanded goods in the economy. In Kenya, estimates of poverty lines are based on various participatory poverty assessment (PPA) surveys conducted occasionally. In the PPA survey conducted in 2001 poverty was invariably associated with inability to meet certain basic needs. Quantitatively, the poverty line was estimated to be 1,239 KES per month per person or 14,868 KES (or $189) per person per year (Mariara and Ndeng'e 2004). The Tanzania National Bureau of Statistics (NBS) uses two poverty lines—the food poverty line and the basic needs poverty line—to assess poverty levels. Both lines are determined from the household budget survey data using the reported consumption patterns of the second quintile of the sample population. To account for household consumption of other non-food items, the basic needs poverty line is calculated by adding 25% of the within-group expenditure on non-food items. For 2001 the food poverty lines were 5,607 Tshs/28 days and 5,107 Tshs/28 days in urban and rural areas, respectively. The analogous values for the basic needs poverty lines were 7,680 Tshs/28 days or 99,566 Tshs/year and 6,996 Tshs/28 days or 90,948 Tshs/year for urban and rural areas, respectively (NBS 2004). This is equivalent to $113/year for the food poverty line and $103/year for the basic needs poverty line.

The poverty lines developed in the respective countries were adopted for the poverty analyses. The basic needs poverty line is determined by a basket of quantities of commodities reflecting basic needs. The monetary value of the poverty line is obtained by multiplying the basic needs basket by their respective prices and aggregating across commodities. The commodity prices are endogenously determined within the model, so is the monetary value of the line. The base year monetary value of the basic needs basket is

the proportion of total household expenditure. By letting the basic need basket remain invariant, it can be shown that the poverty line after the model simulation is:

$$P_sQ_b = P_0Q_b[P_sQ_0/P_0Q_0] = P_0Q_b(RPI), \quad (2)$$

where P_s is the price index of commodities after model simulation, Q_b is the quantities of the basic needs basket, P_0 is the price of all commodities, Q_0 is the quantity of all commodities consumed, P_0Q_b is the poverty line before simulation, P_sQ_b is the poverty line after simulation, and *RPI* is the Laspeyres price index. A change in commodity prices after an external economic shock will cause the poverty line to shift. An increase (decrease) in commodity prices will shift the poverty line to the right (left) and poverty will increase (decrease).

Results

Baseline data

Per capita income and consumption levels estimated from the original SAMs are presented in Table 4. In the table the techniques for grouping households, and thus income and consumption distribution, were different for each country. In Ghana, household grouping is based on occupation, in Kenya, household grouping is based on gender and location, and in Tanzania, household grouping is based on education and location (either rural or urban). Whereas the data for Kenya can be divided into female and male sub-groups those for Tanzania cannot be divided into education sub-groups. Because of these differences between groupings, there is no comparison across the three countries.

In Ghana, on average, agricultural farmers had the highest per capita income and private sector employees had the lowest per capita income, although the difference in average per capita income among Ghanaian households was not significantly high. Per capita income distribution in Kenya indicates that income for female-headed households was lower than for male-headed households. Incomes in rural areas were also lower than in urban areas. For Tanzania, rural income was lower than urban income and was more skewed to the left than urban income. Education has the greatest effect on per capita income, especially in rural areas. There is a significant difference in per capita income between households where a head has a primary education and households where the head has a secondary education.

The data used for poverty analysis are presented in Table 5 on the basis of household groupings. Agricultural farmers in Ghana have the highest and lowest per capita incomes. Because most farmers live in rural areas, this may be an indication of an income gap within rural settings. Although non-farm self-employed households had the lowest maximum income among all household groups, they also had the highest minimum income. The lowest income among non-farm self-employed households was approximately twice that of other household groups. Poorer households in the non-farm self-employed household group were well off compared with poorer households in other household groups.

In Kenya, female-headed households in rural areas had the lowest per capita minimum income and the lowest per capita maximum income. Both values are significantly lower than for other household groups. Poorer female-headed households in urban areas were, however, well off compared with poorer households in the male-headed group in rural areas. The trend was similar for results for Tanzania. In general, urban households are wealthier than rural households. This probably explains the exodus of labor from rural to urban areas.

Table 4 Per capita income and consumption of economic agents

Country and households	Number of individuals[a]	Per capita income
Ghana (*1999 Ghana cedi*; *$1 = 3,420*)		
Agricultural farmers	9,854	2,765,729
Public sector employee	1,883	2,534,159
Private sector employee	1,582	2,206,560
Non-farm self employed	5,127	2,360,109
Miscellaneous households	1,582	2,398,446
Total/Average	20,028	2,994,932
Kenya (*2001 Kenya shillings*; *$1 = 77.896 KES*)		
Rural households		
Female ultra-poor	2,896	6,814
Female poor	1,027	12,491
Female non poor	3,424	27,581
All rural Female	7,347	17,287
Male ultra-poor	5,814	9,929
Male poor	2,476	17,752
Male non poor	8,020	36,897
All rural male	16,309	24,377
Urban households		
Female ultra-poor	139	9,799
Female poor	572	23,069
Female non poor	602	42,538
All urban female	1,314	30,585
Male ultra-poor	348	11,496
Male poor	2,496	16,310
Male non poor	2,838	70,412
All urban male	5,682	43,037
Total/Average	30,652	26,403
Tanzania (*2001 Tanzania shillings*; *$1 = 883.96 TZS*)		
Rural households		
Below food poverty line	5,081	76,578
Between basic needs poverty line	4,605	114,360
Non poor head with non education	3,512	208,015
Non poor head below primary school	3,500	237,625
Non poor head below secondary school	7,842	182,301
Non poor head finished secondary school	662	393,585
All rural households	25,202	165,383
Urban households		
Below food poverty line	675	58,683
Between basic needs poverty line	712	77,812
Non poor head with non education	423	152,130
Non poor head below primary school	689	206,902
Non poor head below secondary school	2,463	246,818
Non poor head finished secondary school	1,147	530,989
All urban households	6,109	248,604
Total/Average	31,311	181,620

[a] Number in thousands

Table 5 Data used for poverty analyses

County and households	Income bounds	
	Min	Max
Ghana (Ghanaian cedi)		
Agricultural farmers	7,665	44,000,000
Public sector employees	13,808	39,000,000
Private sector employees	12,000	24,000,000
Non-farm self employed	23,865	24,000,000
Miscellaneous households	13,738	27,000,000
Kenya (Kenyan shillings)		
Rural households		
Female	1,246	37,579
Male	1,769	197,902
Urban households		
Female	1,889	211,094
Male	2,119	684,815
Tanzania (Tanzania shillings)		
Rural households	5,144	1,514,029
Urban households	5,796	2,997,328

Simulation results on change in income

The simulation results for percentage change in income associated with aquaculture expansion and factor productivity growth are presented in Table 6. On the basis of the structure of the CGE models, the percentage change in income is proportional to the percentage change in the Hicksian equivalent variation, meaning that households with positive percentage change in income will also have a positive percentage change in the Hicksian equivalent variation, and vice versa. The results in Table 6 indicate a relative improvement in income for all household groups in Ghana (approx. 2%). All households groups in Ghana have some form of primary factors involved in aquaculture production. Aquaculture expansion and increased factor productivity will affect expansion of the production possibility curve of households and, thus, income.

For Kenya, improvement in income is relatively small. The Kenyan economy is dominated by large-scale agriculture and intensive farming of rural areas. There is also a well-established manufacturing sector in urban areas. Consequently, aquaculture expansion and increase in factor productivity did not significantly affect the relative price. In Tanzania, the effect of aquaculture expansion was mainly through labor movement from the fishing sector, and movement of non-agricultural capital from urban to rural areas. Income loss among non-poor households was associated with a decrease in labor income from the fishing sector.

Poverty analysis results

The estimated poverty line or minimum income of household groups and poverty lines before and after the CGE model estimation are presented in Table 7. Table 7 also presents the three poverty measure estimates of the Foster–Greer–Thorbecke class before and after

Table 6 Simulation results for percentage change in household income

County and households	Percentage change in income
Ghana	
Agricultural farmers	1.900
Public sector employee	2.200
Private sector employee	2.200
Non-farm self employed	2.200
Non-working	2.200
Average	2.140
Kenya	
Rural households	
Female ultra-poor	0.076
Female poor	0.091
Female non poor	0.012
Male ultra-poor	0.006
Male poor	0.007
Male non poor	0.000
Urban households	
Female ultra-poor	0.002
Female poor	0.004
Female non poor	0.004
Male ultra-poor	0.001
Male poor	0.003
Male non poor	0.003
Average	0.017
Tanzania	
Rural households	
Below food poverty line	3.700
Between basic needs poverty line	8.200
Non poor head with non education	−5.600
Non poor head below primary school	−6.800
Head below secondary school	5.000
Non poor head finished secondary school	6.000
Urban households	
Below food poverty line	13.300
Between basic needs poverty line	18.200
Non poor head with non education	16.300
Non poor head below primary school	8.800
Head below secondary school	9.400
Non poor head finished secondary school	−8.600
Average	5.658

the CGE model simulation. The minimum incomes were obtained by substituting the poverty line variable in Eq. 2. In all countries there is a slight increase in minimum income because of the changes associated with labor movement within the household groups.

Table 7 Results of poverty analyses

	Minimum income after simulation	Poverty line after simulation	Poverty head count	Poverty gap[a]		Severity		Percent change in poverty gap
				Before	After	Before	After	
Ghana (Ghanaian cedi)								
Agricultural farmers	9,198	556,038	0.173	0.171	0.163	0.168	0.164	−0.046
Public sector employees	16,570	555,451	0.193	0.188	0.177	0.184	0.178	−0.059
Private sector employees	14,400	555,464	0.080	0.078	0.074	0.077	0.074	−0.055
Non-farm self employed	28,638	557,867	0.210	0.201	0.185	0.192	0.185	−0.080
Miscellaneous households	16,486	562,380	0.200	0.195	0.184	0.190	0.185	−0.058
Kenya (Kenyan shillings)								
Rural households								
Female	1,495	14,478	0.540	0.486	0.422	0.437	0.426	−0.130
Male	2,123	14,456	0.510	0.437	0.362	0.375	0.364	−0.172
Urban households								
Female	2,267	14,580	0.530	0.449	0.368	0.381	0.370	−0.181
Male	2,543	14,455	0.500	0.414	0.331	0.344	0.333	−0.201
Tanzania (Tanzanian shillings)								
Rural households	6,173	86,298	0.380	0.354	0.319	0.330	0.321	−0.099
Urban households	6,955	90,435	0.230	0.210	0.190	0.200	0.190	−0.100

[a] Calculated based on Eq. 1 were z is the poverty line and y minimum income of the household groups and poverty head count, poverty gap and severity of poverty are in proportion

Using the head-count ratio, it was determined that, in Ghana, approximately 17% of agricultural farmers and approximately 19% of public sector employees lived below the poverty line of 665,300 GHC. The percentages for private sector employees, non-farm self-employed and miscellaneous households were 8, 21, and 20%, respectively. The poverty estimates show that, in Ghana, 8% of private sector employees lived in poverty in 1999. The incidence of poverty was higher among non-farm self-employed households. The estimated indexes are lower than indexes for other countries in Sub-Saharan Africa.

The head-count estimates for Kenya show that 54 and 53% of female-headed households in rural and urban areas, respectively, lived below the poverty line in 2001. The corresponding values were 51 and 50% for male-headed households. The incidence of poverty was relatively low among male-headed households in urban areas. On average, in Kenya, more than 50% of the population lived below the poverty line of 14,868 KES in 2001. The most affected were female-headed households in rural areas.

In Tanzania, 38% of rural households and 23% of urban households lived below the poverty line. The value of the poverty line decreased because of a decrease in relative prices. Incidence of poverty in Tanzania was higher in rural areas (38%) than in urban areas (23%). Lower incidence of poverty in both Kenya and Tanzania can be attributed to relatively higher per capita income among urban dwellers.

Another measure of poverty is the poverty gap index, defined as the difference between the level of income of a household group and the poverty line, and expressed as a proportion of the poverty line. Non-poor households have a poverty gap of zero. This measure is superior to the headcount because it indicates the depth of poverty. The severity poverty index is the mean of the squared poverty gap. Because individuals in poorer households are given more weight than less poor individuals, it provides a better measure than the other two measures of poverty. The poverty severity index is sensitive to the distribution of consumption levels among the poor, whereas the other indexes are not. One poor person sacrificing income so that a poorer person's income is enhanced will alter neither the poverty headcount nor the poverty gap index. This action will reduce the poverty severity index, however.

Greater measures of all the indexes imply poverty is worse, but overall, using the poverty headcount is intuitive. The other two indexes are more useful in making comparisons between different populations. Decisions relating to implementation of any poverty reduction program should target groups with the highest poverty severity index (Benson et al. 1998). For example, results from this study suggest that poverty reduction aquaculture programs should focus on non-farm sector employee in Ghana, female-headed households in Kenya, and rural households in Tanzania.

In Table 7, the column on the percentage change in the poverty gap shows the proportion of individuals that move out of poverty. Approximately 5% of agricultural farmers moved beyond the new poverty line after aquaculture expansion in Ghana. The changes in the poverty gap indicate the most likely beneficiaries of the program. In Ghana, non-farm self-employed households benefit most (most likely the middlemen). In Kenya, aquaculture programs are most likely to benefit urban households and, especially, male-headed households. In Tanzania, both rural and urban households will benefit from an aquaculture development program. From these results it is apparent that the greatest effect of increased aquaculture production is through indirect and induced effects. This is important especially when planning for economic development and poverty alleviation. Sectors that indirectly create demand for goods from other sectors should be targeted first. Intersectoral linkages are important for job creation and economy-wide expansion.

Conclusion and policy implications

There is increased interest and policy support toward aquaculture development in Sub-Saharan Africa. Aquaculture development programs have the potential to create new jobs, improve food security among poor households, remove variability in terms of household income flow, and increase farm level efficiency and sustainability. This study used computable general equilibrium models for Ghana, Kenya, and Tanzania as case studies to estimate the effects on poverty reduction of aquaculture expansion and productivity growth in intermediate inputs and primary factors used in aquaculture production in Sub-Saharan Africa. The general results suggest that aquaculture expansion will have positive effects in terms of per capita income in all households in Ghana and Kenya. In Tanzania, some rich households will experience income loss because of resource shift from the fisheries and manufacturing sectors to aquaculture. The poverty gap decreased in all household groups in all countries because of decreases in poverty lines associated with decreases in relative prices and increases in the minimum income associated with income expansion. Sectoral

linkages make aquaculture development promising for sector-specific policy support aimed at aquaculture development to address poverty issues among poor households in all three countries.

As are other economic models, however, CGE models have several limitations. General strength and weaknesses of different CGE models can be found in Borges (2005). As indicated in the text, CGE models have two main parts. The first part of the model is an input–output matrix showing how production in one sector leads to demands for output from other sectors. The second part of the model shows how producers choose what products to produce and what combination of production resources to use on the basis of output and input prices. This mean that the model is price driven and it is price that signals the backward and forward linked sectors to, respectively, supply additional inputs and services and add value to the new produced products. This requires that the markets be fully integrated to enable smooth price transmission. Price transmission barriers such as lack of competition, tariffs, and regulatory barriers (which are common in Sub-Saharan countries) may magnify or reduce the magnitude of estimated welfare measures of different households in the models.

CGE models results also tend to depend on the closure rule. This is the mechanism that achieves consistency of transactions at the macroeconomic level. In traditional CGE models, which is the case in this study, the savings–investment identity was adopted as the model closure rule, because there is no financial-monetary sector. It is, however, possible to integrate the real and the monetary/financial sectors of the economy into the model and overcome the closure rule limitation. The strict equality of savings and investments can be expanded in a way that any difference between them is financed through changes in money supply, private domestic borrowing of government, net foreign assets and private lending from banks, as practiced by most Sub-Saharan countries. The new set of accounting identities can be expanded to cover a large spectrum of financial market conditions and institutional characteristics. Because of data limitation this approach was not pursued and was beyond the resources available for this study. As demonstrated by different literature, the estimated results still present a snapshot of economic activities after aquaculture expansion and productivity growth and are useful in providing insight into important policy direction and in identifying important pathways for development planning.

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