A CGE Analysis of the potential economic impacts of aquaculture promotion in Sub-Saharan Africa

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Abstract. There is increased policy support towards aquaculture development in Africa. In the region, aquaculture expansion has potential to create new jobs and improve food security among poor households. This study used computable general equilibrium models to estimate the effects of aquaculture expansion and increased input productivity on poverty alleviation. The results of the study suggest that there will be positive effects in per capita income for all households in Ghana and Kenya. In Tanzania, some rich households will experience income loss due to resource shift from other sectors to aquaculture. Due to decreases in poverty lines associated with decreases in relative price, and increases in the minimum income associated with income expansion, the poverty gap decreased in all household groups. Sectoral linkages incorporated in the models suggest that aquaculture development is promising for sector-specific policy support to enhance poverty alleviation programs among poor households in the region.

Key words: Aquaculture, CGE, Economic impacts, Poverty alleviation.

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 to poor households.

Aquaculture can be integrated into existing farming systems to enhance rural employment and income through additional and off-seasonal production activities; improve food security and nutrition; and decrease risk through diversification. Aquaculture can also improve water availability and nutrient recycling and environmental benefits through enhanced resource flows and sustainability (Tacon 2001; Edwards 2000). To have a noticeable impact in Sub-Saharan Africa, Muir *et al*. (2005) suggests that aquaculture has to grow by more than 10% annually in the next 15 years in order to meet projected demand and that annual production has to increase from about 700,000 metric tons to more than 3 million metric tons. This growth requires between $1 to $2 billion, and an annual additional investment of more than $200 million (Muir *et al*. 2005). A well-planned aquaculture development program has potential to create jobs creation, improve food security, smooth household income flow, and increase farm efficiency and sustainability.

Unemployment is a major concern for governments in Sub-Saharan Africa. Labor demand in many Sub-Saharan African countries is seasonal. Aquaculture enterprises can create new jobs and remove seasonality in labor demand. Employment opportunities are also possible on larger farms through job creation in activities such as seed supply networks, marketing chains and manufacturing, repair shops, and other aquaculture support services. Aquaculture can also benefit the landless through utilization of common resources, such as finfish cage and cove cultures, culture of mollusks and seaweeds, and fisheries enhancement in communal water bodies. For small-scale operations, women undertake many aquaculture activities that include marketing. Aquaculture can therefore provide part-time jobs to women who are the key managers of household resources directed at consumption. Empowerment of women encourages them to become further involved in the decision-making process and other development activities (Simba 2001; Edwards 2000).

Achieving food security is an important aspect of general development objectives such as poverty alleviation. Fish are a great source of protein and minerals, are low in saturated fats and are a good source of essential fatty acids, a combination for good health. To be food secure, households and individuals need to have food available to them, have access to food, and also have the ability to fully utilize the food once it is consumed (USAID 1995). Aquaculture can contribute to improved food security and nutrition through various channels. For example, local food supplies can be improved through increased availability of low-cost fish. Increasing the quantity and variety of fish and other foods consumed by the poor will reduce under-nutrition within rural communities (Tacon 2001).

In Tanzania, Kenya and Ghana, 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. Though pond culture is the main production system in most of Africa, there are possibilities for utilizing a wider range of production systems for fish farming such as cage culture, recirculating systems, raceways, and integrated aquaculture production systems. This paper examines the potential economic impacts of aquaculture expansion in Africa using Tanzania, Kenya and Ghana as case studies. Welfare improvement is through reduction in incidence of poverty, poverty vulnerability and poverty gap among poor households.

Materials and Methods:

A proper assessment of the potential impacts of various sector (e.g., aquaculture) investments requires a comprehensive economic framework to analyze interactions and linkages among different sectors of the economy. In this paper, the computable general equilibrium (CGE) model is applied to Ghana, Kenya, and Tanzania in which the social accounting matrix (SAM) is the benchmark dataset. The dataset were developed and used to assess the impacts of increased aquaculture production on poverty alleviation and food security among rural households. The three models are based on the standard neoclassical specification of trade-focused CGE models.

There are five major economic agents and three markets in the model. The economic agents include producers, households, government, firms, and the rest of the world. The three markets are commodity markets, factor markets and financial markets. Income flow among economic agents is channeled through factor and commodity markets. The commodity market is the medium of exchange for domestically produced goods and imports, which are purchased as intermediate inputs by producers and final demand by households and the government. The factor market is the medium of exchange for wages and capital rents to households and firms. The financial market acts as a reserve for savings collected from households and the rest of the

world and disbursed in the form of investments to the commodity market. The basic model simulates a market economy where prices and quantities adjust to clear commodity, factor, and financial markets in the models.

The potential impact of aquaculture expansion in these countries is achieved through simulating the models to account for possible aquaculture production activity expansion and productivity growth in intermediate inputs and primary factors, mainly capital and labor, 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 of Ghana, Kenya, and Tanzania to demonstrate and quantify aquaculture's potential for alleviating poverty and to improve food security in Sub-Saharan Africa.

Computable General Equilibrium (CGE) Models

CGE models are usually built based on SAM data (Cohen 1988). A SAM is the baseline data that contains a static account for all economic transactions taking place in a base year, 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 expenditures made by these accounts. The matrix tracks how national outputs are produced and how household income is generated and distributed (Kehoe 1996).

Techniques for formulating SAM-CGE based models are detailed in Abbink, Braber, and Cohen (1995). Löfgren, Harris, and Robinson (2001) present a procedure for constructing an algebraic standard CGE model in the General Algebra Modeling System (GAMS) Software (Brooke, Kendrick, and Meeraus 1992). Rutherford presents a simplified implementation of the

same model using GAMS/MPSGE (Rutherford 1998). A non-technical discussion of a basic CGE model for developing economies can be found in Wahrheim and Wobst (2005).

The CGE modeling transforms a SAM into an economy-wide model without extensive supplementary data while focusing on the demand side of the economy. This is achieved by simulating the working of a market economy in which prices and quantities adjust to clear all markets (Vargas *et al*. 1999). In its mathematical form, the CGE models contain a system of simultaneous equations divided into four blocks (i.e., price, production and trade, institution, and the economic system constraint). The price block consists of equations in which endogenous model prices are linked to other prices (endogenous or exogenous) and non-price model variables. The production block covers domestic production and input use; allocation of domestic output to home consumption, the domestic market, and export, the aggregation of supply to the domestic market; and the definition of the demand for trade inputs that is generated by the distribution process. The institution block has equations that define distribution of income to factors of production and owners of the factors of production, intra-institutional transfers, household consumption expenditures on both domestically produced and imported commodities, investment demand and savings, and government expenditures. The fourth block contains equations that balance the market for factors of production, the market for commodities (demanded equals supply), and government revenue equals expenditure (Abbink, Braber, and Cohen 1995).

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. Second, prices are set so that equilibrium profits of firms are

zero with all rents accruing to factors. Third, household incomes equal household expenditures. Fourth, government tax revenues equal government expenditures that include subsidy payments. Thus, the CGE model contains a complete specification of the optimization problems facing all actors in the economy. This makes it possible to trace all results of the model to specific agents in the economy (Bautista, Robinson and El-Said 1999).

Poverty Analysis in a CGE Framework

Various 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. This definition is based on a comparison of household income or consumption with some defined threshold below which households are considered as being poor in that particular attribute. Two steps are involved in the measure of incidence of poverty. The first step involves estimating the poverty equivalent scale or welfare measure. The second step involves estimating the poverty line. The standard means of determining whether a household is poor involves a comparison of its estimated poverty equivalent scale to a poverty line.

In the literature, there are two kinds of poverty lines. One is an absolute poverty line and the other is 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 of per capita expenditure or income within the country.

For example, it may be determined that households receiving less than 50% of the median per capita income are poor. Although the minimum basket of goods may remain the same, both lines are not fixed, as 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 an individual or household falling below the poverty line in the near future, i.e., the probability or risk today of being in poverty or falling deeper into poverty at some point in the future. Vulnerability is a key dimension of poverty, since it affects household behavior in terms of investment, production patterns, and coping strategies and their perception of their own situation. Therefore, poverty vulnerability is a stochastic dimension of poverty. Whereas incidence of poverty measures ex-ante poverty (poverty alleviation), vulnerability to poverty is an ex-post concept (measures impact of poverty alleviation programs).

The most popular money-metric measure for incidences of poverty is that of Foster, Greer and Thorbecke (1984) defined as:

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

In equation (1), z is the poverty line or poverty threshold, and ρ is the poverty aversion parameter or a measure of inequality parameter, 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 ρ=0, equation (1) reduces to M/N, the number of poor people in the population divided by the number of people in the sample population. When ρ=1, the measure shows the deficit of the poor people 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 ρ=2, the index measures the

severity (or intensity) of poverty and gives more weight to the poorest of the poor. The welfare measure of poverty (P_ρ) is also known as the headcount ratio when turned into a percentage (Decaluwé *et al*. 1999). A percentage change in a poverty gap is a crude measure of changes in poverty vulnerability.

In 1999, the monetary poverty line for Ghana was 665,300 GHC (or $261) per person per year (Bhasin and Annim 2005). The line was calculated from a consumption basket for the bottom 20% based on the national consumption distribution. The basket provided 2,900 kilocalories per adult equivalent per day. The basket contained all final demanded goods in the economy. In Kenya, poverty lines are calculated 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 Ndege 2004).

The Tanzania National Bureau of Statistics (NBS) uses two poverty lines to assess poverty levels; the food poverty line, and the basic needs poverty line. 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 expenditures on non-food items. For 2001, the food poverty lines were, respectively, 5,607 Tshs/28 days and 5,107 Tshs/28 days in urban and rural areas. 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 food poverty line and $103/year for basic needs poverty line.

The poverty lines developed in 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 aggregated 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 need 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:

$$P_s Q_b = P_0 Q_b \left[P_s Q_0 / P_0 Q_0 \right] \quad = P_{b0} Q_b (RPI), \tag{2}$$

where P_s is the price index of commodities after the 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, $P_0 Q_b$ is the poverty line before simulation, $P_s Q_b$ is the poverty line after simulation, and *RPI* is the Laspeyres price index. Equation (2) indicates that, with a change in commodity prices following an external economic shock, the poverty line will shift. An increase (decrease) in commodity prices will shift the poverty line to the right (left) and poverty will increase (decrease).

Data and the Structure of the CGE Models

The database of the models included SAMs for Ghana, Kenya, and Tanzania. The models have different base years and structures for each country. The Ghana SAM was modified from Bhasin and Annim (2005) and the base year is 2001. Kenya and Tanzania SAMs were obtained from the International Food Policy Research Institute and the base year is also 2001. The structure of the SAM is documented in Wobst and Schraven (2004) for Kenya, and Thurlow and Wobst (2003) for Tanzania.

Based on 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 constituting seven accounts; two accounts for activity and commodity accounts - agriculture, manufacturing and services; and one account for factors of production disaggregated into labor and capital. The household account included five types of households; 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 the rest of the world.

The Kenya SAM had an addition of two 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 constituting ultra-poor, poor and non-poor households. The factors of production were divided into wage labor - agricultural, wage labor - non-agricultural, capital - agricultural and capital non-agricultural.

Apart from the marketing margin and tax account, the Tanzania SAM has an additional account for the enterprise. There are five primary factors associated with factor markets; subsistence, labor, agricultural capital, non-agricultural capital, and agricultural land. The subsistence factor is to account for the household's subsistence production (Thurow and Wobst 2003). Labor supply is divided into child, female, and male labor sub-groups. Child labor supply is for participants aged 10 to 14. Female and male labor supply is for participants aged above 14 years and grouped into those without formal education, with some primary education, with some

secondary education, and completed secondary or higher education. The household account is 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 SAM, aquaculture is lumped together with the crop sector in the case of Ghana and the fishing sector in the case of Kenya and Tanzania. Consequently, the respective sectors in each country were split to create the aquaculture sector. Data for the aquaculture sector on production, exports and imports were obtained from the Food and Agricultural Organization of the United Nations (FAO) database. Intermediate input demand, value added, household demand, and income distribution among households were estimated using data from a farm survey conducted in Ghana, Kenya, and Tanzania between January and April 2005. The marketing margins and tax payments were estimated using tax rates on outputs from the original SAM. Sub-matrices related to government and enterprise commodity demand, investment demand, and marketing margins were estimated using proportion techniques. To ovoid errors that may have been introduced in the new SAM, a cross entropy difference method was used to balance the new SAM (Robinson, Cattaneo, and El-Said 2001a,b; Golan, Judge, and Miller 1996).

Tables 1a to 1c present the balanced aggregated 2001 macro SAM for Ghana, Kenya, and Tanzania respectively, after creating the aquaculture sector. 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. For example, in the Table 1c, the activity column (A) represents expenditure by production activities, which shows that about 6 trillion Tshs was spent on

intermediate inputs, 8 trillion Tshs was spent on factors of production, and the activities paid 21 billion in value added tax. The commodity column (C) shows that goods valued at 12 trillion Tshs were marketed in the domestic market, and the retail and marketing cost was about 356 billion Tshs. The indirect tax on marketed output was 436 billion Tshs, and the value of import at CIF was about 2 trillion Tshs. The factor column (F) shows how the factor income was distributed to households (i.e., 2 trillion to enterprises, 5 trillion to households, 18 billion to government as factor income tax, and 25 billion as dividends to factors owned by foreigners). The enterprise income (column E) was distributed to households (2 trillion Tshs), 1 billion Tshs was paid to the government as dividend, and 96 billion Tshs was paid in form of enterprise or corporate taxes.

Column H, which represents household expenditures, shows that goods valued at about 2 trillion Tshs were produced and consumed at home by households. Private household consumption was valued at about 5 trillion. The households paid 94 billion Tshs in income tax and households saving were 903 billion Tshs. The government column (G) indicates that the government paid for goods and services valued at 514 billion Tshs, distributed 61 billion as direct support to households, and saved about 91 billion Tshs. The government collected 666 billion Tshs in tax revenue (column TA). The trade column (TR) shows that commodities valued more than 1.3 trillion Tshs were exported. Households received 403 billion Tshs in the form of remittances from abroad. Foreign investment was about 324 billion Tshs. About 1.3 trillion Tshs were invested in the production of commodities (Column I). The data in the Ghana and Kenya SAMs has similar interpretation.

The CGE models of all countries were developed following 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 and 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 fixed 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. This is achieved

by exogenously increasing the size of aquaculture production sector by 10% and imposing productivity growth of intermediate inputs, labor and capital by 10%. To account for rigidities common in factors and commodity markets in developing countries, lower elasticities of substitution and transformations of supply and demand functions are used.

Results

Table 2 presents per capita income and consumption levels estimated in the original SAMs. In Table 2, 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). However, while Kenyan data can be divided into female and male sub-groups the Tanzanian data cannot be divided into education sub-groups. Because of the differences in groupings, no comparison is done 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. However, the difference in average per capita income among Ghanaian households was not significantly high. Per capita income distribution in Kenya indicates that female-headed households had the lowest income compared to male-headed households. Incomes in rural areas were also lower when compared to incomes 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 influence on per capita income, especially in rural areas. There is a significant difference in per capita income between households where a head has primary education compared to the household where the head has a secondary education.

The data used for poverty analysis are presented in Table 3 based on the household groupings. Agricultural farmers in Ghana have the highest and lowest per capita incomes. Since the majority of farmers live in rural areas, this may be an indication of an income gap within rural settings. While non-farm self-employed households showed the lowest maximum income among all household groups, it also showed the highest minimum income. The lowest income among non-farm self-employed households was about twice that of other household groups. Poorer households in the non-farm self-employed household group were well off when compared to poorer households in other household groups.

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

Table 4 presents the simulation results on percentage change in income for all countries with an expansion in aquaculture in aquaculture and factor productivity growth. Based on the structure of the CGE models, the percentage change in income is proportional to the percentage change in the Hicksian equivalent variation, i.e., 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 4 indicate a relative improvement in income for all household groups in Ghana (about 2%). All households groups in Ghana have some form of primary factors involved in aquaculture production. Exogenous 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 Kenya economy is dominated by large-scale agriculture and intensive farming in 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 impact 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.

Table 5 presents the estimated poverty line or minimum income of household groups and poverty lines before and after the CGE model estimation. Table 5 also presents the three poverty measures estimates of the Foster-Greer-Thorbecke class before and after the CGE model simulation. The minimum incomes were obtained by substituting the poverty line variable in equation 2. In all countries, there is a slight increase in minimum income due to changes associated with labor movements within the household groups.

Using the head count ratio, it was determined that, in Ghana, about 17% of agricultural farmers lived below the poverty line, and about 19% of the public sector employees lived below the poverty line of 665,300 GHC. The percentages for the private sector employee, 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 when compared to indexes from 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 due to 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 poverty severity index is the mean of the squared poverty gap. As individuals in poorer households receive greater 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. However, this action will decrease the poverty severity index.

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, Machinjili and Kachikopa 1998). For example, results from this study suggest that poverty alleviation programs should focus on the non-farm sector employee in Ghana, female-headed households in Kenya, and rural households in Tanzania.

In Table 5, the column on the percentage change in poverty gap shows the proportion of individuals that move out of the poverty gap. About 5% of agricultural farmers moved beyond the new poverty line after aquaculture expansion in Ghana. The changes in poverty gap indicate the most likely beneficiaries of the program. In Ghana, non-farm self-employed households benefit the most (most likely the middlemen). In Kenya, aquaculture programs are most likely to benefit urban households and especially male-headed households (most likely fish traders). In Tanzania, both rural and urban households will benefit from an aquaculture development program. From these results, it is apparent that the greatest impact 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 towards aquaculture development in 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 alleviation

from 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 due to resource shift from the fisheries and manufacturing sectors to aquaculture. The poverty gap decreased in all household groups in all countries due to 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 sustain poverty alleviation programs among poor households.

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Table 1a: 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 Bhasin and Annin (2005).

Table 1b: 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 1c: 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)

Table 2: 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 female ultra-poor	2,896	6,814
Rural female poor	1,027	12,491
Rural female non poor	3,424	27,581
Rural Female	7,347	17,287
Rural male ultra-poor	5,814	9,929
Rural male poor '	2,476	17,752
Rural male non poor	8,020	36,897
Rural male	16,309	24,377
Urban female ultra-poor	139	9,799
Urban female poor	572	23,069
Urban female non poor	602	42,538
Urban female	1,314	30,585
Urban male ultra-poor	348	11,496
Urban male poor	2,496	16,310
Urban male non poor	2,838	70,412
Urban male	5,682	43,037
Total	**30,652**	**26,403**
Tanzania [2001 Tanzania Shillings ($1=883.96 TZS)]		
Rural below food poverty line	5,081	76,578
Rural between basic needs poverty line	4,605	114,360
Rural non poor head with non education	3,512	208,015
Rural non poor head below primary school	3,500	237,625
Rural non poor head below secondary school	7,842	182,301
Rural non poor head finished secondary school	662	393,585
Rural households	25,202	165,383

Urban below food poverty line	675	58,683
Urban between basic needs poverty line	712	77,812
Urban non poor head with non education	423	152,130
Urban non poor head below primary school	689	206,902
Urban non poor head below secondary school	2,463	246,818
Urban non poor head finished secondary school	1,147	530,989
Urban households	6,109	248,604
Total	**31,311**	**181,620**

[a] Number in thousands

Table 3: Data Used for Poverty Analyses

County and Households		Income Bounds	
		Min	**Max**
Ghana			
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			
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			
Rural households		5,144	1,514,029
Urban households		5,796	2,997,328

Table 4: Simulation Results on Percentage Change in Household Income

County and Households	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 female ultra-poor	0.076
Rural female poor	0.091
Rural female non poor	0.012
Rural male ultra-poor	0.006
Rural male poor '	0.007
Rural male non poor	0.000
Urban female ultra-poor	0.002
Urban female poor	0.004
Urban female non poor	0.004
Urban male ultra-poor	0.001
Urban male poor	0.003
Urban male non poor	0.003
Average	**0.017**
Tanzania	
Rural below food poverty line	3.700
Rural between basic needs poverty line	8.200
Rural non poor head with non education	-5.600
Rural non poor head below primary school	-6.800
Nonpoor head below secondary school	5.000
Rural non poor head finished secondary school	6.000
Urban below food poverty line	13.300
Urban between basic needs poverty line	18.200
Urban non poor head with non education	16.300
Urban non poor head below primary school	8.800
Nonpoor head below secondary school	9.400
Urban non poor head finished secondary school	-8.600
Average	**5.658**

Table 5: Results of Poverty Analyses

		Minimum income after simulation	Poverty line after simulation	Poverty head count	Poverty gap [a]		Severity		Change in poverty gap
					Before	After	Before	After	
Ghana (GHC)									
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 (KES)						0.000			
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 (TZS)						0.000			
Rural Households		6,173	86,298	0.380	0.354	0.319	0.330	0.321	-0.099
Urban households		6,955	90,435	0.23	0.21	0.19	0.20	0.19	-0.10

[a] Calculated based on Equation 1 were z is the poverty line and y minimum income of the household groups