4. Assessment of commercial aquaculture's contribution to economic growth and food security: examples

In the following we will use data collected from secondary sources to illustrate the applications of the assessment frameworks developed in the preceding sections. Appendix 5 provides a template of data needed for the assessment.

4.1 ASSESSING COMMERCIAL AQUACULTURE'S CONTRIBUTION TO ECONOMIC GROWTH

4.1.1 Commercial tilapia culture in Honduras

The upper half of Table 2 contains data on two commercial tilapia farms in Honduras (Green and Engle, 2000), which were used to estimate their economic contribution in terms of value added, labour income and employment. The estimation results are reported in the lower part of the table.

Value added

The export-oriented farm generates US$14 628 in value added per ha whereas the domestic farm generates US$4 949. The difference is mainly due to variations in production intensity: while the live-weight yield for the former is 20 233 kg/ha, yield is only 7 756 kg/ha for the latter. Note that the average tilapia weight for the export-oriented farm is 600 g whereas the domestic-oriented farm achieves a weight of 250 g.

The value added per kilo is US$0.72 for the export-oriented farm, higher as compared to the domestic-oriented farm (US$0.64). The difference reflects the extra value-added creation by fillet processing in the export-oriented farm.

The VAD/revenue ratio for the more intensive export-oriented farm is 0.35, a little smaller than that for the domestic-oriented farm (0.38). This mainly reflects a higher feed usage by the former. While feed costs represent 53 percent of the revenue for the export-oriented farm, they account for only 46 percent for the domestic-oriented farm. It should be noted that this does not necessarily imply a smaller contribution by the former because, should feed be domestically produced, value added contained in feeds will accrue to the farms' indirect contribution through linkages.

Labour income

Note that the salary of the farm manager accounts for a large portion of the two farms' labour incomes: For the export-oriented farm, the manager's salary is US$19 166 (37 percent of the total labour income), whereas the manager's salary is US$8 575 (63 percent of total labour income) for the domestic-oriented farm.

The average wage for labourers is US$1 413 for the export farm and US$1 240 for the domestic farm.

The labour income per hectare is US$2 153 and US$2 256 for the export and domestic farms, respectively. Excluding the manager's salary, the labourer's wage per hectare is US$1 354 and US$827 for the export and domestic farms, respectively.

TABLE 2
Annual production, revenues, costs and value added for tilapia production in Honduras

A 24-ha (pond area) farm		A 6-ha (pond area) farm	
Total production (live weight; kg)	485 585	Total production (live weight; kg)	46 535
Fillet (kg): $6.60/kg	135 502	Whole-dressed fish (kg):$1.85/kg	41 942
Whole-dressed fish (kg): $2.05/kg	52 519		
Revenues ($)	1 001 997	Revenues ($)	77 593
Total costs ($)	826 584	Total costs ($)	72 275
Fixed costs ($)	123 988	Fixed costs ($)	10 841
Variable costs ($)	702 596	Variable costs ($)	61 434
Seed ($)	11 382	Seed ($)	2 835
Feed ($)	534 160	Feed ($)	35 849
Fertilizer and Chemical ($)	n.a	Fertilizer and chemical ($)	n.a
Energy ($)	n.a.	Energy ($)	n.a.
Labour ($): 1 manager ($19 166) + 23 labourers ($1 413 each)	51 665	Labour ($): 1 manager ($8 575) + 4 labourers ($1 240 each)	13 535
Other variable costs ($)	105 389	Other variable costs ($)	9 215
Value added ($)	351 066	Value added ($)	29 694
VAD per ha ($)	14 628	VAD per ha ($)	4 949
VAD per kg live weight ($)	0.72	VAD per kg live weight ($)	0.64
VAD/revenue ratio	0.35	VAD/revenue ratio	0.38
Labour income ($)	51 665	Labour income ($)	13 535
Labour income per ha ($)	2 153	Labour income per ha ($)	2 256
Labour income per kg live weight ($)	0.11	Labour income per kg live weight ($)	0.29
Labour income/revenue ratio	0.05	Labour income/revenue ratio	0.17
Employment (No. of jobs)	24	Employment (No. of jobs)	5
jobs per ha	1.00	jobs per ha	0.83
jobs per tonne live weight	0.05	jobs per tonne live weight	0.11

Note: Currency shown is US$.
Source: Green and Engle (2000).

Employment

The 24-ha export farm hires one manager and 23 labourers, with an average of 1 employee per ha. The 6-ha domestic farm hires one manager and 4 labourers, with an average of 0.83 employee per ha.

For each tonne of live weight tilapia produced in the export (domestic) farm, 0.05 (0.11) jobs are created. For each million of revenue generated by the export (domestic) farm, 24 (64) jobs are created. The data indicate that the domestic farm is more labour intensive.

4.1.2 Commercial shrimp culture in Honduras

Data shown in Table 3 were obtained from a shrimp farm survey conducted in Honduras in 1997. The total pond area for the entire industry (78 farms) is 12 261 ha. Small, medium and large farms accounted for 2 551 ha, 4 621 ha and 5 089 ha, respectively.

Table 3 reports information on three representative farms with different sizes (73, 293 and 966 ha respectively) corresponding to small, medium and large farm scenarios.

Production and revenues

Reported annual yields were 675, 724 and 410 kg/ha for the small, medium and large farm scenarios, respectively. Thus the estimated total production quantity for the commercial shrimp culture sector is equal to

$$675 \text{ kg/ha} * 2\,551 \text{ ha} + 724 \text{ kg/ha} * 4\,621 \text{ ha} + 410 \text{ kg/ha} * 5\,089 \text{ ha} = 7\,154\,019 \text{ kg},$$

where the 2 551 ha, 4 621 ha and 5 089 ha are respectively the total area of small, medium, and large farms.

TABLE 3
Annual production, revenues, costs, value added, labour income and employment (per ha) for shrimp culture in Honduras (1997)

73-ha farm		293-ha farm		966-ha farm	
Yield (kg/ha):	675	Yield (kg/ha):	724	Yield (kg/ha):	410
Price ($/kg):	8.15	Price ($/kg):	7.92	Price ($/kg):	7.08
Revenues ($/ha)	5 504	Revenues ($/ha)	5 736	Revenues ($/ha)	2 902
Total costs ($/ha)	5 140	Total costs ($/ha)	4 446	Total costs ($/ha)	2 634
Fixed costs ($/ha)	1 023	Fixed costs ($/ha)	801	Fixed costs ($/ha)	216
Variable costs ($/ha)	4 118	Variable costs ($/ha)	3 646	Variable costs ($/ha)	2 420
Seed ($/ha)	1 309	Seed ($/ha)	1 496	Seed ($/ha)	844
Feed ($/ha)	986	Feed ($/ha)	723	Feed ($/ha)	574
Energy ($/ha)	168	Energy ($/ha)	204	Energy ($/ha)	258
Interest on operating capital ($/ha)	622	Interest on operating capital ($/ha)	258	Interest on operating capital ($/ha)	195
Labour cost ($/ha)	585	Labour cost ($/ha)	600	Labour cost ($/ha)	477
Other variable costs ($/ha)	448	Other variable costs ($/ha)	365	Other variable costs ($/ha)	72
Value added ($/ha)	2 593	Value added ($/ha)	2 948	Value added ($/ha)	1 154
VAD per kg ($/kg)	3.84	VAD per kg ($/kg)	4.07	VAD per kg ($/kg)	2.81
VAD/revenue ratio	0.47	VAD/Revenue ratio	0.51	VAD/Revenue ratio	0.40
Labour income ($/ha)	585	Labour income ($/ha)	600	Labour income ($/ha)	477
Labour income per kg	0.87	Labour income per kg ($/kg)	0.83	Labour income per kg ($/kg)	1.16
Labour income/ revenue ratio	0.11	Labour income/ revenue ratio	0.10	Labour income / revenue ratio	0.16
Total employment (No. of job equivalent)	n.a.	Total employment (No. of job equivalent)	n.a.	Total employment (No. of job equivalent)	190
full time (No. of positions):	n.a.	full time (No. of positions):	n.a.	full time (No. of positions): $3 668 per job	82
part time (hrs):	n.a.	part time (hrs):	n.a.	part time (hrs): 0.62 per hour	259 637
job per ha	n.a.	job per ha	n.a.	job per ha	0.20
jobs per tonne	n.a.	jobs per tonne	n.a.	jobs per tonne	0.48
Job/revenue ratio (job/$ million)	n.a.	Job/revenue ratio (job/$ million)	n.a.	Job/revenue ratio (job/$ million)	67.84

Note: Currency shown is US$.
Source: Valderrama and Engle (2001).

Estimated revenues (per ha) were, respectively, US$5 504, US$5 736, and US$2 902 for the small, medium, and large farms. Thus the estimated total production value for the commercial shrimp culture sector is equal to

US$5 504 * 2 551 + US$5 736 * 4 621 + US$2 902 * 5 089 = US$55 315 038.

Value added

The estimated value added (per ha) were US$2 593, US$2 948 and US$1 154 for the small, medium, and large farms, respectively. Thus the estimated total value added for the commercial shrimp culture sector is equal to

US$2 593 * 2 551 + US$2 948 * 4 621 + US$1 154 * 5 089 = US$26 110 157.

Labour income

The labour income (per ha) were US$585, US$600 and US$477 for the small, medium, and large farms, respectively. Thus the estimated total labour income for the commercial shrimp culture sector is equal to

US$585 * 2 551 + US$600 * 4621 + US$477 * 5089 = US$6 692 388.

On average, one-ha of shrimp culture can provide $546 in labour income.

Employment

Since Valderrama and Engle (2001) reported employment data only for the 966-ha farm, we estimated employment for the 73-ha and 293-ha farms.

Total employment for the 966-ha farm is 190 full-time equivalent jobs, including 82 full-time positions (with an average annual wage of US$3 668) and 259 637 hours of part-time positions (with an average hourly wage of US$0.62) equivalent to 108 full-time jobs (assuming a full-time job is 8 hours per day and 300 days per year). Thus, the 966-ha farm provides 82 + 108 = 190 full time equivalent jobs. Therefore, on average, one ha of large size farms will provide 190/966 = 0.20 jobs.

The total labour income for the 966-ha farm is

US$3 668 * 82 + US$0.62 * 250 637 = US$460 559.

Thus the average wage rate is US$460 559/190 = US$2 424.

Employment estimates can be derived for the medium and small farms from their labour incomes, assuming the same wage rate estimated for the large farms.

The total labour income for the 73-ha farm is US$585 * 73 = US$42 705. Thus the estimated employment is US$42 705/US$2 424 = 18 (jobs); 0.24 jobs per ha on average.

The labour income for the 293-ha farm is US$600 * 293=US$175 800. Thus the estimated employment is US$175 800/US$2 424 = 73 (jobs), 0.25 jobs per ha on average.

Therefore, the estimated total employment provided by the shrimp farming industry is 0.24 * 2 551 + 0.25 * 4 621 + 0.20 * 5 089 = 2 785 (jobs).

4.1.3 Commercial salmon culture in Chile

Table 4 shows data on Atlantic salmon culture in Chile in 2000. The data on yields and revenues were obtained from FishStat (FAO, 2006) whereas the data on production costs are as reported by Bjorndal (2002).

Table 4 shows that around 61 percent of total revenues correspond to value added. Specifically, one kilo of cultured Atlantic salmon can generate US$3.4 in revenue and US$2.07 in value added. Total revenues and value added for Atlantic salmon culture were US$567 449 800 and US$345 059 548, respectively. According to FishStat, total revenue for coho salmon is US$345 650 300. Assuming coho salmon has the same VAD/revenue ratio as Atlantic salmon, then the estimated value added for coho salmon culture would be equal to

US$345 059 548 * US$345 650 300/US$567 449 800 = US$210 185 900.

Therefore, the estimated total value-added for Chile's salmon industry is equal to

US$345 059 548 + US$210 185 900 = US$555 245 448.

TABLE 4
Production, revenues, costs, value added, labour income and employment for Atlantic salmon culture in Chile (2000)

Yield (tonnes):	166 897.00
Price ($/kg):	3.40
Revenues (1000$)	567 449.80
Total costs ($/kg)	1.62
Fixed costs ($/kg)	0.23
Variable costs ($/kg)	1.39
Seed ($/kg)	0.31
Feed ($/kg)	0.79
Labour cost ($/kg)	0.06
Other variable costs ($/kg)	0.24
Value added	
Total VAD	345 059 547.50
VAD per kg ($/kg)	2.07
VAD/revenue ratio	0.61
Labour income	
Total labour income	9 596 577.50
Labour income per kg	0.06
Labour income/revenue ratio	0.0169

Note: Currency shown is US$.
Source: Bjorndal (2002).

4.1.4 Commercial tilapia culture in sub-Saharan Africa

Table 5 presents information on three commercial tilapia farms in SSA; ZAM1 is a 32-ha polyculture (tilapia and carp) farm integrated with pig farming in Zambia; ZAM2 is a 5-ha integrated (tilapia, pigs and ducks) farm in Zambia; and NIG2 is a 3.7-ha polyculture (tilapia and catfish) farm in Nigeria.

On average, ZAM1 produces 3 125 kg/ha/year of tilapia and 1 560 kg/ha/year of carp, generating US$3 960/ha of value added and US$375/ha of labour income. ZAM2 produces 5 000 kg/ha/year of tilapia and generates US$2 900/ha of value added and US$2 186/ha of labour income. NIG2 produces 10 000 kg/ha/year of tilapia and 5 000 kg/ha/year of catfish, and generates US$15 421/ha of value added and US$3 812/ha of labour income.

4.1.5 Commercial catfish culture in sub-Saharan Africa

Table 6 shows data on catfish culture in the Central African Republic and the Democratic Republic of the Congo during the 1980s (de Graaf and Janssen, 1996).

One hectare of monoculture catfish generates US$12 281 in value added, US$7 018 in labour income and 6.7 jobs. One hectare of polyculture catfish (and tilapia) farming generates US$10 271 in value added, US$7 018 in labour income and 6.7 jobs.

4.1.6 Commercial shrimp culture in Madagascar

Table 7 shows information on two shrimp farms in Madagascar (Hishamunda and Manning, 2002). Farm MD1 has a 640-ha production area and produces 5 000 kg/ha of *Penaeus monodon*. Annually, it directly generates US$20 million in value added, US$529 000 in labour income, and 407 jobs. On average, one hectare of production

TABLE 5
Annual production, revenues, costs, value added, labour income and employment for tilapia

ZAM1: 32-ha (production area) farm		ZAM2: 5-ha (production area) farm		NIG2: 3.7-ha (production area) farm	
Yield (kg/ha):	4 685	Yield (kg/ha):	5 000	Yield (kg/ha): 10 000 tilapia + 5 000 catfish	15 000
Price ($/kg):	1.00	Price ($/kg):	1.04	Price ($/kg):	1.68
Revenues ($/ha)	4 688	Revenues ($/ha)	5 198	Revenues ($/ha)	25 224
Total costs ($/ha)	2 254	Total costs ($/ha)	4 619	Total costs ($/ha)	14 735
Fixed costs ($/ha)	1 152	Fixed costs ($/ha)	131	Fixed costs ($/ha)	1 120
Variable costs ($/ha)	1 102	Variable costs ($/ha)	4 488	Variable costs ($/ha)	13 615
Seed ($/ha)	672.22	Seed ($/ha)	260.30	Seed ($/ha)	2 315
Feed ($/ha)	11.02	Feed ($/ha)	1 606.70	Feed ($/ha)	2 723
Fertilizer and chemical ($/ha)		Fertilizer and chemical ($/ha)	4.49	Fertilizer and chemical ($/ha)	408.45
Electricity ($/ha)		Electricity ($/ha)	17.95	Electricity ($/ha)	
Labour cost ($/ha)	374.68	Labour cost ($/ha)	2 185.66	Labour cost ($/ha)	3 812.20
Other variable costs ($/ha)	33.06	Other variable costs ($/ha)	408.41	Other variable costs ($/ha)	4 220.65
Value added		Value added ($/ha)		Value added ($/ha)	
Total VAD	126 742	Total VAD	14 478	Total VAD	57 058
VAD per ha ($/ha)	3 961	VAD per ha ($/ha)	2 896	VAD per ha ($/ha)	15 421
VAD per kg ($/kg)	0.85	VAD per kg ($/kg)	0.58	VAD per kg ($/kg)	1.03
VAD/revenue ratio	0.84	VAD/revenue ratio	0.56	VAD/revenue ratio	0.61
Labour income		Labour income		Labour income	
Total labour income ($)	11 990	Total labour income ($)	10 928	Total labour income ($)	14 105
Labour income per worker ($/job)		Labour income per worker ($/job)		Labour income per worker ($/job)	
Labour income per ha ($/ha)	375	Labour income per ha ($/ha)	2 186	Labour income per ha ($/ha)	3 812
Labour income per kg	0.08	Labour income per kg ($/kg)	0.44	Labour income per kg ($/kg)	0.25
Labour income/ revenue ratio	0.08	Labour income/ revenue ratio	0.42	Labour income/ revenue ratio	0.15
Employment		Employment		Employment	
Total jobs		Total jobs	35	Total jobs	
Jobs per ha		Jobs per ha		Jobs per ha	
Jobs per tonne		Jobs per tonne		Jobs per tonne	
Job/revenue ratio (job/$ million)		Job/revenue ratio (job/$ million)		Job/revenue ratio (job/$ million)	

Note: Currency shown in US$.

Data source: Hishamunda and Manning (2002).

area generates US$33 000 in value added, US$827 in labour income, and 0.64 jobs. Farm MD2 has a 138-ha production area and grows 9 058 kg/ha of *P. monodon*. Annually, it directly generates US$5.8 million in value added, US$475 000 in labour income, and 301 jobs. On average, one ha of production area generates US$42 000 in value added, US$3 443 in labour income, and 2.18 jobs.

4.1.7 Commercial aquaculture's contribution to GDP in 14 sub-Saharan African countries

Using the VAD/revenue ratios estimated in the preceding examples in tandem with data on production value provided by FishStat (FAO, 2006), the annual value added of commercial aquaculture was estimated for 14 SSA countries from 1984 to 2000. These estimates were subsequently used to calculate the annual share of commercial aquaculture's value-added in the GDP of each country. Results are reported in Table 8.

The species covered include tilapia, catfish, shrimp and trout, which are representative for most of the countries. Exceptions include Tanzania, which has large seaweed production, and Cameroon, Kenya, Madagascar and Rwanda which have non-trivial carp culture.

TABLE 6
Production, revenues, costs, value added, labour income and employment for catfish culture in SSA

	Monoculture	Polyculture: catfish + tilapia
Pond size (ha):	0.04	0.04
Yield (kg):	720.00	468.00
Price ($/kg):	2.81	1.98
Revenues ($)	2 021.05	926.26
Total costs ($/kg)		
Fixed costs ($/kg)		
Variable costs ($/kg)	1 810.53	796.14
Seed ($/kg)	252.63	53.56
Feed ($/kg)	1 061.05	344.84
Labour cost ($/kg)	280.70	280.70
Other variable costs ($/kg)	216.14	117.04
Value added		
Total VAD ($)	491.23	410.82
VAD per ha ($/ha)	12 280.70	10 270.53
VAD per kg ($/kg)	0.68	0.88
VAD/revenue ratio	0.24	0.44
Labour income		
Total labour income	280.70	280.70
Labour income per ha ($/ha)	7 017.54	7 017.54
Labour income per kg	0.39	0.60
Labour income/revenue ratio	0.14	0.30
Employment		
Total working days	80.00	80.00
Wage rate ($/day)	3.51	3.51
job per ha	6.67	6.67
jobs per tonne	0.37	0.57
Job/revenue ratio (job/$ million)	13.19	28.79

Note: Currency shown is US$.
Data source: de Graaf and Janssen (1996).

The VAD/revenue ratios needed in the estimation were obtained from the examples discussed in previous sections. According to section 4.1.3, the VAD/revenue ratio for salmon culture in Chile is 61 percent, which is used as a representative VAD/revenue ratio for trout. The average VAD/revenue ratio for the three tilapia farms in section 4.1.4 is 67 percent, which is used as a representative VAD/revenue ratio for tilapia. Similarly, the representative ratios for catfish and shrimp are respectively 34 and 61 percent, which are calculated based on the example farms in section 4.1.5 and 4.1.6 respectively. Note that, since these "representative" ratios may not be really representative for every country in every year, results in Table 8 may not be accurate. We present them for illustration purposes only.

The bold (colour) numbers in Table 8 represent VAD/GDP ratios that are higher than previous years. For easier visualization, we calculate the average VAD/GDP ratios for the 14 countries in the sample period and plot them in Figure 3. For comparison purposes, the corresponding output/GDP ratios are also shown in Figure 3.

TABLE 7
Annual production, revenues, costs, value added, labour income and employment for shrimp culture in Madagascar

MD1: 640-ha (production area) farm		MD2: 138-ha (production area) farm	
Yield (kg/ha):	5 000	Yield (kg/ha):	9 058
Price ($/kg):	9.65	Price ($/kg):	8.46
Revenues ($/ha)	48 269.00	Revenues ($/ha)	76 644.00
Total costs ($/ha)	22 235.00	Total costs ($/ha)	39 390.00
Fixed costs ($/ha)	5 703.00	Fixed costs ($/ha)	1 137.00
Variable costs ($/ha)	16 532.00	Variable costs ($/ha)	38 252.00
Seed ($/ha)	2 149.16	Seed ($/ha)	4 207.72
Feed ($/ha)	9 919.20	Feed ($/ha)	24 863.80
Fertilizer and chemical ($/ha)	661.28	Fertilizer and chemical ($/ha)	382.52
Electricity ($/ha)	1 322.56	Electricity ($/ha)	3 442.68
Labour cost ($/ha)	826.60	Labour cost ($/ha)	3 442.68
Other variable costs ($/ha)	1 818.52	Other variable costs ($/ha)	2 295.12
Value added		Value added ($/ha)	
Total VAD	20 840 704	Total VAD	5 773 186
VAD per ha ($/ha)	32 564	VAD per ha ($/ha)	41 835
VAD per kg ($/kg)	6.51	VAD per kg ($/kg)	4.62
VAD/revenue ratio	0.67	VAD/revenue ratio	0.55
Labour income		Labour income	
Total labour income ($)	529 024	Total labour income ($)	475 090
Labour income per worker ($/job)	1 300	Labour income per worker ($/job)	1 578
Labour income per ha ($/ha)	827	Labour income per ha ($/ha)	3 443
Labour income per kg	0.17	Labour income per kg ($/kg)	0.38
Labour income/revenue ratio	0.02	Labour income/revenue ratio	0.04
Employment		Employment	
Total jobs	773	Total jobs	482
No. of jobs for farming	407	No. of jobs for farming	301
No. of jobs for processing	366	No. of jobs for processing	181
Farming jobs per ha	0.64	job per ha	2.18
Farming jobs per tonne	0.13	jobs per tonne	0.24
Farming job/revenue ratio (job/$ million)	13.17	job/revenue ratio (job/$ million)	28.46

Note: Currency shown is US$.
Data source: Hishamunda and Manning (2002).

Table 8 and Figure 3 shows that – we should stress again that the results may not be accurate – although commercial aquaculture's direct contribution to GDP is small (less than 0.05%), it is on an upward trend since the 1990s. Note that the similarity between the dynamics of the VAD/GDP ratio and the output/GDP ratio results primarily from our assumption of a constant VAD/revenue ratio for each species, meaning that potential changes in VAD/revenue ratio over time are disregarded. Yet the estimations do capture the change in the composition of aquaculture products over time, which explains why the VAD/GDP ratio went down from 1995 to 1996 whereas the output/GDP ratio was up.

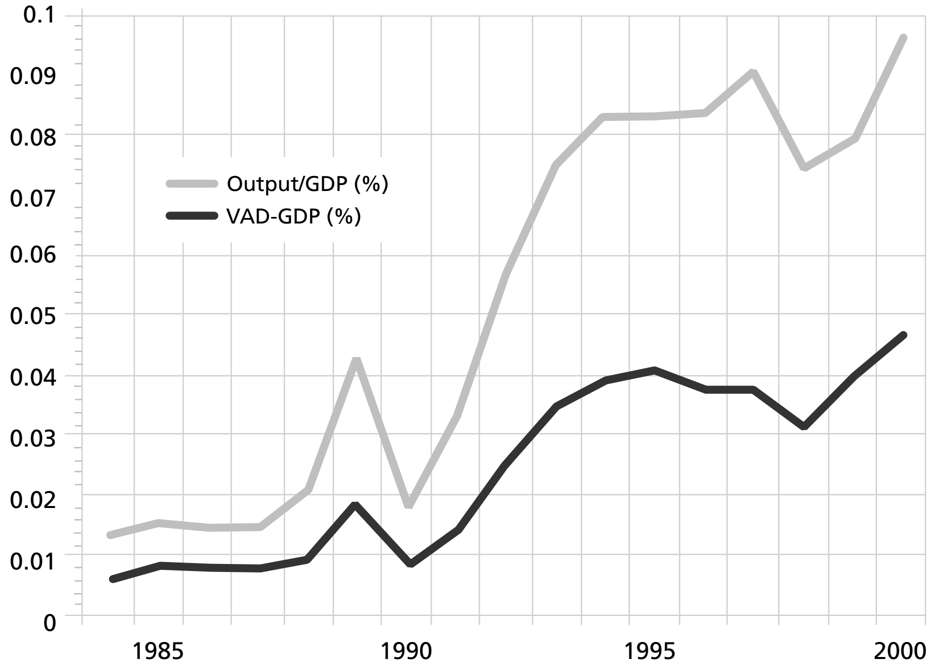
Recall that commercial aquaculture's VAD represents only its direct contribution to GDP. An example showing total (direct and indirect) contribution is presented in the next section.

TABLE 8
Commercial aquaculture's value-added as a percentage of GDP: 14 SSA countries 1984–2000 *(in percentage)*

Year	Cameroon	Central African Republic	Democratic Republic of the Congo	Congo	Côte d'Ivoire	Ghana	Kenya	Madagascar	Malawi	Nigeria	Rwanda	United Republic of Tanzania	Zambia	Zimbabwe
1984	0.0020	0.0444	0.0012	0.0025	0.0002	0.0064	0.0055	0.0114	0.0062	0.0087	0.0021	n.a.	0.0179	0.0055
1985	0.0009	0.0445	0.0027	0.0032	0.0006	0.0051	0.0053	0.0096	0.0093	0.0138	0.0017	n.a.	0.0263	0.0058
1986	0.0007	0.0331	0.0097	0.0050	0.0022	0.0038	0.0048	0.0064	0.0084	0.0157	0.0024	n.a.	0.0295	0.0057
1987	0.0008	0.0159	0.0113	0.0053	0.0024	0.0041	0.0039	0.0069	0.0078	0.0149	0.0032	n.a.	0.0278	0.0052
1988	0.0010	0.0136	0.0092	0.0044	0.0017	0.0047	0.0108	0.0066	0.0076	0.0202	0.0021	0.0003	0.0191	0.0046
1989	0.0011	0.0133	0.0052	0.0034	0.0015	0.0037	0.0123	0.0060	0.0070	0.0566	0.0019	0.0048	0.0187	0.0041
1990	0.0010	0.0135	0.0047	0.0029	0.0011	0.0039	0.0112	0.0086	0.0054	0.0158	0.0101	0.0061	0.0273	0.0039
1991	0.0008	0.0143	0.0057	0.0036	0.0025	0.0047	0.0113	0.0151	0.0057	0.0348	0.0029	0.0060	0.0586	0.0035
1992	0.0008	0.0358	0.0066	0.0124	0.0030	0.0053	0.0106	0.0598	0.0075	0.0524	0.0023	0.0061	0.1115	0.0044
1993	0.0008	0.0310	0.0058	0.0217	0.0053	0.0066	0.0196	0.1225	0.0071	0.0787	0.0024	0.0043	0.1823	0.0048
1994	0.0006	0.0295	0.0082	0.0124	0.0015	0.0083	0.0193	0.1452	0.0113	0.0659	0.0075	0.0035	0.2379	0.0047
1995	0.0008	0.0120	0.0086	0.0093	0.0034	0.0075	0.0195	0.2116	0.0094	0.0641	0.0056	0.0044	0.2607	0.0049
1996	0.0007	0.0088	0.0084	0.0062	0.0084	0.0074	0.0070	0.2587	0.0057	0.0403	0.0070	0.0036	0.3830	0.0043
1997	0.0008	0.0064	0.0135	0.0063	0.0033	0.0058	0.0013	0.3710	0.0055	0.0473	0.0065	0.0028	0.2280	0.0044
1998	0.0008	0.0061	0.0071	0.0087	0.0056	0.0241	0.0009	0.2769	0.0081	0.0462	0.0066	0.0026	0.1324	0.0064
1999	0.0007	0.0121	0.0081	0.0088	0.0066	0.0377	0.0018	0.3537	0.0219	0.0571	0.0134	0.0025	0.1358	0.0073
2000	0.0005	0.0127	0.0074	0.0071	0.0092	0.1122	0.0054	0.4421	0.0226	0.0533	0.0123	0.0019	0.1374	0.0056
2001	0.0005	0.0134	0.0070	0.0083	0.0086	0.1270	0.0105	0.4099	0.0257	0.0430	0.0168	0.0032	0.1211	0.0050

Note: n.a. = not available.

FIGURE 3
Average commercial aquaculture's VAD/GDP (output/GDP) ratios for 14 SSA countries (1984–2000)



4.1.8 Total economic contribution of fishing and fish farming in Tanzania

Data

With the aid of the social accounting matrix (SAM) for Tanzania (Thurlow and Wobst, 2003), the total (direct and indirect) contribution of fishing and fish farming to Tanzania's economy was estimated – part of the data and estimation results are reported in Table 9. Since the available SAMs do not disaggregate fishing and fish farming, additional data are needed to estimate the economic contribution of commercial aquaculture. Yet the methodology will be the same.

Similar to input-output tables, a social accounting matrix is a consistent data framework for describing the intersectoral relationships of an economy, which allows us to apply the two-sector model developed in section 2.2.1 to estimate the contribution of fishing and fish farming through their own production and linkage impacts.

Data availability allows us to estimate the contribution of fishing and fish farming to Tanzania's economy in each of the four years in the period 1998–2001 and hence evaluate its contribution to economic growth.

Contribution to GDP

The real GDP growth rates for Tanzania in 1999, 2000 and 2001 were 7.78, 5.54 and 7.92 percent, respectively.

The value added generated by own production of fishing and fish farming was 4.26, 4.28, 4.18 and 4.09 percent of GDP in 1998, 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the total "contribution" of the sector is 15.28, 15.53, 14.73 and 14.23 percent of GDP in 1998, 1999, 2000 and 2001, respectively.

Fishing and fish farming directly contributed 4.53, 2.36 and 2.93 percent of GDP growth in 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the sector contributed (directly and indirectly) 18.73, 0.32 and 7.93 percent of GDP growth in 1999, 2000 and 2001, respectively.

TABLE 9
Economic contribution of fish and fish farming in Tanzania (1998–2001)

Year	1998	1999	2000	2001
Entire economy				
Consumer price index (1995 = 100)	158.42	170.92	181.04	190.34
Total output (million Tanzania shillings)	10 217.83	11 812.46	13 197.75	14 861.86
GDP (million Tanzania shillings)	5 140.31	5 977.10	6 681.85	7 581.22
GDP growth	n.a.	7.78%	5.54%	7.92%
Total labour income (million Tanzania shillings)	3 048.55	3 556.88	3 952.55	4 502.89
Total labour income growth	n.a.	8.14%	4.91%	8.36%
Total consumption (million Tanzania shillings)	4 905.31	5 662.28	6 065.65	6 911.30
Total employment	?	?	?	?
Agriculture				
Agri output (million Tanzania shillings)	3 084.28	3 573.57	3 960.89	4 456.54
Agri value added (million Tanzania shillings)	2 491.58	2 885.65	3 175.36	3 569.87
Agri labour income (million Tanzania shillings)	1 757.24	2 029.46	2 181.58	2 469.49
Agri consumption (million Tanzania shillings)	1 924.72	2 238.74	2 390.94	2 701.68
Agri employment	?	?	?	?
Commercial fishing and fish farming				
Fish output (million Tanzania shillings)	243.08	282.87	310.37	346.11
Fish VAD (million Tanzania shillings)	219.14	255.96	279.38	310.03
Fish labour income (million Tanzania shillings)	115.40	135.55	144.45	161.77
Fish consumption (million Tanzania shillings)	190.44	225.67	241.78	271.37
Fish sector's intermediate purchases from ROE (million Tanzania shillings)	21.69	23.39	27.20	31.41
Fish sector's intermediate sales to ROE (million Tanzania shillings)	3.33	6.01	10.54	9.40
v_1 (fish sector's VAD/output ratio)	0.9015	0.9049	0.9001	0.8957
v_2 (ROE VAD/output ratio)	0.4934	0.4962	0.4968	0.5009
a_{21} (fish sector's intermediate purchases from ROE/output ratio)	0.0892	0.0827	0.0876	0.0908
a_{22} (ROE intra-industry transaction/output ratio)	0.3535	0.3595	0.3762	0.3639
$_t$ (total consumption/GDP ratio)	0.9543	0.9473	0.9078	0.9116
$_q$ (share of fish products in total consumption)	0.0388	0.0399	0.0399	0.0393
$_v$ (share of fish VAD to GDP)	0.0426	0.0428	0.0418	0.0409
$_w$ (share of fish labour income in total labour income)	0.0379	0.0381	0.0365	0.0359
$_e$ (share of fish employment in the total employment)				
Fish sector's multipliers				
Fish sector's VAD multiplier	3.58	3.63	3.52	3.48
Fish sector's labour income multiplier	4.04	4.07	4.03	3.96
Fish sector's employment multiplier	?	?	?	?
Fish sector's economic contribution				
Contribution to value added				
direct contribution to VAD (million Tanzania shillings)	219.14	255.96	279.38	310.03
percentage to GDP	4.26%	4.28%	4.18%	4.09%
direct VAD growth	n.a.	8.26%	3.05%	5.55%
direct contribution to GDP growth	n.a.	4.53%	2.36%	2.93%
total contribution to VAD (million Tanzania shillings)	785.42	928.16	984.25	1 078.89
percentage to GDP	15.28%	15.53%	14.73%	14.23%
direct + indirect VAD growth	n.a.	9.53%	0.12%	4.26%
direct + indirect contribution to GDP growth	n.a.	18.73%	0.32%	7.93%
Contribution to labour income				
direct contribution to labour income (million Tanzania shillings)	115.40	135.55	144.45	161.77
percentage to total labour income	3.79%	3.81%	3.65%	3.59%
direct labour income growth	n.a.	8.88%	0.61%	6.52%
direct contribution to total labour income growth	n.a.	4.13%	0.47%	2.85%
total contribution to labour income (million Tanzania shillings)	465.80	552.33	582.22	640.81
percentage to total labour income	15.28%	15.53%	14.73%	14.23%
direct + indirect labour income growth	n.a.	9.90%	-0.48%	4.69%
direct + indirect contribution to total labour income growth	n.a.	18.59%	-1.52%	8.26%
Contribution to employment				
direct contribution to employment	?	?	?	?
percentage to total employment	?	?	?	?
total contribution to employment	?	?	?	?
percentage to total employment	?	?	?	?

Data source: Thurlow and Wobst (2003).

Contribution to total labour income

The growth rates of real labour income for Tanzania in 1999, 2000 and 2001 were 8.14, 4.91 and 8.36 percent, respectively.

Labour incomes generated by own production of fishing and fish farming were 3.79, 3.81, 3.65 and 3.59 percent of total labour income in 1998, 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the total "contribution"

TABLE 10
Energy and protein contents of several aquatic products

Species	Edible content per kilo of live weight (kg)	Protein content per kilo of fillet (kg)	Protein content per kilo of live weight (kg)	Energy content per kilo of fillet (kcal)	Energy content per kilo of live weight (kcal)
Common carp	0.35	0.15	0.053	1 270	445
Tilapia	0.25	0.19	0.048	1 230	308
Catfish	0.30	0.16	0.048	1 350	405
Shrimp	0.48	0.20	0.096	1 060	509
Rainbow trout	0.35	0.21	0.074	1 380	483
Salmon (Atlantic)	0.40	0.20	0.080	1 830	732
Salmon (coho)	0.40	0.21	0.084	1 600	640

Data sources: Billard (1999); Fontaínhas-Fernandes *et al.* (1999); NFI (2008); USDA/ARS (2008).

of the sector was 15.28, 15.53, 14.73 and 14.23 percent of total labour income in 1998, 1999, 2000 and 2001, respectively. Note that the ratios are identical to the sector's total GDP contribution. This results from aggregating the rest of the economy as one sector in the two-sector model.

Fishing and fish farming directly contributed 4.13, 0.47 and 2.85 percent of labour income growth in 1999, 2000 and 2001, respectively. When linkage impacts are taken into consideration, the sector contributed (directly and indirectly) 18.59, 1.52 and 8.23 percent of labour income growth in 1999, 2000 and 2001.

Contribution to total employment

Since the social accounting matrices provided in Thurlow and Wobst (2003) do not provide employment information, other sources must be consulted to estimate fishing and fish farming's contribution to employment, which is yet to be completed. However, the above estimations imply that the shares of the sector's direct and indirect employment as a contributors to total employment will be identical to the shares of direct and indirect GDP (or labour income) contribution; that is, 15.28, 15.53, 14.73 and 14.23 percent for 1998, 1999, 2000 and 2001.

4.2 EXAMPLES OF CONTRIBUTION TO FOOD SECURITY

4.2.1 Contribution to food availability (protein supply)

Data

We have gathered data on the energy and protein content of several common aquaculture species from a variety of sources. Table 10 summarizes this information.

In addition to statistics on commercial aquaculture production, data in Table 10 allow us to estimate commercial aquaculture's contribution to food energy and protein supply. Since aquatic products are not a major source of food energy supply, focus is made on its contribution to protein supply.

Results

Table 11 shows the results of the estimation. We consider commercial aquaculture's contribution to protein supply in 14 SSA countries during three time periods: 1986–1990, 1991–1995, and 1996–2000.

Data for aquaculture production were obtained from FishStat (FAO, 2006). We considered only the species covered in Table 10, which generally include most of aquaculture production. Data on the countries' total fish and animal protein supplies come from FAO's food balance sheets (FAO, 2008).

To measure the importance of fish as a source of proteins, we calculated the contribution of fish to the total supply of animal protein (first set of columns in Table 11). Fish is a fairly important animal protein source in the 14 SSA countries: on average, around 30 percent of animal protein supply comes from aquatic products.

TABLE 11
Aquaculture's share of fish and animal protein

Countries	Fish/animal protein ratio (%)				Aquaculture percentage of total fish protein			Aquaculture percentage of total animal protein		
	1986–1990	*1991–1995*	*1996–2000*	*Average*	*1986–1990*	*1991–1995*	*1996–2000*	*1986–1990*	*1991–1995*	*1996–2000*
Ghana	63	59	64	62	0.04	0.05	0.29	0.03	0.03	0.19
Congo	61	48	48	52	0.09	0.10	0.08	0.06	0.05	0.04
Malawi	48	42	40	43	0.05	0.03	0.17	0.02	0.01	0.07
Côte d'Ivoire	43	39	37	40	0.08	0.19	0.31	0.03	0.08	0.12
United Republic of Tanzania	37	32	33	34	0.02	0.04	0.02	0.01	0.01	0.01
Democratic Rep. of the Congo	34	33	32	33	0.12	0.11	0.08	0.04	0.04	0.03
Nigeria	36	26	23	28	0.61	0.82	0.58	0.22	0.22	0.13
Cameroon	28	24	25	26	0.04	0.02	0.02	0.01	0.01	0.01
Zambia	27	25	23	25	0.72	2.25	2.45	0.19	0.56	0.57
Madagascar	15	16	15	15	0.12	1.46	4.28	0.02	0.23	0.65
Kenya	10	11	10	10	0.28	0.45	0.11	0.03	0.05	0.01
Central African Republic	12	10	8	10	0.33	0.78	0.37	0.04	0.08	0.03
Zimbabwe	7	10	11	9	0.37	0.24	0.24	0.02	0.03	0.03
Rwanda	3	5	5	4	1.25	0.66	1.89	0.04	0.03	0.09
Average	**31**	**28**	**26**	**29**	**0.31**	**0.44**	**0.51**	**0.06**	**0.09**	**0.10**

One notable fact is that the contribution of fish to the animal protein supply decreased from 31 percent during the second half of the 1980s to 26 percent during the second half of the 1990s. Unfortunately, this does not imply a shift to superior protein sources. Rather, the protein supply in SSA countries declined during the period under study; the declining fish/animal protein ratio implies that fish protein supply has been falling at even a faster rate.

The last two column sets in Table 11 show the contribution of aquaculture to fish and animal protein supply, respectively. Because aquaculture is severely underdeveloped in the region, it contributes less than one percent of total fish protein supply. Nevertheless, these findings highlight the importance of aquaculture development. As population growth in the region places increased pressure on food supply in general and fish supply in particular, capture fisheries will eventually not be able to meet the full demand for fish protein; hence aquaculture must assume an important role in filling the protein gap. A positive development in this regard is that aquaculture's contribution has been increasing during the sample period.

4.2.2 Contribution to food access

To estimate aquaculture's contribution to food access, we calculated aquaculture's labour income indices for 11 SSA countries during 1986–2000. First we estimated total labour income provided by aquaculture activities in each year. We used the labour income-revenue ratios estimated from the examples in sections 4.14–4.16 together with the revenue data provided by FishStat to estimate labour incomes. Limited by the availability of labour income-output ratios, we considered only tilapia, catfish and

TABLE 12
Real labour income as an indicator of aquaculture's contribution to food access

Year	Central African Republic	Congo	Ghana	Kenya	Madagascar	Malawi	Nigeria	Rwanda	United Rep. of Tanzania	Zambia	Zimbabwe
1986	146	55	9	45	8	75	19	51	21	40	116
1987	73	63	11	43	10	65	40	61	21	44	99
1988	69	53	13	133	10	65	41	40	11	27	100
1989	71	47	10	149	10	63	127	37	151	21	100
1990	73	40	11	151	12	51	43	185	185	26	98
1991	79	52	15	132	11	59	103	58	181	64	110
1992	184	198	18	109	93	64	229	49	193	97	91
1993	161	227	25	187	101	67	182	43	138	145	80
1994	162	159	33	163	187	88	116	64	114	192	83
1995	68	120	27	205	145	80	76	78	143	214	82
1996	48	91	29	129	146	57	47	98	118	285	86
1997	33	88	23	20	315	57	52	97	101	182	89
1998	33	92	96	15	168	86	41	90	93	99	124
1999	72	112	165	37	219	234	217	237	96	102	130
2000	76	150	569	92	235	258	262	221	79	114	101

shrimp, which are the most important species in most of the sample countries. An additional problem is that the ratios may not be representative; hence the estimated labour incomes may not be accurate.

Since the estimated labour incomes are in nominal terms, we deflated them with food price indices to provide a measure of their food purchasing power. These labour income indices can then be interpreted as indicators of aquaculture's contribution to food access.

Results are shown in Table 12. Labour incomes have fluctuated over time, with a recent trend towards increasing incomes.

4.2.3 Contribution to short-term food security

We used the average percentage deviation from an estimated trend as a measure of the volatility of aquaculture's protein supply, which is one indicator of its potential contribution to short-term food security.

We first estimated aquaculture's protein supply in the sample periods. Then we used least-squares regression to determine a linear time trend for the data. The differences between actual supply and the supply trend were viewed as random transitory shocks. The ratio between the residuals and the corresponding supply trend prediction provided percentage deviations; averages were subsequently computed based on the absolute values of the percentage deviations over the sample periods. The resulting volatility measure is similar to $\tilde{\sigma}_{X_t}$ in indicator [9.1.2].

The first column in Table 13 shows the average volatility (during 1990–2000) of commercial aquaculture's production value in 12 SSA countries. In aggregate, the average volatility is 28 percent. Yet, the dispersion is uneven: the Central African Republic, Kenya, Rwanda and Zambia have large production volatility; the Democratic

TABLE 13
Aquaculture's contribution to transitory food security (1990-2000)

Countries	Average percentage deviation from trend		Correlations among different sources of protein supply	
	Commercial aquaculture's production value *(%)*	Commercial aquaculture's protein supply *(%)*	Aquaculture and total fish protein	Aquaculture and total animal protein
Cameroon	14.61	17.72 (-)	0.93	0.87
Central African Republic	44.73	36.64 (+)	-0.58	-0.10
Democratic Rep. of the Congo	6.57	3.29 (+)	0.24	0.26
Congo	34.91	26.76 (-)	0.65	0.19
Côte d'Ivoire	32.10	38.04 (+)	0.09	0.27
Kenya	61.90	52.10 (+)	0.43	0.08
Madagascar	3.57	23.93 (-)	-0.21	-0.08
Nigeria	17.90	25.27 (+)	-0.73	-0.68
Rwanda	54.79	47.30 (+)	0.10	-0.79
United Rep. of Tanzania	12.72	23.31 (+)	0.19	0.17
Zambia	49.22	18.88 (-)	0.64	0.68
Zimbabwe	5.18	4.92 (+)	-0.10	0.47
Average	**28.18**	**26.51**	**0.14**	**0.11**

Republic of the Congo, Madagascar and Zimbabwe have low production volatility. Low volatility implies stable incomes and jobs for employees and hence a greater contribution to the food-access dimension of short-term food security.

The second column in Table 13 shows the average volatility for commercial aquaculture's protein supply, with an average 27 percent deviation from the trend for the 12 countries. To examine whether commercial aquaculture contributes to stabilize total animal protein supply, we calculated the average volatility for total animal protein supply with and without commercial aquaculture. A positive (negative) sign in the parentheses in the second column indicates that commercial aquaculture makes the total protein supply less (more) volatile. Results show that commercial aquaculture plays a stabilizing role in the supply of animal protein in most of the sample countries except Cameroon, Congo, Madagascar and Zambia.

Another measure of the role of commercial aquaculture in stabilizing protein supply is provided by the correlations between its own protein supply and the total supply of fish protein or animal protein (last two columns in Table 13). On average, the correlations are small (0.14 and 0.11 for total fish and animal protein supply, respectively), which implies a general stabilizing role for commercial aquaculture. Again, the dispersion across countries is large. Nigeria and Rwanda have correlations between commercial aquaculture protein supplies and total animal protein supplies close to -1, which implies a potentially large contribution to short-term food security. On the contrary, Cameroon, Zambia and Zimbabwe show correlations close to 1 and hence imply a potentially small contribution from aquaculture to short-term food security.

Note that Madagascar's commercial aquaculture has been identified (in the second column of Table 13) as a destabilizing factor for total animal protein supply whereas a negative correlation is shown in the fourth column, which implies otherwise. This is not a contradiction. The negative correlation in the fourth column implies a high frequency for commercial aquaculture and total animal protein supplies to deviate from their trends in opposite directions in a given period. Yet, if the magnitudes of their low-frequency, positively-correlated deviations are sufficiently large, commercial aquaculture will still play a destabilizing role for total protein supply.

Another caveat is in order. We assumed linear trends during the sample period. However, if the trends are not linear for reasons such as structural changes in commercial aquaculture or other protein supply sources, then we would have interpreted changes in long-term trends as short-term volatilities. Therefore, an adequate choice of sample periods is essential.