Appendix 1

Derivation of the value added multiplier M_v

By total differentiating simultaneous equations (1) – (8), we obtain

$$dX_1 = a_{11}dX_1 + a_{12}dX_2 + dC_1 + dG_1 + dN_1 \quad \text{(A.1)}$$

$$dX_2 = a_{21}dX_1 + a_{22}dX_2 + dC_2 + dG_2 + dN_2 \quad \text{(A.2)}$$

$$dV_1 = v_1 dX_1 \quad \text{(A.3)}$$

$$dV_2 = v_2 dX_2 \quad \text{(A.4)}$$

$$dY = dV_1 + dV_2 \quad \text{(A.5)}$$

$$dC = \eta dY \quad \text{(A.6)}$$

$$dC_1 = \theta dC \quad \text{(A.7)}$$

$$dC_2 = (1-\theta)dC \quad \text{(A.8)}$$

We first derive dY/dX_1, which measures the change in GDP (dY) caused by a one-unit change in commercial aquaculture's output ($dX_1 = 1$).

Using equations (A.6) and (A.8) to replace dC, we obtain

$$dC_2 = \eta(1-\theta)dY \quad \text{(A.9)}$$

Using equations (A.3), (A.4) and (A.5) to replace dV_1 and dV_2, we obtain

$$dX_2 = v_2^{-1}dY - v_2^{-1}v_1 dX_1 \quad \text{(A.10)}$$

Assume that the change in commercial aquaculture's production (i.e. dX_1) does not affect government's consumption of the ROE's products (i.e. $dG_2 = 0$) and the net export of the ROE's products ($dN_2 = 0$). Then equation (A.2) can be reduced to

$$dX_2 = a_{21}dX_1 + a_{22}dX_2 + dC_2 \quad \text{(A.2')}$$

Substituting equation (A.9) and (A.10) into (A.2'), we obtain
which can be rearranged into

$$(1-a_{22})(v_2^{-1}dY - v_2^{-1}v_1 dX_1) - a_{21}dX_1 - \eta(1-\theta)dY = 0$$

We now derive the value added multiplier $M_v = dY/dV_1$, which measures the change

$$\frac{dY}{dX_1} = \frac{(1-a_{22})v_1 + a_{21}v_2}{1-a_{22}-\eta(1-\theta)v_2} \quad \text{(A.11)}$$

in GDP (dY) that corresponds to a one-unit change in aquaculture's value added ($dV_1 = 1$).

$$M_v = \frac{dY}{dV_1}$$

$$= \frac{dY}{v_1 dX_1} \quad \text{(using A.3)} \quad \text{(A.12)}$$

$$= \frac{1-a_{22}+a_{21}(v_2/v_1)}{1-a_{22}-\eta(1-\theta)v_2} \quad \text{(using A.11)}$$

Appendix 2

Derivation of the employment multiplier M_e

The employment multiplier $M_e = dE^{total}/dE^{ca}$ measures the change in total employment for the entire economy (dE^{total}) that corresponds to a one-unit change in commercial aquaculture's employment ($dE^{ca} = 1$).

Let

$$e^{total} = Y / E^{total} \tag{A.13}$$

denote GDP per worker.

Let

$$e^{ca} = X_1 / E^{ca} \tag{A.14}$$

denotes output per worker for commercial aquaculture.
Assume e^{total} and e^{ca} are constant; then we obtain

$$\begin{aligned}
M_e &= \frac{dE^{total}}{dE^{ca}} \\
&= \frac{e^{ca}}{e^{total}} \frac{dY}{dX_1} && \text{(using A.13 and A.14)} \\
&= \frac{e^{ca}}{e^{total}} v_1 M_v && \text{(using A.12)} \qquad \text{(A.15)} \\
&= \frac{X_1 / E^{ca}}{Y / E^{total}} \frac{V_1}{X_1} M_v && \text{(using A.13, A.14 and the definition of } v_1\text{)} \\
&= \frac{\varpi}{\varepsilon} M_v
\end{aligned}$$

where $\varpi = V_1 / Y$ measures the share of commercial aquaculture's value added in GDP; and $\varepsilon = E^{ca} / E^{total}$ measures the share of commercial aquaculture employment in total employment.

Appendix 3
Derivation of the labour income multiplier M_w

The labour income multiplier $M_w = dW^{total} / dW^{ca}$ measures the change in total labour income for the entire economy (dW^{total}) that corresponds to a one-unit change in commercial aquaculture's labour income ($dW^{ca} = 1$).

Let

$$l^{total} = W^{total} / Y \qquad \text{(A.16)}$$

denote the share of labour income in GDP.

Let

$$l^{ca} = W^{ca} / V_1 \qquad \text{(A.17)}$$

denotes the share of labour income in value added for commercial aquaculture. Assume l^{total} and l^{ca} are constant; then we obtain the following.

$$\begin{aligned} M_w &= \frac{dW^{total}}{dW^{ca}} \\ &= \frac{l^{total}}{l^{ca}} \frac{dY}{dV_1} && \text{(using A.16 and A.17)} \\ &= \frac{W^{total} / Y}{W^{ca} / V_1} M_v && \text{(using A.12, A.16 and A.17)} \qquad \text{(A.18)} \\ &= \frac{V_1 / Y}{W^{ca} / W^{total}} M_v \\ &= \frac{\varpi}{\omega} M_v \end{aligned}$$

where $\varpi = V_1 / Y$ measures the share of commercial aquaculture's value added in GDP and $\omega = W^{ca} / W^{total}$ measures the share of commercial aquaculture labour income in total labour income.

Appendix 4
Derivation of the tax multiplier M_t

The tax multiplier $M_{\tau} = dT^{total} / dT^{ca}$ measures the change in total tax revenues for the entire economy (dT^{total}) that corresponds to a one-unit change in commercial aquaculture's tax payment $(dT^{ca} = 1)$.

Let

$$t^{total} = T^{total} / Y \tag{A.19}$$

denote the share of tax revenues in GDP.

Let

$$t^{ca} = T^{ca} / V_1 \tag{A.20}$$

denotes the share of tax payments in value added for commercial aquaculture. Assume t^{total} and t^{ca} are constant; then we obtain the following:

$$\begin{aligned} M_{\tau} &= \frac{dT^{total}}{dT^{ca}} \\ &= \frac{t^{total}}{t^{ca}} \frac{dY}{dV_1} && \text{(using A.18 and A.19)} \\ &= \frac{T^{total} / Y}{T^{ca} / V_1} M_v && \text{(using A.12, A.18 and A.19)} \\ &= \frac{V_1 / Y}{T^{ca} / T^{total}} M_v \\ &= \frac{\varpi}{\tau} M_v \end{aligned} \tag{A.21}$$

where $\varpi = V_1 / Y$ measures the share of commercial aquaculture's value added in GDP; and $\tau = W^{ca} / W^{total}$ measure the share of commercial aquaculture's tax payments relative to the total tax revenues for the entire economy.

Appendix 5
Data template

The following is a template of data needed for assessing commercial aquaculture's contribution to economic growth, poverty alleviation and food security.

CA contribution to growth, poverty alleviation and food security (data template)

Aggregate							
	General:	Value	Quantity	Price			
1	Aggregate output	?	—	—			
2	Gross national product (GNP)	√?	—	—			
3	Aggregate employment	—	√?	—			
4	Aggregate labour Income	√?	—	—			
	Aggregate consumption	√?	—	—			
	Savings rate	√?	—	—			
Agriculture							
	General:	Value	Quantity	Price			
5	Agriculture output	?E	—	—			
6	Agriculture VAD	?	—	—			
7	Agriculture employment	—	E	—			
8	Agriculture labour income	?	—	—			
	Major agriculture products:	Value	Quantity	Price			
	Item I	?E	?	?			
	Item II	?E	?	?			
	Item N	?E	?	?			
9	Total	?E	—	—			
Commercial aquaculture (CA)							
	Basic:	**CA Product I, II, III…**			**Total**		
		Value	Quantity	Prices	Value	Quantity	Price
10	Output	E	?	?	E	—	—
11	Value added	?E	—	—	E	—	—
12	Employment	—	?E	?E	—	E	—
13	Labour income	?E	—	—	E	—	—
	Sales:	**CA Product I, II, III…**			**Total**		
		Value	Quantity	Prices	Value	Quantity	Price
14	Domestic sales	E	?	?	E	—	—
15	Domestic intermediate sales	E	?	—	E	—	—
16	Domestic consumption	E	E	—	E	—	—
17	Exports	√?	√?	?E	E	—	—

Symbols: **?** (to be collected); √ (high availability); **E** (to be estimated or calculated); **—** (unnecessary)

Data template (continued)

Commercial aquaculture (CA)									
	Cost structure:	**CA Product I, II, III…**			**Total**				
		Value	Quantity	Prices	Value	Quantity	Price		
18	Fixed costs	?E	?	?	E	—	—		
19	Variable costs	?E	?	?	E	—	—		
20	Labour costs	?E	?	?	E	—	—		
21	Profits	?E	—	—	E	—	—		
	Productive capital structure:	**CA Product I, II, III…**			**Total**				
		Value	Quantity	Prices	Value	Quantity	Price		
22	Land	?E	?	?	E	E	—		
23	Ponds	?E	?	?	E	E	—		
24	Equipments	?E	?	?	E	E	—		
25	Infrastructure	?E	—	—	E	—	—		
	Intermediate input structure:	**CA Product I, II, III…**				**Total**			
		Value	Quantity	Prices	Import content	Value	Quantity	Price	Import content
26	Feed	?E	?	?	?	E	—	—	E
27	Seed	?E	?	?	?	E	—	—	E
28	Fertilizer and chemicals	?E	?	?	?	E	—	—	E
29	Fuel	?E	?	?	?	E	—	—	E
30	Electricity	?E	?	?	?	E	—	—	E
31	Water	?E	?	?	?	E	—	—	E
32	Others	?E	?	?	?	E	—	—	E
	Investments:	Value							
33	Infrastructures	?							
34	Employment training	?							
Others									
	Food imports:	Value	Quantity	Price	Calorie	Protein			
	Item I	E	√?	√?	E	E			
	Item II	E	√?	√?	E	E			
	Item N	E	√?	√?	E	E			
35	Total	E	—	—	E	E			
	Food supply:	Total	Domestic	Import					
36	Calorie	√?E	?	?					
37	Protein	?	?	?					

Symbols: **?** (to be collected); √ (high availability); **E** (to be estimated or calculated); **—** (unnecessary)

There is ample evidence that, when properly conducted, especially as a business (commercial) activity, aquaculture can make significant contribution to national food security, poverty alleviation and economies, factors which often determine policy makers' support to any sector. Yet, quantitative evaluation of these merits is poorly documented, particularly in developing countries, which often limits the much needed political and financial support to the sector for its adequate development. This paper suggests to measure aquaculture's contribution to a country's economy through the "aquaculture value-added multiplier" and its contribution to poverty alleviation through "aquaculture employment multiplier". It also suggests to use the "net sum of protein-equivalent" and the "ratio between the net foreign exchange earning of aquaculture and the total value of food imports" to assess the direct and indirect contributions of the sector to food availability (one of the three dimensions of food security), the "aquaculture labour-income and employment multipliers" to quantify the sector's contribution to food access (second dimension of food security) and the "aquaculture tax multiplier" and the "Ratio between the Aquaculture Net Foreign Exchange Earning and the Whole Economy Net Foreign Exchange Earning" to estimate aquaculture's contribution to food utilization (the third dimension of food security). While the document refers to "commercial aquaculture" throughout, the methodology developed can be applied to aquaculture in general.

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