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Future fish supply and demand in Tanzania

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Photo credits

Front cover, Ranwel Nelson Mbukwah/Deep Sea Fishing Authority; page 3, Asiya Maskaeva.

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List of abbreviations

BAU	business-as-usual
CES	Constant Elasticity of Substitution
EEZ	exclusive economic zone
FAO	Food and Agriculture Organization
GAMS	Generalized Algebraic Modelling System
GDP	gross domestic product
MLF	Ministry of Livestock and Fisheries
OECD	Organization for Economic Development and Co-operation
PE	partial equilibrium (model)
t	metric tons
WB	World Bank

Executive summary

Aquatic food production in Tanzania has substantial room to grow as multiple indicators of fishery performance are lower than expected. Tanzania's population growth is outpacing the rate of growth in the aquatic food supply, leading to an annual per capita fish consumption rate of roughly 8.5 kg. For comparison, the rate among the Least Developed Countries is 12.6 kg (FAO 2020). This is not caused by the preferences of consumers in Tanzania, as the demand gap for fish has been estimated at roughly 300,000 t (MOLF 2020), a substantial amount. Furthermore, the demand for aquatic foods worldwide is projected to double by 2050, with higher increases in areas where such foods will become more accessible. To meet the supply shortage, imports of low-value fish in Tanzania have risen steadily in recent years, closing the gap between import and export quantities. The fisheries sector in the country directly provides jobs for about 200,000 people, while 4.5 million people (approximately 35% of rural employment) indirectly depend on fishery activities. The sector makes up about 1.75% of Tanzania's gross domestic product (GDP). Moreover, aquaculture production remains disappointingly low at just 4% of total national fish production.

Understanding the interaction between demand and supply of aquatic food products and their implications is crucial for food and nutrition security in Tanzania. Moreover, future projections of the dynamics of fish production, consumption, trade and prices are critical to support national policy and decision-making to ensure sustained growth in fish production while minimizing unexpected losses because of climate change and other economic shocks. As such, the main objective of this study is to develop a multispecies and multisector dynamic equilibrium model of the Tanzanian fisheries sector and use it as a policy analysis tool to examine the dynamic interaction between fish supply and fish demand. The model captures dynamics of fisheries and aquaculture subsectors and the links between fisheries and aquaculture in the country. The study relied heavily on official data for modeling long-term effects of the magnitude of policy shocks for the fisheries sector.

Five simulation scenarios for describing future fish supply-demand dynamics were analyzed. The business-as-usual (BAU) scenario was developed following historical trends of the main variables of the Tanzanian fisheries sector. Alternative scenarios explored include (i) rising fish demand fueled by demographic change, economic growth and a dietary shift, (ii) subsidies to the tuna and tuna-like species subsector, (iii) improvement in aquaculture productivity and (iv) an increase in export supply derived from a shift in foreign market demand toward fish consumption. The BAU scenario projected positive growth of fish supply and demand through 2035, with marine and inland fisheries continuing to outpace aquaculture growth. High demand for fish because of optimistic higher economic growth resulted in increasing fish output supply and exports. Subsidies to the tuna and tuna-like species subsector led to an increase in output of not only this subsector but also other capture and aquaculture subsectors and helped increase fish consumption. Improvement in aquaculture productivity benefitted fish output supply and consumption, but higher prices resulted in slow growth of fish exports. Lastly, the export-oriented fishery sector is likely to increase fish exports without constraining domestic supply. Yet, domestic consumption slowed because of a market shift by domestic producers. It is therefore certain that fish supply and demand in Tanzania will continue to increase in the future. Based on the results, there is a room to invest in marine fisheries, especially the tuna and tuna-like subsector, in the economic exclusion zone (EEZ) as it is currently underexploited. Furthermore, the future of the fish supply in Tanzania depends highly on aquaculture growth, so it is necessary to make appropriate investment strategies a priority. Regarding the promotion of fishery exports to increase government revenue, regulation is necessary to ensure there is no fish supply deficit in the country, which would have a negative effect on the food security and nutrition of the population.

Introduction

In recent decades, most countries have been focusing on changing fisheries policy from use to sustainability of natural aquatic resources, and Tanzania is one such country (URT 2015; FAO 2020a; Asche et al. 2021). It should be noted that marine and inland fisheries are important economic activities in Tanzania. As one of the world's major fisheries nations, Tanzania ranked ninth out of the 16 major countries in inland capture fisheries production, according to the Food and Agriculture Organization (FAO) (2020).

National strategies such as the Tanzania Development Vision 2025 and the Zanzibar Development Vision 2020 highlight the need to strengthen the management of inland and marine coastal aquatic resources to support environmentally sustainable economic development. The National Fisheries Policy of 2015 promotes the conservation, development and sustainable management of Tanzania's fishery resources for present and future generations.

In Tanzania, the fisheries industry is a significant supplier of economic activity. In 2020, the sector employed about 200,000 full-time fishers, and about 4.5 million people earned their livelihoods from fisheries sector-related activities. In addition, the fisheries sector contributes 1.75% to GDP (MLF 2020). However, aquaculture production still remains low at only 4% of total national fish production.

Despite these efforts, the potential of the fishery sector in Tanzania is only partially known, and the country has yet to fully benefit from this valuable resource. There is a lack of information as to what socioeconomic impacts may result from future shocks, such as changing yields, the imposition of a production/consumption tax and increases in fuel prices. Policymakers must consider the effect of these possibilities when designing Tanzania's fisheries policy in the future. Specifically, with the rapid global growth of aquaculture production, the benefits of expanding the sector domestically must be understood (WB 2013).

With this in mind, this study aims to provide a better understanding of the dynamics of the fisheries sector in Tanzania by modeling the outcomes of a certain set of possible future scenarios. Integrating optimized behaviors of the economic actors with fish production uniquely provides a platform for analyzing different policy changes/shocks and estimating their relative socioeconomic impacts.

To attempt to provide these insights, this study uses a dynamic partial equilibrium (PE) model (2019 to 2035) that considers multiple species and multiple sectors, such as aquaculture, marine and inland fisheries production. The goal is to examine the impacts of various policy options and to compare possible scenarios for the Tanzanian fisheries sector with a BAU scenario. Fish supply and demand in the country was analyzed based on the trends of fisheries and aquaculture production and those of the consumption of fish, driven by income and population growth.

Thus, understanding the dynamics of fish production, consumption, trade, prices and their implications on food and nutrition security in Tanzania is critical to support national policy and decision-making to ensure sustained fish production growth while minimizing unexpected socioeconomic and environmental impacts.

The main objective of this study is to provide a future macro picture of the fish sector in Tanzania by projecting the dynamics of fish supply and demand and drawing interesting policy implications for policymakers in Tanzania.

The study considers the following research questions:

- What are the factors that will influence future fish supply, demand and trade in Tanzania?
- What are the economic effects of an increase in input costs (feed, seed, fuel, capital, etc.) on fisheries and aquaculture production in Tanzania?
- What development strategies and trade regulations could increase the fish sector's contribution to the Tanzanian economy?

1. Methodology

1.1. Model

To study the interaction of fish demand and supply in Tanzania, we model the fisheries sector using a PE model developed by WorldFish (Tran et al. 2019). Similar models have been used in other studies (Rosegrant 2012) to analyze policies regarding the agriculture sector, climate change and trade. This is a comprehensive sector and subsector model that analyzes both demand and supply, prices, and the relationship between various inputs and outputs. The model is driven by the objective of maximizing producer profits and consumer utility in the interaction of demand and supply (Kotevska 2013).

The PE model is not considered as strong as the computable general equilibrium (CGE) model, in that the former considers one sector of the economy in isolation. Despite this weakness, the PE model has the following strengths: (i) it is specifically suitable to analyze small sectors in the economy, such as the fisheries sector in Tanzania, and (ii) it does not require the extensive data inputs that a CGE model does for calibration. Because of the inconsistency of data and the few econometric studies carried out in Tanzania to estimate these parameters, the PE model was found to be a suitable alternative to a CGE model.

Tanzania's fisheries sector model is made up of producer, consumer, trade and price formation blocks, as shown in Figure 1. The producer block shows the supply of fish while the consumer block depicts the demand for fish. The production equation is differentiated by the environment (inland, marine or aquaculture) and fish species. Different inputs are combined to produce outputs, and a shift in the supply function from productivity changes was included in the production function. Fish output can either be supplied domestically or exported to the rest of the world.

A double layer Constant Elasticity of Substitution (CES) utility function was used to model household consumption preferences. At the first stage, consumers decide to consume either locally produced fish or imported fish to maximize use, subject to budgetary constraints. In the second stage, the consumption decision is made within the specified species groups. The Armington preference was used in both stages instead of a Cobb-Douglas function, which is normally used to allow substitutability resulting from price changes.

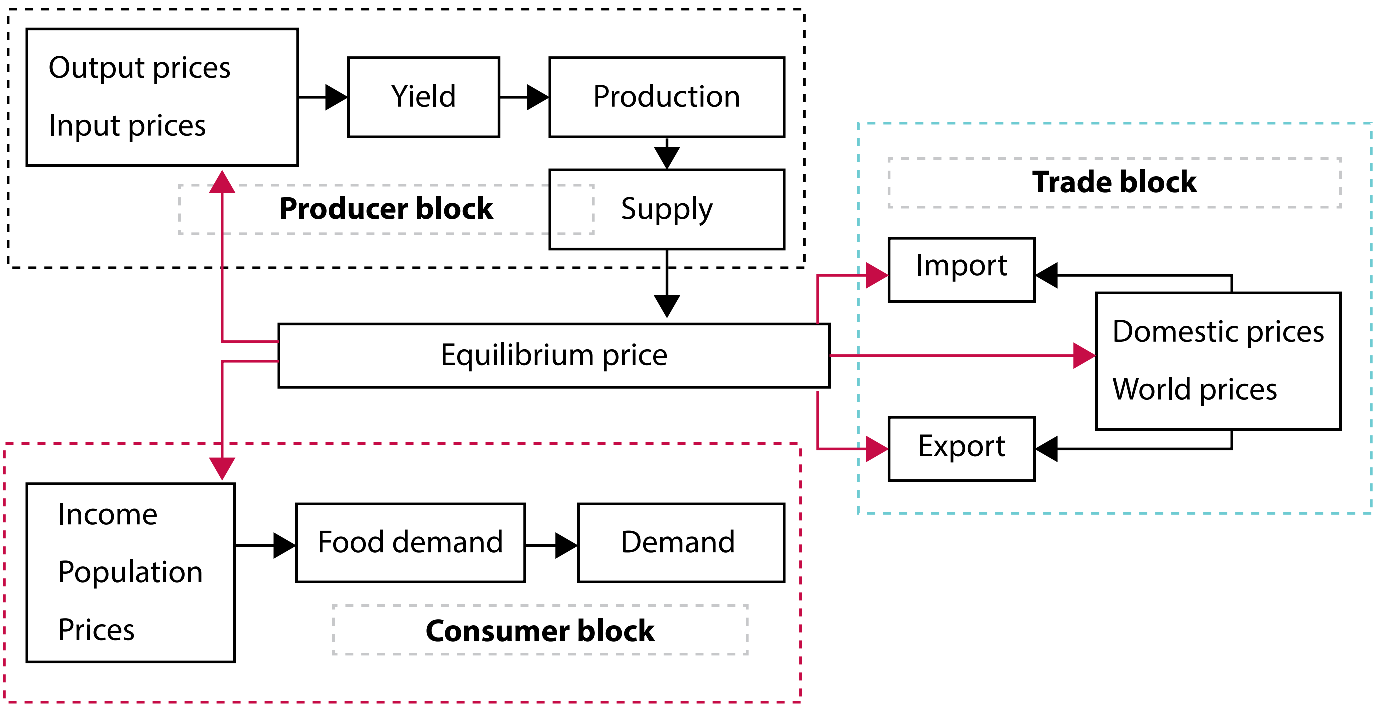

Figure 1. The flows in the PE model.

The trade block comprises fish exports and imports, whereby the former is specified as a constant elasticity function. The equation also specifies price shift coefficients and the elasticity coefficient, which shows how export demand responds to price changes. Regarding the price formation block, the consumer price of fish produced domestically is a function of the farmgate price, margins, taxes and fees (fishing license, local government fees, etc). Similarly, the export price is the summation of the farmgate price, margins and export tax (if any). The model closure is the equilibrium condition that establishes that the total supply for all fish species in all categories is equal to the total consumption demand and export.

The elasticity parameters used during calibration were taken from the literature, some being specifically estimated for Tanzania and others estimated for similar countries. Elasticities incorporated into the model include the elasticity of substitution for stages 1 and 2, which is 1.5 (Olabisi and Sawyer 2020) and specifications in the consumption function, which is 2.224 (Tran et al. 2019). The elasticity of export demand is -0.591, implying that demand for fish exports is inelastic. As the price of fish increases 1%, the export volume of fish decreases approximately 0.6% (Bukenya et al. 2012). The model dynamics are calibrated assuming a constant population growth rate of 3.1% (NBS 2020 and 2021). Indirect taxes are incorporated into the model. The rate of the value-added tax is 18%. The model is then solved by using the Generalized Algebraic Modelling System software (GAMS).

The following show how the values of output variables for each respective year after simulations were computed relative to the baseline values (Equation 1):

$$(1) \quad X_{current\ year} = X_{base\ year}\ (1 + \frac{P_{current\ year}}{100})$$

Where:

$X_{current\ year}$ the value of the output variable in the current year (after simulation)

$X_{base\ year}$ the value of the initial variable is the base year (before simulation)

$P_{current\ year}$ the percentage change of the output variable in the current year (after simulation)

1.2. Data

Benchmark data, which was used to calibrate the current PE model, was arranged in the form of a fisheries production dataset for the year 2019. Data was collected from various sources, including Tanzanian government records, national statistics and FAO. Given data availability, 2019 was chosen as the base year for the model. The production dataset developed in this section serves two purposes: first, it helps understand the structure of the Tanzanian fisheries sector; second, it provides a database for the PE model. The fisheries sector production dataset is presented in Table 1.

There are two production techniques: aquaculture and capture fisheries (wild catch production). Aquaculture production is classified into two types: freshwater aquaculture (e.g. tilapia and catfish) and mariculture (e.g. tiger prawns, milkfish and seaweed). Wild catch includes marine and inland fisheries production. In total, there are four production categories: freshwater aquaculture, mariculture, inland capture and marine capture. There are 15 fish species groups. Combining the 4 production categories and 15 fish species equals 60 combinations of category-species groups. Each of the 60 combinations is named a "sector."

The production sectors use different types of inputs. The aquaculture sector uses seed, feed, labor and fuel inputs. Wild catch production uses only labor and fuel inputs. Prices of fish feed and seed, labor and fuel were collected during interviews with fishers and obtained through reports from the Ministry of Livestock and Fisheries (MLF 2021a).

Domestic fish consumption in Tanzania for the year 2019 is shown in Table 2. The data reveals that inland fish species have the highest rate of domestic consumption. Sardines are the most consumed fish followed by perch and tilapia.

The international trade pattern of fish and fish products in Tanzania for 2019 is reflected in Table 3. Aquarium fish are not included in the database, as they are counted in pieces. Following the approach of Tran et al. (2019), data in Tables 1, 2 and 3 has been cross-checked to ensure consistency. In other words, the sum of domestic production and imports equals the sum of consumption and exports.

Category	Production	Species	Output			Input			
			Quantity supplied	Revenue	Price	Seed cost	Feed cost	Labor cost	Fuel cost
			(t)	(USD)	(USD/t)	(USD)	(USD)	(USD)	USD
Aquaculture	Inland production	Tilapia	15,477	33,542,677	2167	2,771,712	17,323,198	3,256,808	0
	Marine production	Catfish	788	1,758,390	3258	185,111	969,632	165,721	0
		Tiger prawn	336	2,919,840	8690	482,347	460,422	833,145	416,572
		Milkfish	24	72,984	3041	17,760	25,361	5724	0
		Seaweed	1449	434,700	300	120,881	0	224,805	0
Wild catch production	Marine production	Reef fish	12,567	27,237,256	2167	0	0	13,443,039	4,017,937
		Coral fish	15,395	32,837,662	2133	0	0	18,717,223	4,292,811
		Tuna and tuna-like	15,182	32,897,612	2167	0	0	22,908,091	6,687,706
		Medium pelagic	5287	11,460,025	2167	0	0	6,461,207	2,115,833
		Small pelagic	10,635	23,051,049	2167	0	0	8,393,893	3,278,279
		Prawn	693	6,022,170	8690	997,905	1,041,292	1,345,002	954,517
		Other marine	3203	6,856,390	2141	0	0	3,668,435	984,299
	Inland production	Sardines	183,456	397,607,383	2167	0	0	267,401,815	13,282,175
		Nile perch	128,264	277,988,683	2167	0	0	197,683,921	13,802,534
		Tilapia	19,756	42,817,974	2167	0	0	28,686,270	1,316,916
		Other inland	55,845	121,033,929	2167	0	0	7,4935,549	4,784,223

Table 1. Production data by source, species and production type.

Species	Quantity (t)	Revenue (1000 USD)
Sardines	172,184	570,962,000
Perch	104,091	345,166,000
Tilapia	35,233	116,833,000
Other inland	53,736	178,189,000
Catfish	788	3,953,000
Reef fish	12,567	41,672,000
Coral fish	14,629	47,749,000
Prawn	787	10,088,000
Tuna and tuna-like	15,182	50,328,000
Medium pelagic	5287	17,532,000
Small pelagic	9543	31,645,000
Other marine	2068	6,775,000
Seaweed	1449	601,000
Milkfish	24	110,000

Table 2. Domestic fish consumption in Tanzania, 2019.

Species	Import (t)	Import tax-inclusive price (USD/t)	Export (t)	Tax-inclusive price (USD/t)
Sardines	0	0	11,272	635
Perch	0	0	24,173	5476
Other inland	0	0	2109	10,288.5
Prawn	0	0	242	11,355
Coral fish (lobster, octopus, crab)	0	0	766	16,035
Tuna and tuna-like	0	0	0	1000
Medium pelagic	0	0	0	1000
Small pelagic	0	0	1092	2481
Other marine	5.33	8411	1130	8371

Table 3. International trade of fish in Tanzania, 2019.

1.3. Scenario assumptions

According to the World Bank (2013), fisheries growth can be simulated in a PE model in two ways: (1) directly through exogenously increasing the output by sufficiently adjusting the sector's productivity or inputs, or (2) indirectly through exogenously increasing productivity or inputs to stimulate output.

Using the modified PE model, this study takes on the challenge of inferring the long-term picture of the Tanzanian fisheries and aquaculture sector. The discussion begins with the BAU scenario, which reflects the current trends of the fishery sector that are observed and deemed most plausible given the present knowledge. The following five simulation scenarios are introduced:

Scenario 1: Business-as-usual (BAU)

Scenario 2: Rising fish demand fueled by demographic change, economic growth and a dietary shift

Scenario 3: Subsidies to the tuna and tuna-like species subsector

Scenario 4: Improvement of aquaculture productivity

Scenario 5: An increase in export supply derived from a shift in foreign market demand toward fish consumption.

2. Description of scenarios

Scenario 1: Business-as-usual (BAU)

Based on official data from the MLF (20202021and 2021a), other sources (BOT 2020; NBS 2020 and 2021) and stakeholder consultations, the model runs from 2019 and simulates results that are then compared with the BAU path of the economy and the Tanzanian fisheries sector. The model generates projections until 2035.

The BAU of the fisheries sector assumes that there is no significant change in household fish consumption attitudes and priorities, technology, the economy, or fishery policy, and thus past trends are expected to remain unchanged.

The BAU scenario continues past trends into the future. It is defined such that the output of capture fisheries and aquaculture grow at an annual rate of 2.4% over the projection period and the sales tax at a rate of 18%. The GDP growth rate equals 4.9%, and the population growth rate is assumed at 3.1% by 2035. The annual GDP growth rate recorded in 2020 was 4.9%, much less than the 7% recorded in 2019. This was a result of the impact from the COVID-19 pandemic on the Tanzanian economy (NBS 2020 and 2021).

Scenario 2: Rising fish demand fueled by demographic change, economic growth and a dietary shift

Considering the trends and prospects of Tanzania's fisheries sector, future increases in fish demand are almost certain to occur because of increases in the country's population and economic growth and from changes in consumer preferences. Tanzania's GDP grew by just 4.9% in 2020 following the shock of the pandemic (NBS 2021), though the country recorded a growth rate of 5.2% in the third quarter of 2021, a sign that the economy is recovering.

Therefore, we conduct a simulation to understand the impact of an optimistic increase in GDP, a switch in consumer preferences to a more healthy and nutritious diet, and the current population growth trend. We assume the current population growth rate of 3.1% is maintained, GDP grows at an average rate of 6%, and consumers shift their preference toward consuming more fish.

Scenario 3: Subsidies to the tuna and tuna-like species subsector

In this scenario, we implement a subsidy that is allocated to small-scale coastal fisheries in the marine subsector to adopt new technologies, such as echo sounders and satellite positioning systems. This policy option aims to improve and strengthen the ability of small-scale fisheries to combat poverty, increase food and nutrition security, and provide socioeconomic benefits to households in Tanzania. Additionally, this policy option is consistent with the government's plan to help improve the fisheries sector (MLF 2021). This scenario is implemented in the model as a 1% reduction of the sales tax.

Scenario 4: Improvement of aquaculture productivity

In this scenario, we assume increases in private sector investments in production capacity cause total aquaculture sector productivity to grow at 10% per year. Other assumptions remain as those in the BAU scenario. This scenario addresses the case that the aquaculture subsector can grow faster than under the baseline scenario by 10% between 2019 and 2035. In particular, the scenario assumes faster technological progress such that aquaculture would be able to increase fish supply at a lower cost, but it assumes the same feed requirements per unit weight of aquaculture production. According to Kulyakwave and Ngondo (2020), poor technology comes with higher production costs for an average aquaculture production yield of up to 654 kg per pond per production cycle, while advanced technology is capable of producing 800 kg per pond per production cycle.

Scenario 5: Increase in export supply derived from a shift in foreign market demand toward fish consumption

Globally, fish consumption is projected to increase by 16.3%, or by an additional 25 million metric tons, to a level of 180 million metric tons by 2029 (the World Bank, 2013). This expanded demand is expected globally with varying magnitudes in different locations, depending on baseline fish consumption levels and population growth rates (OECD and FAO 2022). According to another study by Rosemond et al. (2021), the demand for aquatic foods worldwide is projected to double by 2050. This rise in fish consumption will be driven by higher incomes, a more diverse diet in the types of food and fish, and a growing urban population. Therefore, we simulate a 5% increase in the export price shift parameter to capture the shift (increase) in the projected foreign export demand worldwide.

Dar es Salaam, Kunduchi landing site.

3. Results and discussion

This section presents the simulation results focusing on the macroeconomic and sectoral levels. The current research findings are a result of an analysis that considered the impacts of several shocks on economic growth, sectoral production and prices. The base year is 2019, and the simulated results were compared to the BAU path of the fisheries sector to determine the shock impacts.

3.1. Business-as-usual findings of the Tanzanian fisheries sector

Results from the BAU scenario indicate that by 2035 fisheries demand and supply in Tanzania will be high, as shown in Table 4. With a total productivity growth rate of 2.4% per year, total production of the marine capture fisheries is projected to increase 29.7% by 2035, the production of inland fisheries 29.5% and aquaculture production 21.7% by 2035 compared to the base year 2019 (Table 4).

The projection for demand indicates rising aggregate fish consumption for all species, as shown in Tables 4 and 5. Overall consumer demand for domestic fisheries production is projected to increase 22.5% for inland fisheries and 22.2% for marine fisheries by 2035 (Table 4). An increase in overall fisheries consumption is attributable mostly to population growth. According to national price data, the real farmgate prices of fish from capture and aquaculture fishery sources will increase by approximately 10% annually between 2025 and 2035, as shown in Table 6. The increase in farmgate prices is attributed to the rise in specific and common input prices.

	Base year output (t)	2025 (%)	2030 (%)	2035 (%)
Aquaculture	18,074	11.6	16.7	21.7
Capture inland fisheries	387,321	15.1	22.7	29.5
Capture marine fisheries	62,962	15.2	22.9	29.7
Consumer demand for domestic production				
Inland fisheries	365,244	18.7	22.5	22.5
Marine fisheries	62,324	19.2	22.2	22.2

Table 4. Projected growth rate for the BAU scenario.

Species	Base year output (t)	Deviation from BAU (%)			Average annual change (%)
	2019	2025	2030	2035	
Sardines	172,184	14.86	21.24	26.15	1.6
Perch	104,091	16.08	20.26	21.03	1.3
Tilapia	35,233	12.91	18.84	24.39	1.5
Other inland	53,736	10.33	14.26	18.44	1.2
Catfish	788	14.09	20.45	25.75	1.6
Reef fish	12,567	13.93	20.85	27.11	1.7
Coral fish	14,629	14.77	21.33	26.56	1.7
Prawn	787	11.64	11.58	8.45	0.5
Tuna and tuna-like	15,182	22.04	33.01	41.51	2.6
Medium pelagic	5287	15.79	23.85	30.78	1.9
Small pelagic	9543	12.07	15.67	18.05	1.1
Other marine	2068	13.68	9.99	-0.7	0
Seaweed	1449	14.15	21.21	27.51	1.7
Milkfish	24	10.01	13.56	17.41	1.1

Table 5. Fisheries domestic consumption, BAU simulation.

Species	Base year price (USD)	Projected farmgate prices (USD)			Average annual change (%)
	2019	2025	2030	2035	
Sardines	2167	2789	3921	5602	9.9
Perch	2167	2779	3932	5681	10.1
Tilapia	2167	2805	3947	5629	10
Other inland	2167	2827	4000	5723	10.3
Catfish	3258	4202	5908	8432	9.9
Reef fish	2167	2796	3925	5588	9.9
Coral fish	2133	2745	3858	5508	9.9
Prawn	8690	11,292	16,174	23,652	10.8
Tuna and tuna-like	2167	2731	3799	5387	9.3
Medium pelagic	2167	2781	3892	5534	9.7
Small pelagic	2167	2812	3984	5730	10.3
Other marine	2141	2767	4013	6029	11.4
Seaweed	300	386	542	772	9.8
Milkfish	3041	3953	5626	8056	10.3

Table 6. Changes in farmgate prices, BAU simulation.

3.2. Rising fish demand fueled by demographic change, economic growth and a dietary shift

Compared to the BAU scenario, higher GDP growth and constant population growth will increase the demand for fish, except for other marine fish species. In 2035, tuna and tuna-like species and medium pelagic species will record the highest increase in demand, that is 45% and 33% higher, respectively, than the baseline estimates of 15,182 and 5287 t. The increase in demand is because of a rise in consumer purchasing power together with changes in consumer preferences toward consuming more fish, as shown in Table 7.

Category	Species	Base year demand (t)	Projected demand, (t)			Average annual change (%)
		2019	2025	2030	2035	
Aquaculture	Catfish	788	873	909	947	1.3
Aquaculture	Seaweed	1449	1669	1781	1883	1.9
Aquaculture	Milkfish	24	27	27	29	1.2
Aquaculture	Prawn	787	880	874	836	0.4
Inland	Sardines	172,184	199,427	211,213	220,075	1.7
Inland	Perch	104,090	121,661	125,711	125,432	1.3
Inland	Tilapia	35,233	40,073	42,401	44,589	1.7
Inland	Other inland	54,547	62,743	66,516	69,641	1.7
Marine	Reef fish	12,567	14,442	15,402	16,275	1.8
Marine	Coral fish	14,629	16,934	17,969	18,781	1.8
Marine	Tuna and tuna-like	15,182	18,789	20,558	21,951	2.8
Marine	Medium pelagic	5287	6185	6650	7053	2.1
Marine	Small pelagic	9543	10,747	11,109	11,324	1.2
Marine	Other marine	2068	2349	2231	1915	-0.5

Table 7. Changes in fish demand by species, 2019–2035.

Fish output is expected to increase for all species because of higher demand fueled by economic growth, as shown in Table 8. The highest increase is for tuna and tuna-like species at 21,951 t in 2035 compared to 15,182 t in 2019. This is because these species are currently underexploited, especially in the EEZ, creating an opportunity for considerable yield growth. Milkfish (1.2%) and both tilapia and catfish (1.3%) are aquaculture species that are expected to record a low average annual growth. This implies that further investments in this subsector are crucial to tackle the expected higher demand in the future.

As in the BAU, fish output outweighs demand through 2035, leading to an increase in exports. It is noteworthy to point out that the output of other marine fish species is expected to increase to 4251 t in 2035 compared to 3203 t in 2019. As shown in Figure 2, producer prices of the same are expected to more than double, reducing consumer demand from 2068 t in 2019 to 1915 t in 2035. Consumer prices are projected to follow a similar trend to producer prices. As a result, under this scenario, optimistic economic growth and a higher population growth are expected to increase fish demand and exports. This calls for further strategies to increase fish supply by improving capture and aquaculture production techniques.

Category	Species	BAU (t)	Deviations from BAU (t)			Average annual change (%)
		2019	2025	2030	2035	
Aquaculture	Tilapia	15,477	17,139	17,832	18,576	1.3
Aquaculture	Catfish	788	873	909	947	1.3
Aquaculture	Prawn	336	384	410	435	1.8
Aquaculture	Seaweed	1449	1669	1781	1883	1.9
Aquaculture	Milkfish	24	27	27	29	1.2
Inland	Sardines	183,456	212,893	228,232	241,826	2
Inland	Perch	128,264	150,485	162,327	172,644	2.2
Inland	Tilapia	19,756	22,934	24,570	26,014	2
Inland	Other inland	55,845	64,333	68,716	72,676	1.9
Marine	Reef fish	12,567	14,442	15,402	16,275	1.8
Marine	Coral fish	15,395	17,848	19,124	20,257	2
Marine	Prawn	693	787	837	886	1.7
Marine	Tuna and tuna-like	15,182	18,789	20,558	21,951	2.8
Marine	Medium pelagic	5287	6185	6650	7053	2.1
Marine	Small pelagic	10,635	12,060	12,777	13,464	1.7
Marine	Other marine	3203	3705	3985	4251	2

Table 8. Changes in fish output by species, 2019–2035.

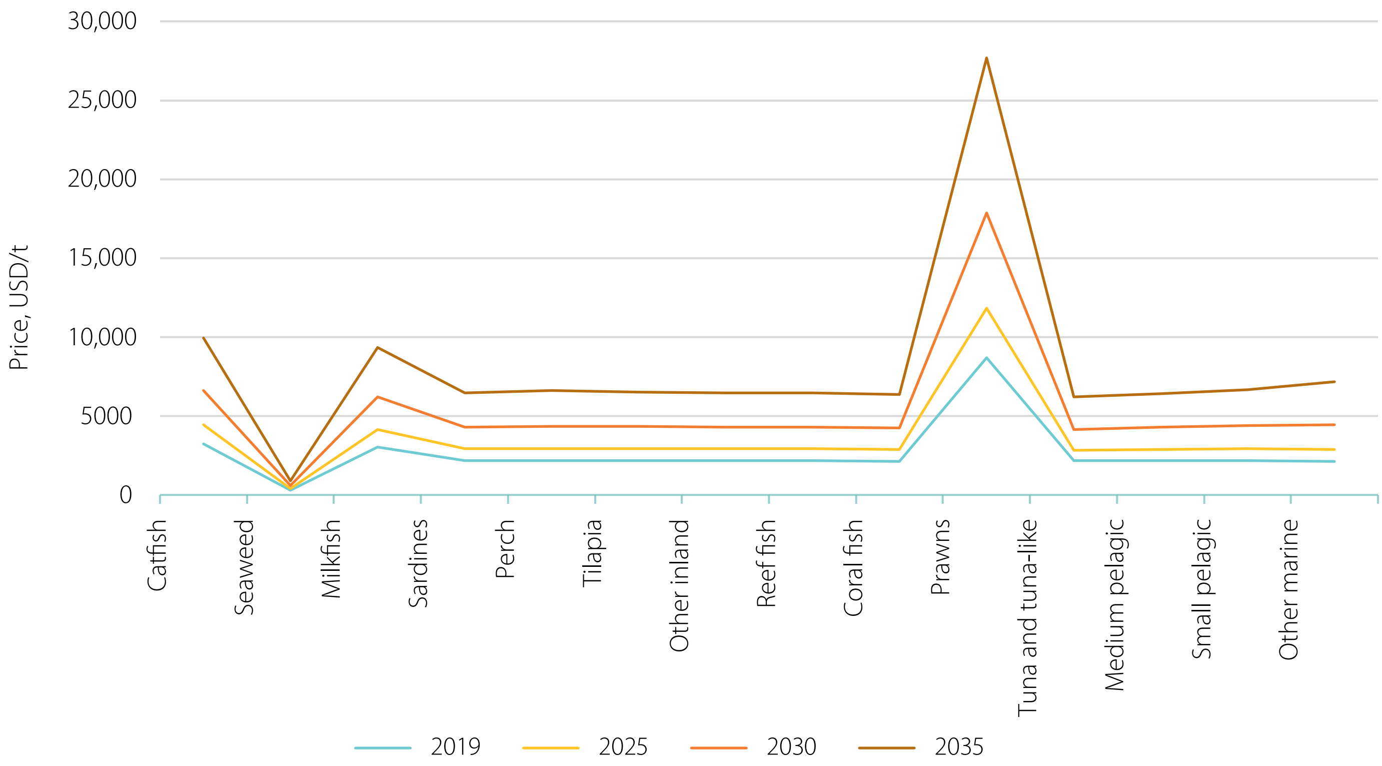

Figure 2. Changes in producer prices.

3.3. Subsides to the tuna and tuna-like species subsector

This scenario assumes faster productivity growth for tuna and tuna-like species. As such, tuna and tuna-like species output is forecasted to be 41.7% higher than the BAU in 2035, as shown in Table 9. Average fish production, which combines aquaculture with inland and marine fisheries, is projected to be 24.1% higher. The projections for marine species are 27.1% for reef fish, 29.05% for coral fish, 30.7% for medium pelagic, 24.33% for small pelagic and 29.77% for other marine species above BAU by 2035. Aquaculture production of tilapia (18.3.5%), catfish (18.4%) and milkfish (17.4%), as well as shrimp and prawn (26.79%) show a positive trend from 2019 to 2035. This simulation (subsidies to the tuna and tuna-like species subsector) also has a positive impact on the output of other capture species and aquaculture fisheries.

As shown in Table 10, increases in the domestic fish supply led to a rise in domestic fish consumption exceeding BAU.

3.4. Improvement of aquaculture productivity

Based on this simulation scenario, which is a 10% increase in efficiency of specific inputs in aquaculture, output from land and cage-based commercial aquaculture is expected to increase by 21.2% for tilapia, 16.1% for catfish, 13% for milkfish and 25.4% for brackish water fish, as shown in Table 11. Total fish production (aquaculture and capture fisheries) in 2035 is also expected to be higher than the BAU.

Following the increase in the overall domestic supply of fish, average consumption is also projected to be 42% higher than the BAU in 2035, as shown in Table 12.

The higher supply of fish resulting from the higher productivity in this simulation led to increased domestic consumption and producer prices. The combined effects of higher fish prices and high domestic production explain the low change in exports.

3.5. Increase in export supply derived from a shift in foreign market demand toward fish consumption

Simulation results in Table 13 show that an increase in the export price shift parameter will increase exports more than 90% by 2035. While exports increase for all exported species, the highest increase is for other marine species, which is expected to rise from 1130 t in 2019 to 2336 t in 2035. An increase in exports is accompanied by a moderate fish output growth and a lower increase in domestic demand for fish. Aquaculture species, except prawns and seaweed, exhibit a lower output growth because of an export demand shift compared to inland and marine fish species.

A lower increase in domestic demand for fish, as shown in Table 14, is a result of a higher increase in producer prices and consequently consumer prices. This is because of a more favorable export market that necessitates domestic producers to supply more to this market and reduce domestic supply, hence the rise in prices. Consumer demand for other marine species continues to exhibit a decreasing trend, as in the BAU scenario, from 2068 t in 2019 to 1915 t in 2035. The most consumed fish species in Tanzania are freshwater or inland species, so it is likely that much higher prices will further reduce demand for marine species.

Simulation 5 results show that the export-oriented fishery sector will not reduce the domestic supply of fish. Instead, it is expected to promote output growth. However, this would come at the expense of higher domestic prices, which might reduce domestic demand, especially for other marine species and prawns from aquaculture. As such, policies geared to promoting fish exports should be undertaken with close government supervision. This will maintain the domestic supply and keep prices affordable for Tanzanians, and will ensure that the food security of the population is not affected.

Category	Species	BAU (t)	Deviations from BAU (%)			Average annual change (%)
		2019	2025	2030	2035	
Aquaculture	Tilapia	15,477	10.24	14.14	18.3	1.1
Aquaculture	Catfish	788	10.33	14.26	18.4	1.2
Aquaculture	Prawn	336	13.34	20.25	26.79	1.7
Aquaculture	Seaweed	1449	14.16	21.21	27.51	1.7
Aquaculture	Milkfish	24	10.01	13.57	17.41	1.1
Inland	Sardines	183,456	14.97	22.56	29.26	1.8
Inland	Perch	128,264	16.08	24.54	31.83	2
Inland	Tilapia	19,756	14.99	22.54	29.16	1.8
Inland	Other inland	55,845	14.18	21.28	27.68	1.7
Marine	Reef fish	12,567	13.93	20.85	27.1	1.7
Marine	Coral fish	15,395	14.85	22.39	29.05	1.8
Marine	Prawn	693	12.69	19.12	25.36	1.6
Marine	Tuna and tuna-like	15,182	22.34	33.22	41.68	2.6
Marine	Medium pelagic	5287	15.79	23.85	30.77	1.9
Marine	Small pelagic	10,635	12.56	18.59	24.33	1.5
Marine	Other marine	3203	14.55	22.45	29.77	1.9

Table 9. Percent change in fish output by species, 2019–2035.

Species	BAU (t)	Deviations from BAU (%)			Average annual change (%)
	2019	2025	2030	2035	
Sardines	172,184	14.86	21.24	26.15	1.6
Perch	104,091	16.08	20.26	21.03	1.3
Tilapia	35,233	12.91	18.84	24.39	1.5
Other inland	53,736	10.33	14.26	18.44	1.2
Catfish	788	14.09	20.45	25.75	1.6
Reef fish	12,567	13.93	20.85	27.11	1.7
Coral fish	14,629	14.77	21.33	26.56	1.7
Prawns	787	11.64	11.58	8.45	0.5
Tuna and tuna-like	15,182	22.36	33.22	41.67	2.6
Medium pelagic	5287	15.79	23.85	30.78	1.9
Small pelagic	9543	12.07	15.67	18.05	1.1
Other marine	2068	13.68	9.99	-0.7	0
Seaweed	1449	14.15	21.21	27.51	1.7
Milkfish	24	10.01	13.56	17.41	1.1

Table 10. Changes in consumer demand for domestic production.

		Outcome	Deviation from BAU (%)		
Fish supply (t) and species		**BAU**	**2025**	**2030**	**2035**
Aquaculture	Tilapia	15,477	13	17	21.2
	Catfish	788	8.2	12	16.1
	Prawn	336	11.6	18.8	25.4
	Seaweed	1449	13.1	20.2	26.5
	Milkfish	24	6.3	9.5	13
Inland	Sardines	183,456	14.9	22.6	29.3
	Perch	128,264	16.1	24.5	31.8
	Tilapia	19,756	14.9	22.5	29.1
	Other inland	55,845	14.2	21.3	27.7
Marine	Reef fish	12,567	13.9	20.8	27.1
	Coral fish	15,395	14.8	22.4	29
	Prawns	693	11	17.6	23.9
	Tuna and tuna-like	15,182	22	33	41.5
	Medium pelagic	5287	15.8	23.8	30.8
	Small pelagic	10,635	12.6	18.6	24.3
	Other marine	3203	14.5	22.4	29.8
International trade (t)					
	Exports of which	BAU	2025	2030	2035
	Sardines	11,272	16.3	42.7	76.8
	Perch	24,173	16.1	42.9	78.3
	Other inland	2109	16.5	42.9	76.9
	Coral fish	766	16.3	42.7	76.7
	Prawns	242	17.5	45.7	83
	Small pelagic	1092	16.9	44.1	79.2
	Other marine	1130	16.6	45.8	86.1

Table 11. The effects of simulation scenarios on key sectoral indicators in deviation from the BAU scenario in 2035.

Species	BAU (USD)	Deviation from BAU (USD)			Average annual change (%)
	2019	2025	2030	2035	
Sardines	2167	2787	3919	5600	9.9
Perch	2167	2777	3930	5679	10.1
Tilapia	2167	2794	3932	5607	9.9
Other inland	2167	2845	3928	5606	9.9
Catfish	3258	4203	6053	8660	10.4
Reef fish	2167	2788	3924	5585	9.9
Coral fish	2133	2791	3857	5506	9.9

Species	BAU (USD)	Deviation from BAU (USD)			Average annual change (%)
	2019	2025	2030	2035	
Prawns	8690	10,952	16,275	23,795	10.9
Tuna and tuna-like	2167	2780	3798	5385	9.3
Medium pelagic	2167	2811	3891	5532	9.7
Small pelagic	2167	2800	3982	5728	10.3
Other marine	2141	2766	4011	6026	11.3
Seaweed	300	388	544	774	9.9
Milkfish	3041	4016	5694	8158	10.5

Table 12. Changes in producer prices.

International trade: Change in exports		BAU (t)	Deviations from BAU (t)			Average annual change (%)
		2019	2025	2030	2035	
Aquaculture	Prawn	242	291	373	485	6.3
Inland	Sardines	11,272	13,466	17,020	21,752	5.8
Inland	Perch	24,173	28,824	36,616	47,212	6
Inland	Other inland	2109	2523	3188	4071	5.8
Marine	Coral fish	766	915	1156	1477	5.8
Marine	Small pelagic	1092	1312	1667	2139	6
Marine	Other marine	1130	1356	1754	2336	6.7
Change in fish output supply						
Aquaculture	Tilapia	15,477	17,139	17,832	18,576	1.3
	Catfish	788	873	909	947	1.3
	Prawns	336	384	410	435	1.8
	Seaweed	1449	1669	1781	1883	1.9
	Milkfish	24	27	27	29	1.2
Inland	Sardines	183,456	212,893	228,232	241,826	2
	Perch	128,264	150,485	162,327	172,644	2.2
	Tilapia	19,756	22,934	24,570	26,014	2
	Other inland	55,845	64,333	68,716	72,676	1.9
Marine	Reef fish	12,567	14,442	15,402	16,275	1.8
	Coral fish	15,395	17,848	19,124	20,257	2
	Prawns	693	787	837	886	1.7
	Tuna and tuna-likes	15,182	18,789	20,558	21,951	2.8
	Medium pelagic	5287	6185	6650	7053	2.1
	Small pelagic	10,635	12,060	12,777	13,464	1.7
	Other marine	3203	3705	3985	4251	2

Table 13. Changes in export supply and fish output by production category and species, 2019–2035.

Category	Species	BAU (t) 2019	Deviations from BAU (t) 2025	2030	2035	Average annual change (%)
Aquaculture	Catfish	788	873	909	947	1.3
Aquaculture	Seaweed	1449	1669	1781	1883	1.9
Aquaculture	Milkfish	24	27	27	29	1.2
Aquaculture	Prawn	787	880	874	836	0.4
Inland	Sardines	172,184	199,427	211,213	220,075	1.7
Inland	Perch	104,090	121,661	125,711	125,432	1.3
Inland	Tilapia	35,233	40,073	42,401	44,589	1.7
Inland	Other inland	54,547	62,743	66,516	69,641	1.7
Marine	Reef fish	12,567	14,442	15,402	16,275	1.8
Marine	Coral fish	14,629	16,934	17,969	18,781	1.8
Marine	Tuna and tuna-like	15,182	18,789	20,558	21,951	2.8
Marine	Medium pelagic	5287	6185	6650	7053	2.1
Marine	Small pelagic	9543	10,747	11,109	11,324	1.2
Marine	Other marine	2068	2349	2231	1915	-0.5

Table 14. Changes in consumer demand for domestic production by category and species, 2019–2035.

4. Conclusion and recommendations

The dynamic PE model was applied to analyze five possible scenarios of the fisheries and aquaculture sectors in Tanzania. The results reveal that both the supply and demand of fish in the country will increase steadily, driven primarily by population and economic growth. The key findings show that expanded aquaculture production could play a crucial role in fish supply to meet the country's growing demand for aquatic food. Moreover, the expansion of Tanzania's aquaculture sector should be combined with significant increases in the supply of feed and seed in the country.

The model used in this study presented the first step to forecast the fisheries sector in Tanzania. With such models in place, it is possible to simulate different policy scenarios and understand the impacts of proposed policies even before implementation. For this reason, the government could use the models to make evidence-based policy decisions.

However, it is noted that some data on Tanzania's fisheries sector is unavailable, specifically for inputs costs, such as feed and seed for aquaculture, as well as labor costs and specific inputs like investment. Insufficient data could reduce the scope of research on the fisheries sector. Therefore, there should be efforts to improve the collection, availability and accessibility of fisheries data. These could include a comprehensive survey involving the Tanzania Fisheries Research Institute and fisheries/aquaculture teaching instructions. Also, a data bank should be created to provide access to reliable data on fishstock assessments.

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