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Economic Analysis of Potential Offshore Aquaculture Practice to Enhance Diversification of Blue Economy in Nigeria

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ABSTRACT: The oil and gas industry has long dominated Nigeria's blue economic growth. However, a new frontier that can play sustainable economic growth in the maritime industry and therefore national economic leverage is offshore aquaculture. Hence, this paper aims to provide relevant information on the economic analysis of the potential offshore aquaculture practice to enhance the diversification of the blue economy in Nigeria using secondary data. Sensitivity analysis considering input variations of up to 45% is also performed to take care of the unforeseen. Offshore aquaculture in this paper refers to fish production in the Open Ocean using large cages/nets. Ten (10) fish cages of 37500-fish capacity per cage were hypothetically designed with fiberglass materials and installed in Escravos offshore. A mortality of 30% was used with the current prices of other required investments. The analysis recorded a breakeven period of 2 years and NPV value of over one trillion Naira in 9 years indicating massive profitability comparable to the oil and gas industry! Sensitivity analysis identified mortality/loss of fish and falling prices of fish as events that could adversely affect the investment. It is suggested that the investment should be done with experienced professionals in fishery, offshore engineering, and cost control.

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The most important source of human sustenance is the ocean which makes up around 70% of the earth's surface, including the ocean, seas, rivers, streams, and lakes (Allison. *et al*., 2020) cited in (Osuji and Agbakwuru, 2024). Fisheries and Offshore Aquaculture include the sustainable harvesting of marine resources such as fish, shellfish, and other aquatic organisms, as well as the cultivation of fish in controlled environments. At least 50% of fish for human consumption is provided by aquaculture (Osuji and Agbakwuru, 2024). Hasankhani, *et al*., (2023), discussed the extent of interest in offshore aquaculture to the extent of employing the Wave Energy Converter (WEC) in powering a Salmon aquacultural facility in North East of the United States of America. Energy is generally required in offshore aquacultural facilities, particularly for feed and nutrient disbursement and in some cases, depending on design, to ballast and de-ballast the facility in and out of water. This is again a huge plus to the interest of aquaculture in West Africa as the solar energy source is among the best in the world. In many other countries, especially those in the temperate region, wind energies, hybrids of solar and WEC or fossil and Solar etc. are possible. Nigeria and

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indeed West Africa have not been known for offshore aquacultural practices. It is relatively new in this region. Offshore aquaculture refers to situations where fishes are raised in oceans, rivers and seas in large nets and cages. This differs from land-based aquaculture which typically involves the use of ponds, tanks, trampolines etc. to confine and contain the fishes. Hence, the objective of this paper is to provide relevant information on the potential offshore aquaculture practices to enhance the diversification of the blue economy in Nigeria.

MATERIALS AND METHOD

Description of Working Materials: The following in Table 1 provides basic differences between offshore and land-based aquaculture as defined in this paper.

Table 1: Basic Differences Between the Offshore and Land-based Aquaculture

S/N	Land-based	Offshore based
1	The water mass used in this form of aquaculture is confined and has relatively no or little free flow compared to offshore-based one	The water mass in offshore-based aquaculture is voluminous and has a relatively large free flow between the containment and environment
2	Regular water change-out is required.	No water change-out is required. Therefore cost involved in this activity is zero.
3	The fish is confined. Therefore the fish depend on the food provided by the farmer	The flowing river does transport natural food into the fish cage, reducing the feed cost.
4	Infections can be easily managed since they are confined and separated from wild fishes.	Contact with wild fishes can involve the transmission of disease. Control of diseases may be difficult. Mortality can be very high compared to land-based systems
5	Land-based system does not require much logistics and equipment for production compared to the offshore based.	The equipment/vessels required for the logistics of offshore-based systems are large compared to land-based.
6	The size of the land-based system can be limited. There is competition for land between the farmer and other social-economic sectors	The size of the offshore-based aquaculture is only limited by the investment fund. There is little or no competition with other socio-economic sectors.

Source: Authors

In 2023, the Nigerian government created the Ministry of Blue Economy. The drive for this work is to enlarge the frontier of the maritime industry to include offshore aquaculture. Offshore aquaculture is practiced in Europe, Asia, and America and it has turned out that it has contributed generously to the blue economic values in the countries where they are practiced. The drive for investment is profitability. This work aims to assess the economic viability of investments in offshore aquaculture.

Development of an offshore aquacultural engineering model in Nigeria: Nigeria has a vast coastline along the Atlantic Ocean, offering several suitable locations for offshore aquaculture. When considering specific locations for offshore aquaculture in Nigeria, it is essential to assess factors like water quality, ocean currents, infrastructure, accessibility, and regulatory considerations.

Additionally, collaboration with local communities and stakeholders is crucial to ensure sustainable and mutually beneficial projects. Proper environmental impact assessments and feasibility studies should guide the selection of suitable sites for offshore aquaculture ventures. Some potential places for offshore aquaculture in Nigeria include:

1. Lagos**:** Lagos State, with its extensive coastline, is a prime candidate for offshore aquaculture development. Areas along the Lagos coastline, such as Lagos Island and Lekki Peninsula, have the necessary infrastructure and access to markets.
2. Delta State: The Niger Delta region, including areas like Warri and Escravos, provides favorable conditions for offshore aquaculture due to its proximity to water bodies and relatively calm waters.
3. Rivers State: Locations along the Bonny River and the Niger Delta coastline offer opportunities for offshore aquaculture ventures. Port Harcourt, the capital of Rivers State, could serve as a hub for related activities.
4. Bayelsa State: Situated in the heart of the Niger Delta, Bayelsa State has numerous creeks, rivers, and estuaries, making it suitable for offshore aquaculture.
5. Cross River State: Cross River State, particularly areas along the Calabar River and the Atlantic coast, has potential for offshore aquaculture development.
6. Ogun State: Coastal areas of Ogun State, such as Ilashe Beach and areas around the Lagos Lagoon, are accessible and suitable for offshore aquaculture.
7. Akwa Ibom State: Akwa Ibom, with its extensive coastline along the Gulf of Guinea, offers multiple locations for offshore aquaculture, particularly around coastal towns like Eket and Uyo.

8. Ondo State: Ondo State's coastline along the Atlantic Ocean, including communities like Ilaje and Ode-Irele, presents opportunities for offshore aquaculture projects.
9. Edo State: Edo State's coastline, including locations near Warri and the Benin River, can support offshore aquaculture initiatives.
10. Oyo State: Coastal communities in Oyo State, such as Ajasin, also have the potential for offshore aquaculture development.

Framework on operation of offshore aquaculture: Offshore environments are characterized by high energy. For offshore aquaculture, facilities must be built to be stronger than their inshore counterparts. The new technologies of offshore aquaculture should aim at reducing the cost and maintenance of facilities. Offshore facilities can be made more efficient and safer if they are automated as being practiced in some developed countries. However, this will not come cheap. It will take time and money. Agbakwuru and Udosoh (2023), documented a design procedure for such offshore facilities (see Figure 1). Though their design was made with steel structures protected with cathodic protection and paints, the authors suggest that fiber material will perform best because of lower weight and resistance to destructive corrosion.

Fig 1: Design and constructed offshore submersible fish cage.
Source: (Agbakwuru and Udosoh, 2023)

Furthermore, Osuji and Agbakwuru (2022) anticipated that designers can use sandwich methodology while developing boats for marine transportation and other related items putting into consideration the proposed plastic sandwiched fiberglass reinforced (PSFGR) strengths. Application of PSFGR technology in the design and construction of offshore fishing facilities will drastically reduce plastic pollution in the marine ecosystem thereby making the marine environment plastic-free because they will be used in the production of offshore fishing structures. According to Osuji and Agbakwuru (2024), fishery contributed 2,978.6 (trillion) to Nigeria's GDP between 2015 – 2022 with a drop in GDP contribution in 2016 and the fishery's contribution to GDP has increased geometrically yearly. As pointed out by Osuji and Agbakwuru (2024), the deficit is proportionate to the blooming human population. This is expected to remain so, and we argue in this work that it is possible to overturn this through the application of offshore aquaculture considering the enormous coastline in Nigeria as modeled in the work of (Agbakwuru and Udosoh, 2023). This is possible with the use of available economic tools such as Present Net Value (NPV).
NPV is a concept used to mean the value of future cash flows discounted to the present value. In other words, it takes into consideration risks, especially financial risks. Mathematically, it is simply the difference between the present value of cash inflows and outflows over a period of time. The critique of the NPV methodology for valuing projects is based on the claim that it cannot cope with the potential flexibility that comes with investment projects, resulting in changes in the original cash flow pattern (De Reyck, *et al*., 2008). The flexibility referred to includes but not limited to abandonment, deferring or delaying the project, expanding the project within the period, contracting, or switching to a different project. These are expected not to apply in the present presentation.

Collection of Materials: The materials are secondary data acquired from published journals and interviews with fishery experts. Net present value as an economic tool is used. The project is designed for Escravos offshore in Delta State with a water depth of 21m.

1. Fish cage fabrication:
A 50m x 25m x 3m fiber cage is designed and installed in less than 50m and moored to position.
Materials required.

Resin	100 drums
Fiber-glass (cloth)	50 bundles
Hardner	10 drums
Accelerator	10 drums
Mooring system	4 mooring wires
Cost	N10M

Total cost for 10 (ten) cages N100M

2. Fish quantity per volume of water is taken as 10 individual fish for tilapia or catfish per m3 of water.
The offshore cage of 50m x25m x3 m has volume of 3750 m^3
The 3750 m^3 will accommodate 37500 fishes
Take Mortality rate of 30%.
The actual fish harvestable will be 26250 fishes

Let the average fish weight be 0.7kg
The total fish weight harvested will be 18375 kg
Take the cost of 1kg fish to be N1400 (against market price of N2100/kg)
Revenue is computed as N514.5M, accounting for two (2) harvests per year for the ten (10) cages.

3. Fish feeding cost
1000 fishes to maturity will require 20 bags of feed (for five (5) months)
Meaning a fish will consume 0.02 of a bag.
The total bags of feed required by 318750 fishes will be 525 bags
Taken present cheapest fish feed cost of N20000/bag
The cost for the fish feed for the 318750 fishes will be N105,000,000.00
Total cost of feed required for the ten (10) nets for two (2) harvests per year =N210M

4. Site inspection is carried out to map the location of cage installation offshore. This will involve the use of mini vessels such as W23 or Passport 19. Such cost is put at N3M.

5. Community relations involves informing the community of the intended project. Usually, the communities will ask for a stake in the project. A total cost of N5M annually is located on this item.
6. Installation of ten (10) cages will involve towing of the fabricated 10 (ten) cages to offshore locations and mooring them in place for operations. A sum of N20M is allocated to this activity.

7. In the second year, during the cost of operations, there will be at least one (1) W23 or Passport 19 in service for the project. Purchasing such a boat is about N10M. Operating such a boat will cost fuel/oil of about N10M per year. This accounts for N20M in the 2nd year.

8. Annual salaries and wages of N32M are taken considering the following staff and their wages in Table 2.

Table 2: Staff Salary and Wages

Staff	Quantity	Wage/year/mil
General Manager	1	4.8
Offshore Engineer/ Manager	1	4.8
Fishery professionals	2	8.4
Boatman	2	3.6
Captain	1	3.6
Security	2	2.4
Administration	3	3.6
Total cost		**31.2**

The amount is increased annually by N1M to account for wage annual increment

9. Income tax of N5M per year is added to the wages. For the first operational year (2nd year), for instance, it is N32M plus N5M which is N37M.

$$\text{Net Present Value (NPV)} = \sum_{n=0}^{t} \frac{C_n}{(1+r)^n} \quad (1)$$

Where t =Total number of time periods; n= time period; $C_n = Cash\ flow\ in\ the\ time\ period$; r= Discounted rate

RESULTS AND DISCUSSIONS

The result of the NPV analysis is shown in Table 3. The first column is the duration of investment and the project in years. Column two is the unit year in which the investment/project is taking place. Columns three and four describe the investment/project task and the cost of such investment in million naira. Column five describes the period at which the cages/nets undergo maintenance or replacements. Columns six to nine indicate the cash flows arising from the investment. The tenth column is the NPV computation based on Equation (1). The NPVs are cumulated in the eleventh column. The NPV value of over N1 trillion in this presentation points to the very attractiveness of offshore aquaculture in boosting the blue economic growth of Nigeria. The breakeven period is within two (2) years of the investment. This result indicates that the industry can compete favorable with the oil and gas industry. Considering the presented work plan and cost investments for only ten (10) cages, it is obvious that a national investment and interest in offshore aquaculture can become a huge economic boom for the country. Moreso, it is noted that most of the costs in the investment are in feeding the fish. This is another area of job creation and opportunity that could employ a reasonable number of people. Sensitivity analysis is conducted on the NPV analysis of Table 3 to analyze the effect of variations of the component inputs of the analysis for variations up to 45%. The result is presented in Table 4. It is clearly evident that the results of the NPV analysis is most sensitive to mortality or fish market prices with the effect on the analysis reaching 196.3%. Mortality of 70% or price reduction of 50% will lead to negative NPV. The NPV result is also sensitive to the investment cost (92.4%). The consequence is that investors must involve all expertise and professionals required to control mortality and fish losses. Offshore engineers and cost experts with very good experience should be involved in the project for quality cost control. It is very believed that the price reduction of fish will hardly reach below 20% based on market history.

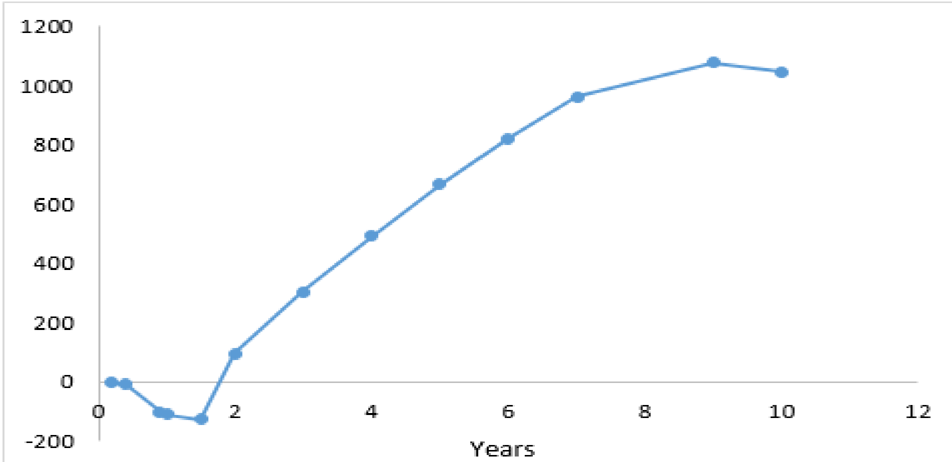

Fig 2: Accumulated NPV over the cage file (*Source:* Computed by Authors)

Table 4: Sensitivity analysis of the NPV analysis

	Variation	NPV (million Naira)	Effect/%
Discount rate	45%	1371	
	0%	1107	41.9
	-45%	907	
Investment cost	45%	596	
	0%	1107	92.4
	-45%	1619	
Fish production or Price/kg	45%	2193	
	0%	1107	196.3
	-45%	20	
Operating costs	45%	1541	
	0%	1107	14.1
	-45%	1697	

Major constraints of offshore aquaculture in Nigeria: Akinsorotan, *et al.*, (2019), identified the following as the major constraints of offshore aquaculture in Nigeria;

1. Nigeria's coastal areas, like other developed coastal towns in the world, are densely populated with heavy commercial and industrial activities, which results in pollution.
2. Inshore and offshore oil exploration usually leads to oil spillage with a resultant effect on water chemistry and fish kill.
3. The Nigeria coastal water from Lagos to Calabar region is between 0 – 40m nearshore (very shallow as the whole bathymetry spans a depth of 0 to 1000 meters [20]. Coastal offshore aquaculture may require a deep depth.
4. Under-develop technology for sustainable aquacultural production offshore.
5. Lack of political will on the part of the government to have preferred crude oil to offshore aquaculture in the coastal area due to the dependent nature of the Nigeria mono-economy.

The authors also identified non-participation of the private sector as part of the major constraints.

Benefits of Offshore Aquaculture in Nigeria's Blue Economy: Offshore aquaculture can play a pivotal role in advancing Nigeria's Blue Economic content in several ways:

1. Economic Diversification: By establishing offshore aquaculture operations, Nigeria can diversify its economy beyond traditional sectors like oil and gas. This diversification can reduce the nation's economic vulnerability to fluctuations in oil prices.
2. Food Security**:** Nigeria's growing population requires a consistent and diverse source of seafood. Offshore aquaculture can provide a stable supply of fish and seafood, contributing to food security and reducing reliance on imports.
3. Job Creation: The development of offshore aquaculture projects creates employment opportunities in various sectors, including fish farming, equipment manufacturing, logistics, and seafood processing, bolstering local economies.
4. Export Potential: High-quality aquaculture products can be exported, generating foreign exchange earnings for the country. Meeting international standards for quality and sustainability can help Nigeria access global markets.

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Table 3: Net Present Value Analysis

Years	Unit years	Investment description	Investments (mill naira)	Operating cost mill Naira (including Tax)	Facilities TAM or replacement (mill Naira)	**Total Cash Outflow in mill Naira**	Fish production per harvest	Fish production in three (2) harvests per year for ten (10) cages	**Cash Inflow in mill Naira (@1400Naira/kg)**	**PV = [(R(t)[out)+R(t)[in)] / [1+10%]^t**	**Accumulated PV over the cage life**
						R(t)[out]			**R(t)[in)**		
0.2	**t=1**	Site inspection/localization	3			-3	0	0	0	-2.943355487	-2.943355487
0.4	**t=1**	Community Relations (CR)	5			-5	0	0	0	-4.812967513	-7.756323
0.9	**t=1**	Design/Fabrication	100			-100	0	0	0	-91.77968934	-99.53601234
1	**t=1**	Installation/ Commissioning/ operations	10			-10	0	0	0	-9.090909091	-108.6269214
1.5	**t=2**	Equipment costs (Equip Cost)/Salaries	20			-20	0	0	0	-17.33568344	-125.9626049
2	**t=2**	Feed	210	37		-247	18375	367500	514.5	221.0743802	95.11177529
3	**t=3**	PR+Equip Cost+Feed	235	38		-273	18375	367500	551.25	209.0533434	304.1651186
4	**t=3**	PR+Equip Cost+Feed	235	39		-274	18375	367500	551.25	189.3654805	493.5305991
5	**t=3**	PR+Equip Cost+Feed	235	40		-275	18375	367500	551.25	171.5295155	665.0601146
6	**t=3**	PR+Equip Cost+Feed	235	41		-276	18375	367500	551.25	155.3714492	820.4315639
7	**t=3**	PR+Equip Cost+Feed	235	42		-277	18375	367500	551.25	140.7336139	961.1651778
9	**t=3**	PR+Equip Cost+Feed	235	43		-278	18375	367500	551.25	115.8846742	1077.049852
				NET PRESENT VALUE AT 10% DISCOUNT (at 9-yrs) =						**1077.049852**	
10	**t=10**		35	44		-79				-30.45791986	
		NET PRESENT VALUE AT 10% DISCOUNT (with facilities TAM or changeout at 10-yrs) =								**1046.591932**	
						Accumulated NPV Over the entire 10-years life =					**4071.688984**
						Maximum Exposure (maximum negative cumulative NPV) =					**125.9626049**
						Total Cash inflow over the 14 years life (Million Naira)					**3822**

10	**t=10**	35	44	-79	-30.45791986	
Net present value at 10% discount (with facilities TAM or change-out at 10-yrs) =					**1046.591932**	
Accumulated NPV Over the entire 10-years life =						**4071.688984**
Maximum Exposure (maximum negative cumulative NPV) =						**125.9626049**
Total Cash inflow over the 10 years life (Million Naira)					**3822**	

Keynotes: 1. Discount rate of 10% is used in this analysis. 2. The design shall be made for 10-years life. 3. TAM means turn-around maintenance. Replacement means complete change-out of the facility.

7. Job Creation: The development of offshore aquaculture projects creates employment opportunities in various sectors, including fish farming, equipment manufacturing, logistics, and seafood processing, bolstering local economies.

8. Export Potential: High-quality aquaculture products can be exported, generating foreign exchange earnings for the country. Meeting international standards for quality and sustainability can help Nigeria access global markets.

Environmental Stewardship: Properly managed offshore aquaculture can help protect wild fish stocks by reducing overfishing and illegal fishing practices. Sustainable farming methods can minimize environmental impacts and support marine conservation efforts.

Technology and Innovation: Offshore aquaculture necessitates technological advancements, encouraging research and development in aquaculture-related fields. This innovation can spill over into other sectors and enhance Nigeria's technological capabilities

9. Infrastructure Development**:** Building the necessary infrastructure for offshore aquaculture, such as floating farms, feed production facilities, and transportation networks, stimulates economic growth in coastal regions and improves local infrastructure.

10. Climate Resilience**:** Offshore aquaculture is less susceptible to the adverse effects of climate change compared to traditional agriculture. It can offer a resilient source of food production, contributing to the country's climate adaptation efforts.

11. Regulatory Framework: A well-designed regulatory framework is essential to ensure responsible and sustainable offshore aquaculture practices. This framework should address environmental concerns, quality standards, and resource management.

12. Community Engagement: Engaging local communities in offshore aquaculture projects can foster social development and cooperation. This involvement can lead to shared benefits and minimize potential conflicts.

Conclusion: Offshore aquaculture has the potential to significantly contribute to Nigeria's blue economy by promoting economic diversification, enhancing food security, creating jobs, supporting environmental conservation, and fostering technological innovation. However, it requires careful planning, investment, and regulation to ensure long-term sustainability and maximize its positive impact. The Nigerian Institute for Oceanography and Marine Research (NIOMR) should as a matter of urgency and responsibility, develop and engineer rear-able fishes for offshore aquacultures to attract investors.

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