Path Analysis Model of Factors Affecting Production Performance and Productivity of Intensive System White Shrimp in Indonesia

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Abstract. The intensive system is expected to increase production and productivity in white shrimp cultivation. However, several latent variables such as social, economic and technical aspects have little known influence on shrimp production performance and productivity. This research aimed to evaluate the path analysis model factors that influence production performance and productivity in intensive white shrimp cultivation systems using structural equation models. The method used was a survey of 50 shrimp pond industry managers in Indonesia as respondents who were selected by purposive sampling to be interviewed in depth. The path analysis model uses SEM-PLS 3.0 software with two testing stages. The first stage is a model measurement test and the second stage is a model structure test. The results show that economic aspects and technical aspects have a positive and significant direct effect on changes in production performance and productivity in intensive system white shrimp cultivation, while social aspects have a significant indirect effect with technical aspects as a mediating variable. This study provides a new contribution to the influence of technical mediation aspects that influence social aspects on production performance and productivity in intensive system white shrimp cultivation in Indonesia.

1 Introduction

Sustainable aquaculture is production management that takes into account three pillars, namely economic, social and environmental [1]. Sustainability indicators for fisheries cultivation according to [2] there are three indicators, namely biological indicators, ecological indicators, and cross-sectoral indicators. Sustainability indicators for fisheries cultivation according to [3] there are 56 indicators in aquaculture including 14 economic indicators, 22 environmental indicators and 20 social indicators, each of which can be used at the farm, regional, global and sectoral levels. Sustainable production in

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aquaculture requires the integration of new technologies that maximize economic benefits while minimizing environmental impacts on life in the future [4]. A bioeconomic model approach was created to evaluate sustainable aquaculture. Bioeconomics combines biological models and economic models to study the interactions that influence complex aquaculture production [5].

Aquaculture production is influenced by many factors. The three main factors supporting the sustainability of aquaculture production are environmental, economic and social. One of the factors that drives the achievement of high productivity is environmental factors, one of the indicators of which is the technical aspect. Technical aspects such as land and water efficiency, water quality and water availability are important factors in supporting sustainable fish farming [6,7,8,9]. Cultivation locations that have good access to water availability are significantly more efficient than ponds located in areas with limited access to water sources [10]. Joint management of public water resources will increase the technical efficiency of cultivation followed by other driving factors [11]. Another factor that influences productivity and efficiency is land ownership status. The productivity and efficiency of cultivation with rented land is higher than with own land [12]. In addition, production efficiency on own land status decreases along with the size of the land area owned. Ease of access to formal credit also influences the productivity of shrimp farming. Productivity will increase significantly for cultivators who do not experience credit constraints [13]. Providing credit of 30% of the cost total can increase white shrimp production by around 1.4 times [14]. This is important because in the absence of credit constraints, farmers have the freedom to buy quality inputs and use them in more optimal input combinations. A similar thing was also reported [15] that limited access to credit and financial capital influences the choice of raw materials that are cheaper and often of lower quality, which can affect productivity in white shrimp cultivation. The characteristics of human resources as labor have an influence on production management and productivity, such as level of education, and work experience in the field of aquaculture [7, 11]. The socio-economic characteristics of cultivators and compensation systems have been proven to increase productivity [16].

The main factors that influence the production performance and productivity of white shrimp cultivation are the environment, quality of seeds and feed, cultivation systems and technology. However, there are other factors that also influence production performance and productivity, such as water availability [17], land ownership status [12], financial support [15], and social factors such as human resource characteristics including level of education, training and work experience in the field of aquaculture [11]. The factors included in sustainable aquaculture indicators are environmental (especially technical), economic and social aspects [3]. It is not yet known how much influence this aspect has on production performance and productivity in intensive white shrimp cultivation systems. This study will answer the question of whether technical, economic and social aspects have a direct or indirect influence on production performance and productivity in intensive system white shrimp cultivation. Through the path analysis model, the factors that influence the production performance and productivity of white shrimp will be known, then efforts can be made to improve the inhibiting factors and increase the supporting factors for successful production and productivity in intensive system white shrimp cultivation. There are still many unknown factors and how the

mechanisms relate to production performance and productivity. This research is important to conduct in order to answer questions regarding what factors influence production performance and productivity in intensive white shrimp cultivation systems. This research aims to determine the path analysis model of the factors that influence production performance and productivity in intensive system cultivation of white shrimp (*Litopenaeus vannamei*).

2 Material and methods

2.1 Time and location

The research was carried out in February – April 2024 in the white shrimp pond of farmers located in several provinces in Indonesia, such as East Java, Central Java, West Java, Banten, Lampung, West Sumatra, Riau, West Nusa Tenggara and Bali (Fig 1). The research respondents were production managers in production units totalling 50 people who were selected using purposive sampling with the criteria that the commodity cultivated was white shrimp in an intensive system with a density of 80 - 120 post larvae/m, and the pond business carried out had been running for at least one year or a minimum of three production cycles.

Fig. 1. The location of the intensive system white shrimp pond of farmers as a study site

Primary data collection was carried out through interviews and observations of respondents using questionnaires. Direct observations at several research locations to obtain more in-depth information regarding the situation and conditions of shrimp cultivation.

2.2 Model design

Path analysis is an analytical technique used to analyze the inherent cause and effect relationships between variables arranged in a temporary order using the path coefficient as a marker of magnitude in determining the magnitude of the influence of the exogenous independent variable on the endogenous dependent variable (Fig 2). The model design

that will be tested is the influence of technical, economic and social aspects on production performance and productivity in intensive system white shrimp cultivation with the hypothesis proposed as follows:

H1 : Economic aspects influence the production performance and productivity of intensive white shrimp

H2 : Social aspects influence the production performance and productivity of intensive white shrimp

H3 : Social aspects influence technical aspects of intensive white shrimp

H4 : Technical aspects influence the production performance and productivity of intensive white shrimp

H5 : The influence of social aspects on production performance and productivity is mediated by technical aspects in intensive system white shrimp.

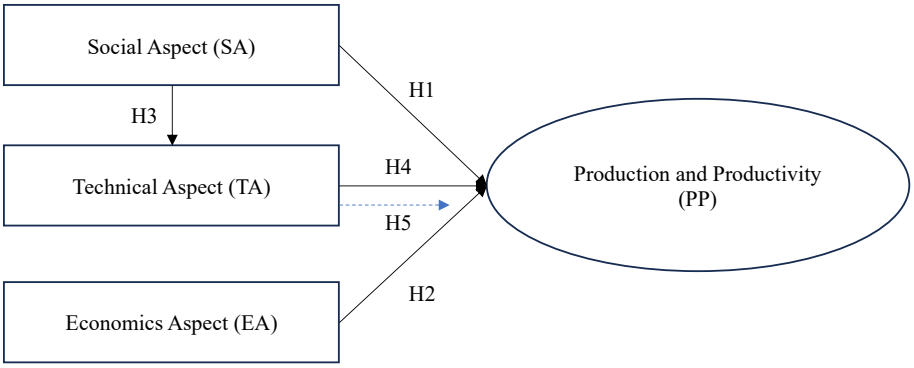

Fig 2. Presents hypotheses and path analysis models of factors that influence production performance and productivity in intensive system white shrimp

2.3 Description and measurements variable

Indicator variables are measured using the Likert scale method of 1 to 5 [18, 19]. The Likert scale is usually used to measure a person's perceptions and opinions regarding the research object. This scale is often used in educational, social and humanities studies. Structural equation modeling using a Likert scale regarding the ornamental fish industry has been carried out and allows it to be used in the field of aquaculture. The use of a likert scale shows better reliability results [21].

Table 1. Operational definition of the path analysis model of factors that influence production performance and productivity in intensive white shrimp cultivation systems.

Latent variables	Definition operational	Code	Variable indicator
Production Performance and Productivity (PP)	The results of production performance and productivity of an organization	PP1	*Survival Rate* (SR)
		PP2	*Feed Conversion Ratio* (FCR)
		PP3	Harvest size (kg $^{-1}$ head)
		PP4	Production (kg ha $^{-1}$ cycle $^{-1}$)
		PP5	Productivity (ton ha $^{-1}$ year $^{-1}$)

Latent variables	Definition operational	Code	Variable indicator
Technical Aspects (TA)	Organizational knowledge of environmental management based on standard operating procedures (SOP)	TA 1	Preparation pond covers activity repair equipment, drying and cleaning pond based on type pond, installation, and water filling and preparation
		TA2	Distribution seed start from selection, acclimatization And process distribution
		TA3	Management feed start from count, weigh, give and feeding
		TA4	Growth monitoring start from sampling and counting rate growth shrimp
		TA5	Management water quality starts from measurement routine and monitoring included convenience in access waters general
		TA6	Prevention and treatment disease and health monitoring shrimp
		TA7	Do activity harvesting (harvest Partial or total harvest) and action postharvest
Economics Aspects (EA)	The resources and financial capabilities of the organization	EA1	Convenience access formal credit
		EA2	Ownership land status
		EA3	Venture capital
		EA4	Scale enterprises
		EA5	Permission business
		EA6	Trends shrimp price
		EA7	Type consumer
		EA8	Target market
		EA9	R/C ratio
		EA10	Average income of farmers every month
Aspect Social (SA)	Human resources and abilities possessed by shrimp cultivation business actors	SA1	Formal education undertaken influence decision
		SA2	Training attended add outlook
		SA3	Experience Work strengthen understanding
		SA4	Involved in organization informal cultivation

2.4 Data analysis

Preparation of *path analysis* models using Smart-PLS 3.0 *software* (www.smartpls.com) [20]. There is two stage analysis on PLS-SEM, namely testing *outer* model (measurement model) and *inner* model (structural model). Stage testing *outer model* namely validity testing and reliability testing to indicators and constructs with criteria; valid if mark *Loading factor* > 0.7 and AVE value > 0.5 (PLS algorithm results), and reliable if mark *Cronbach's alpha* > 0.6 (PLS algorithm results). Next, *an inner model* test namely the T test for test significance independent influence on variable dependent (bootstrapping results), influential (significant) if p value <0.05 or statistical T value > 1.96 (value critical table), then the R^2 and f^2 tests were carried out for measure big influence variable exogenous to endogenous variables simultaneous and individual based on PLS Algorithm

results. Criteria big influence partial that is big if f^2 value = 0.35, moderate if f^2 =0.15, and small if f^2 value = 0.02). Whereas big influence simultaneous using (R^2) with index (R^2: 0.19= small, 0.33= moderate, and 0.6= large. Next test is the Q^2 and SRMR test for measure strength model predictions and model feasibility. Q^2 is *predictive relevance* namely testing the model's ability to predict based on blindfolding results. If the value Q^2 >0 shows that the model has *predictive popularity*. Next is the SRMR test, namely for testing the fit model, which means the model is feasible used If SRMR value <0.10 based on results algorithm.

3 Result and discussion

3.1 Respondent characteristics

Intensive white shrimp cultivation is the main job of shrimp farmers in Indonesia with an average cultivation time of between 5 - 15 years. The characteristics of shrimp farmers in Indonesia can be seen in Table 2.

Table 2. Characteristics of respondents

Characteristics	Category	Percentage (%)
Sex	Man	96
	Woman	4
Age	Gen Z (<25 years old)	4
	Millennials (26 - 41 years old)	52
	Gen X (41-57 years)	36
	Boomers (> 57 years old)	8
Education	Middle school or equal	6
	High school or equal	24
	Diploma	14
	Bachelor	44
	Postgraduate	12
Experience Work	0-5 years	28
	5 -10 years	32
	10-15 years	18
	>15 years	22
Application probiotics	Use probiotics	94
	No use probiotics	6

Table 2 showed that almost all research respondents were male 96%, including the millennial generation aged between 26 – 41 years. Education level is a bachelor's degree. As many as 94% of intensive system shrimp farms in Indonesia use probiotics and the remaining 7% choose not to use them.

3.2 Evaluation of measurement models

The PLS SEM model and hypotheses were analyzed in two stages. The first stage is the outer model test, namely PLS analysis of the relationship between indicators and constructs as a measurement model. The second stage is the inner model test to test the hypothesis of the relationship between exogenous and endogenous variables. The model

used in this research is a regression model with mediating variables. The path analysis model of factors that influence production performance and productivity in intensive system white shrimp cultivation is presented in Figure 3.

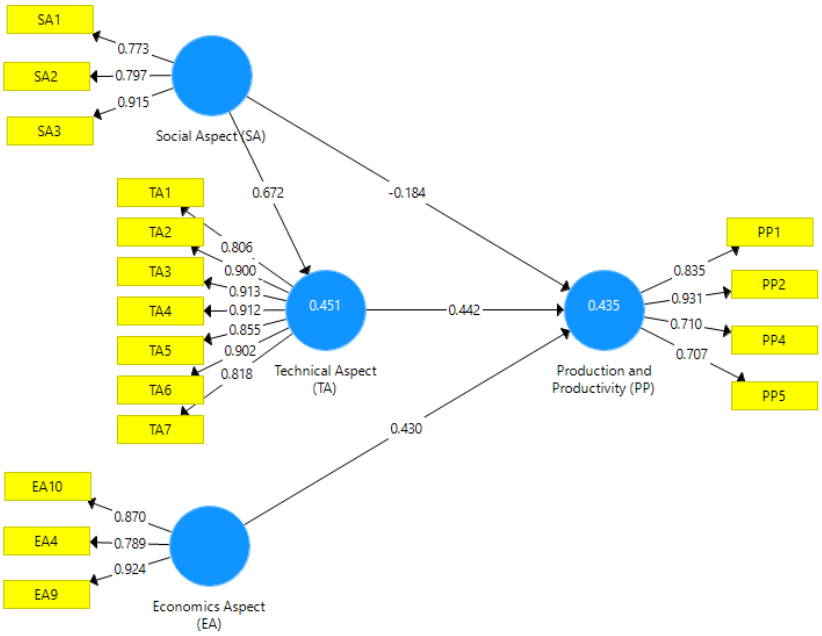

Fig 3. Path analysis model of factors that influence production performance and productivity in intensive white shrimp cultivation systems.

Figure 3 showed that mediating variable is a variable that mediates (intermediaries) the influence of a variable on another variable. Path coefficient of economic aspects of production performance and productivity = 0.430. The path coefficient from social aspects to production and productivity is -0.184. Path coefficient from social aspects to technical aspects = 0.672, and path coefficient from technical aspects to production and productivity = 0.442. The path analysis model influences social aspects (SA) and economic aspects (EA) as antecedents to production performance and productivity (PP) with technical aspects (TA) as mediating variables.

Table 3. Assessment of measurement models

Variable	Items	Factor Loading	Cronbach's Alpha	Composite Reliability (CR)	AVE
Production and Productivity (PP)	PP1	0.835	0.811	0.876	0.642
	PP2	0.931			
	PP4	0.710			
	PP5	0.707			
Technical Aspects (TA)	FY1	0.806	0.948	0.957	0.763
	FY2	0.900			
	TA3	0.913			
	FY4	0.912			
	TA5	0.855			
	TA6	0.902			

Variable	Items	Factor Loading	Cronbach's Alpha	Composite Reliability (CR)	AVE
	TA7	0.818			
Economic Aspects (EA)	EA4	0.789	0.828	0.897	0.745
	EA9	0.924			
	EA10	0.870			
Social Aspects (SA)	SA1	0.773	0.773	0.869	0.690
	SA2	0.797			
	SA3	0.915			

Note: PP3, EA1, EA2, EA3, EA5, EA6, EA7, EA8, and SA4 have deleted Because loading low

Table 3 showed that the measurement model items have valid loadings between 0.707 and 0.931, with Cronbach's alpha values between 0.773 and 0.948, AVE values between 0.642 and 0.763 and CR between 0.869 and 0.975. Thus, the construct measurement model is convergently valid and internally consistent. Evaluation of a measurement model must meet the requirements of convergent validity and discriminant validity. Convergent validity is achieved if the measurement model criteria are valid, namely the loading factor value is more than 0.7 and the average variance extracted (AVE) value is more than 0.5. If the Cronbach's alpha value is more than 0.6 and the reliability consistency value is more than 0.7, then the measurement model can be said to be convergently valid and internally consistent. Because the loading factor value is less than 0.7, PP3, EA1, EA2, EA3, EA5, EA6, EA7, EA8, and SA4 are disqualified.

Table 4. Criteria Fornell – Larcker (HTMT Ratio) for validity discriminant

	AE	PP	SA	TA
Economics Aspects (AE)	-			
Production and Productivity (PP)	0.582	-		
Social Aspects (SA)	0.483	0.321	-	
Technical Aspects (TA)	0.544	0.553	0.672	-

The validity of discriminant variables is determined using the Fornell – Larcker value criterion by comparing the square root of AVE and the correlation value between variables. As can be seen in Table 4, the discriminant validity of the evaluation is good because all the diagonal cross loading values of the variables are higher than the crossloading values below them. This shows that the indicators for each variable are appropriate to their construct.

3.3 Evaluation of structural models

After evaluation of valid and reliable measurement model tests, next phase testing is carried out second namely structural model testing includes significance tests, magnitude tests influence in a way simultaneous (R^2) and partial (f^2), predictive relevance test (Q^2), and model fit test using mark *standardized root mean square residual* (SRMR) < 0.10. introduced SRMR as size suitability for PLS-SEM that can used For avoid error in model specifications.

The coefficient of determination (R^2) is the simultaneous influence of exogenous latent variables on endogenous variables. The R^2 values of 0.67, 0.33 and 0.19 respectively can be supposed to have a large (significant), moderate (medium) and small (weak)

influence. The coefficient of determination (R^2) on production performance and productivity is 0.435 (Figure 3). Thus, social and economic aspects have a moderate influence simultaneously on changes in production performance and productivity in intensive white shrimp cultivation systems. The magnitude of the impact can be explained from the size of the impact (f^2). Recommends [22] that the impact size be 0.02, 0.15, and 0.35 for small, medium, and large impacts. It can be seen in Table 5 that there is a small impact for SA to PP = 0.03, a medium impact for EA to PP = 0.222, and TA to PP = 0.169 and a large impact for SA to TA = 0.821, which means that the social aspect has a small influence on performance production and productivity, but have a large influence on the technical aspects of intensive system white shrimp cultivation

The PLS algorithm and bootstrapping procedure on 5000 sub-samples with a significance level of 0.05 were used to produce path coefficients and significance tests. Structural model analysis to test the variable relationship hypothesis. If the P-value <0.05 or the T-statistic value is >1.96 then the exogenous variable has a significant influence on the endogenous variable. Hypothesis testing is presented in Table 5.

Table 5. Structural model hypothesis testing

Hypothesis	Connection	Path coefficient	f^2	Std error	T-statistic	P-Value	Decision
H1	EA →PP	0.430	0.222	0.201	2,137	0.033 **	*Significant*
H2	SA →PP	-0.184	0.032	0.201	0.912	0.362	*Not Significant*
H3	SA →TA	0.672	0.821	0.092	7,309	0,000 *	*Significant*
H4	TA →PP	0.442	0.169	0.199	2,227	0.026 **	*Significant*
H5	SA→TA →PP			0.146	2,040	0.042 **	*Significant*

* hose 99% confidence (P<0.01)
** hose 95% confidence (P<0.05)

Table 5 showed that the results of hypotheses H1, H3, and H4 are positive and significant for testing direct effects. In H1 and H4, economic aspects (EA) and technical aspects (TA) have a positive and significant effect on production performance and productivity (PP) in intensive system white shrimp cultivation. The results of this research strengthen previous research that white shrimp production is influenced by good technical capabilities and economic supporting factors to ensure the continuity of shrimp cultivation businesses. Cultivation systems and technology will affect production value and productivity. Several research results show that an integrated multi-trophic cultivation system (IMTA) in white shrimp cultivation [23] and a polyculture system [7] can increase production. Hypotheses H2 and H3 found that social aspects do not have a significant effect on production performance and productivity, but have a significant effect on technical aspects (TA). These results are in accordance with previous research that the level of formal education undertaken does not guarantee the success of cultivation production. Competence in white shrimp cultivation can be obtained from training on certain topics and work experience in the field of cultivation can increase technical abilities and success in cultivation [24].

Hypothesis H2 indicates that social aspects (SA) do not have a significant direct effect on production performance and productivity (PP) in intensive white shrimp cultivation

systems. These results contradict the initial hypothesis which stated that social aspects influence production performance and productivity. Therefore, hypothesis H5 mediates the influence of social aspects on production performance and productivity which is mediated by technical aspects. The results of our analysis prove that social aspects have a significant influence indirectly through mediating factors. In this case, the technical aspect is a full mediation for the social aspects that influence production performance and productivity in intensive white shrimp cultivation systems. Therefore, the results of this research are a new contribution in mediating the influence of technical aspects that influence social aspects on production performance and productivity in intensive white shrimp cultivation systems in Indonesia.

4 Conclusion

The path analysis model shows that technical and economic aspects have a positive and significant influence on production performance and productivity in intensive white shrimp cultivation systems. The results of this research provide a new contribution that technical, social and economic factors influence production performance and productivity with technical aspects as mediation for the sustainability of intensive system white shrimp cultivation. This research provides new insights into the theory of sustainable aquaculture and path analysis of the influence of these factors on production performance and productivity in intensive white shrimp cultivation systems which have not been widely discussed in previous studies of aquaculture systems and management. These findings prove that social aspects such as level of education, training and work experience influence technical abilities which in turn indirectly influence increasing production performance and productivity in intensive white shrimp cultivation systems.

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