Role of Agricultural Sector and Quality of Its Production Factor in Indonesia: An Application of Input-Output Analysis and Panel Model

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Abstract. Indonesia has been known as the largest agricultural country in Southeast Asia. However, the sector contribution to national output has declined. This indicates a low interconnection between agriculture and the other sectors despite the sector's significant potential to stimulate other industries' output through strong backward and forward linkages. This condition is caused by the role of production factors that determine agricultural output. Therefore, the research aims to analyse agriculture's linkages with other sectors and to assess the effects its production factor on agricultural output. Using Input–Output multiplier analysis, it is found the agriculture, forestry, and fisheries sector is the largest absorber of labour in Indonesia. This sector is predominantly consumed directly by households. Meanwhile, panel model results for 2010–2024 show that increases in labour without accompanying improvements in quality have a negative effect, whereas investment and credit, as manifestations of capital, have positive effects on agricultural gross value added. Policy implications include prioritizing skills development and improving access to credit and investment to foster adoption of productivity-enhancing technologies, thereby enabling the agricultural sector to grow and exert greater influence on other sectors and on the national economy.
Keyword: Agriculture Sector, Capital, Indonesia, Input-Output Analysis, Labour Quality.

1. Introduction

Indonesia's agricultural sector remains an essential role in the national food security and economy, both as a source of food livelihood for millions of households [7]. However, between the period 2010–2024, the agriculture sector has faced a paradox. The declining trend of investment share in Indonesia's agricultural sector—particularly in food crops, plantations, and livestock—provides further context for the urgency of this study. As shown in figure 1, the share of investment in these subsectors decreased significantly from 8.23 percent in 2010 to only 3.62 percent in 2025. Although some fluctuations occurred, such as short-lived increases in 2014 and 2018, the overall trajectory indicates a gradual reduction in the sector's ability to attract investment.

These challenges highlight the importance of understanding agriculture's role within Indonesia's economic development. It is not enough to conclude agriculture's inter-sectoral linkages; it is equally important to identify the key factors that sustain its performance over time. Human capital development and the effective utilization of labour remain critical in this regard, particularly in ensuring that agricultural value added (GVA) continues to expand despite structural shifts in the economy.

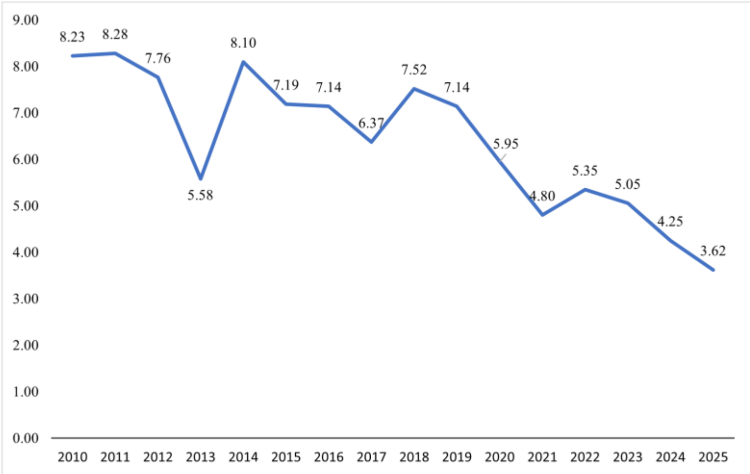

Figure 1. Investment share in food crop, and plantation sectors

In the figure 1, analysing both the multiplier effects of agriculture through the Input–Output framework and the determinants of gross value added via human capital and labour becomes highly relevant. The descriptive analysis of agriculture's inter-sectoral contributions, combined with empirical analysis of its performance drivers, will help understand why investment in agriculture has not kept pace with its economic potential, and what policy measures may be needed to revitalize the sector.

Previous studies underscore a long-term decline in agriculture's share of GDP (from around 19% in 1990 to 14.4% in 2013) [7], while Input–Output analysis has shown agriculture's multiplier effects across output, employment, and income [8]. Agricultural resilience amid economic shocks has also been demonstrated [9]. Further, a panel models incorporating human capital, such as health and education, underscore their influence on agricultural productivity. Yet, limited research has integrated these perspectives under current investment constraints and structural changes.

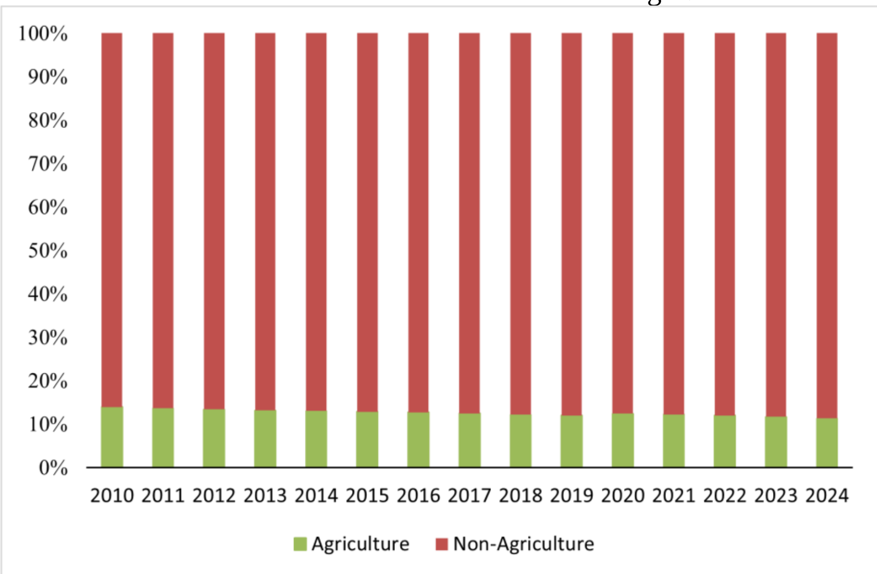

Figure 2. Investment share in food crop, and plantation sectors

Figure 2 illustrates proportion of agricultural sector (green) compared with the non-agricultural sector (red) in Indonesia's economy during the period 2010–2024. It shows that agriculture's contribution remains around 12–13 percent and has gradually declined, while the non-agricultural sector dominates more than 85 percent of the economy. This condition reflects the structural transformation in Indonesia, where the roles of industry and services have strengthened. Nevertheless, despite its relatively smaller contribution, agriculture continues to serve as an essential pillar, particularly in providing employment and livelihoods for millions of rural households.

The importance of agriculture becomes even more evident when linked to national food security. As the primary supplier of food, the sector directly supports price stability and the availability of staple

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goods for society. Furthermore, agriculture is closely connected to other sectors, both as a provider of inputs for processing industries and as a market for services and trade. Therefore, discussions on agriculture remain highly relevant, as strengthening the sector not only improves farmers' welfare but also contributes to overall economic stability, particularly in addressing food security challenges and promoting sustainable development. To address this, the present study aims to (i) deliver updated descriptive evidence using Input–Output methods, and (ii) evaluate the impact of human capital and labour on agricultural GVA via panel regression over 2010–2024.

2. Research Method

2.1. Data and Variables

This study utilized data collected by across Indonesia's government institutions, such as Statistics Indonesia (BPS), Indonesian Investment Coordinating Board (BKPM), and Bank Indonesia. Table 1 represents the data used and its sources. This study used a panel data spanned from 2010-2024 with the object of analysis is all Indonesia Provinces. In the output-input table, this study used Indonesia Input-Output table in year 2016.

Table 28. Data sources and unit

Data	Sources	Symbol	Unit
Input-Output Table	BPS-Statistics	-	-
Human Development Index	BPS-Statistics	Hum	Index
Labour in Agriculture Sector	BPS-Statistics	Lab	Million people
Agriculture Sector Gross Value Added	BPS-Statistics	GVA	Billion Rupiah
Credit Realization	Bank Indonesia	Cred	Billion Rupiah
Investment in Agriculture Sector	Indonesian Investment Coordinating Board (BKPM)	Inv	Billion Rupiah

2.2. *Quality and Number of Labour Agricultural Sector*

The quality and number of labour are two key determinants of agricultural sector performance. Quality encompasses the education, technical skills, health, and experience of farmers, which influence their ability to adopt technology, efficient cultivation practices, and farm management [17]. Meanwhile, number of labour reflects the availability of seasonal and permanent labour, unemployment/underemployment rates, and labour migration flows to non-agricultural sectors [18]. Increasing labour force size without improving quality often results in low marginal productivity; conversely, a high-quality labour force can increase output per labour and encourage production diversification.

Accurate measurements and indicators are essential for designing effective policies. Quality indicators can include formal education levels, participation in agricultural training and extension services, digital skills, and health status that affects productivity; while number indicators include age composition, seasonal vs. permanent ratio, and labour mobility. Demographic changes, such as urbanization and the exodus of young workers, require accurate data so that policy interventions can be targeted, for example, training programs, skills certification, or support for seasonal workers.

Therefore, policies must be simultaneous and integrated: developing human capital through education, vocational training, and health services, while providing incentives and access to financing for appropriate technologies that complement workers skills [19]. Technology can reduce barriers to entry by lowering the initial costs required to start an industry [20], thereby reducing costs with better quality workers. Special attention should be given to the role of women in agriculture, social safety nets for seasonal workers, and programs that restore the interest of the younger generation, through access to credit, agribusiness entrepreneurship training, and environmentally friendly technologies, so that agricultural productivity increases sustainably without sacrificing job stability.

2.3. Input-Output Analysis

Measuring economic performance by sector requires data which can accurately represent current situation while also serving as the fundamentals consideration for future development projections. The interconnections among sectors provide important insights into the capacity of each sector to contribute to regional development and foster economic growth. The shift of economic activity within each sector is unified into a structure that pictures the overall economy performance among sectors within an area.

One of the analytical instruments commonly used to capture these inter-sectoral linkages is the Input-Output (I-O) Table. I-O Table provides valuable information on the extent of interdependence among sectors within an area during a specific time.

According to [10], the I-O Table is presented in the form of a mathematical matrix that describes the movement of goods and services, as well as the interconnections among sectors or economic activities within a region during a given time frame. Each row and column in the table has a distinct interpretation. The rows illustrate the allocation of outputs produced by one sector to meet the demands of other sectors during the period. In contrast, the columns represent the composition of inputs utilized by each sector in its production processes, which may consist of intermediate inputs or primary inputs.

In a mathematical term, multiplier can be written as:

$$O_j = \sum_{i=1}^{n} b_{ij} \quad (1)$$

$$P_i = \sum_{j=1}^{n} b_{ij} \quad (2)$$

$$I_j = \sum_{i=1}^{n} a_{n+1,i} b_{ij} \quad (3)$$

$$w_j = \frac{l_j}{x_j} \quad (4)$$

$$L_j = \sum w_j b_{ij} \quad (5)$$

where O_j denotes the output multiplier for industry-j, b_{ij} is element of multiplier matrix row i and column j. Then P_i denotes the GVA industry-i, I_j is the household income multiplier for industry-j, $a_{n+1,i}$ is salary per total output, L_j is the labour multiplier for industry-j, w_j is labour coefficient for industry-j, l_j is number of labour for industry-j, and x_j is number of output for industry-j.

2.4. Fixed Effect Method with Robust Covariance Matrix

There's a problem oftenly occurred in the process of analysing panel data called spatial dependence. This problem leads to an inconsistent estimate of the standard errors of the panel regression parameters. As the remedies toward this problem, [1] proposed the robust estimation of panel data regression. This method extends the Newey-West Heteroskedasticity-and autocorrelation-consistent (HAC) estimator, which was originally designed for time-series, to the panel data setting where cross-sectional dependence is often present.

They consider a general linear panel model estimated using OLS:

$$y_{it} = \beta x_{it} + u_{it}, i = 1, 2, \ldots., N; t = 1,2, \ldots, T, \quad (6)$$

where y_{it}, x_{it}, β, u_{it} are dependent variable, vector form of the independent variable, vector form of the parameter, and the error term, respectively. Standard covariance matrix estimators (like White's robust standard errors) assume independence across cross-sectional units, which is often violated in macroeconomic or regional data due to common shocks or spillovers. The covariance matrix is consistently estimated even when $N \to \infty$ and $T \to \infty$, under weak assumptions on cross-sectional and temporal dependence. The key estimator can be written as:

$$\hat{V}_{DK} = \hat{\tau}_0 + \sum_{l=1}^{L} \omega_l (\hat{\tau}_l + \hat{\tau}_l') \quad (7)$$

where $\hat{V}_{DK}, \hat{\tau}_0, \omega_l, \hat{\tau}_l, \hat{\tau}_0$ are Discoll-Kraay covariance matrix, variance of the average residual score, autocovariance on the lag l, and Bartlett Kernel, respectively.

3. Result and Discussion

3.1. Analysis of the Multiplier Effects of the Agriculture, Forestry, and Fisheries Sector in Indonesia

The input-output analysis conducted was a multiplier effects analysis for several categories, namely GVA multiplier effects, output multiplier effects, and household multiplier effects. The results of the analysis were highlighted specifically in seven industries classified in the agricultural sector out of a total of fifty-two industries. This multiplier effect analysis provides an initial overview of the impact that industries in the agricultural sector have on the economy and households when a shock occurs. The results of this multiplier effect analysis will help strengthen the analysis in the panel model that is being developed.

Table 2. Multiplier effects of the agriculture, forestry, and fisheries sector in Indonesia

Industries	GVA Multiplier	Output Multiplier	Household Multiplier
Food Crop Agriculture	1.059	1.225	0.372
Seasonal and Perennial Horticultural Crops, and Others	0.914	1.216	0.333
Seasonal and Perennial Plantations	1.180	1.286	0.443
Livestock	0.809	1.556	0.442
Agriculture Services and Hunting	0.834	1.334	0.455
Forestry and Logging	1.063	1.188	0.384
Fisheries	0.992	1.214	0.372

The GVA Multiplier reflects the effect of agriculture sector final demand from the overall GVA across all industries. When the GVA Multiplier is more than 1, the final demand of its industry would give a bigger influence to the GVA than the influence of the final demand itself. In this case, Food Crop Agriculture, Seasonal and Perennial Plantations, and Forestry and Logging would affect to the national GVA by 1.059, 1.180, and 1.063 billion rupiah in every increase of 1 billion rupiah, respectively.

The values presented in the output multiplier indicate the extent to which changes in final demand affect the formation of total output across all industries. This means if there's an increase in final demand of one billion rupiah in the industries of Food Crop Agriculture; Seasonal and Perennial Horticultural Crops and Others; Seasonal and Perennial Plantations; Livestock; Agricultural Services and Hunting; Forestry and Logging; as well as Fisheries, will cause additional total output in the Indonesian economy adding up to 1.225 billion rupiah, 1.216 billion rupiah, 1.286 billion rupiah, 1.556 billion rupiah, 1.334 billion rupiah, 1.188 billion rupiah, and 1.214 billion rupiah, respectively.

Unlike the output and value-added multipliers, the household income multiplier reflects the extent to which changes in final demand translate into earnings for households across Indonesia. An increase in final demand of one million rupiah in the Food Crop Agriculture, Seasonal and Perennial Horticultural Crops, and Others, Seasonal and Perennial Plantations, Livestock, Agriculture Services and Hunting, Forestry and Logging, Fisheries industries will affect in household income increases of 372 thousand rupiah, 333 thousand rupiah, 443 thousand rupiah, 442 thousand rupiah, 455 thousand rupiah, 384 thousand rupiah, and 372 thousand rupiah, respectively.

Table 3. Employment multiplier of the 17 sectors in Indonesia

Rank	Sectors	Multiplier
1	Agriculture, Forestry, and Fisheries	0.02663
2	Manufacture	0.02597
3	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles	0.01442
4	Other Services	0.01312
5	Education Services	0.01016
6	Accommodation and Food and Beverage Service Activities	0.00867
7	Transportation and Storage	0.00738
8	Public Administration, Defense, and Compulsory Social Security	0.00695
9	Business Services	0.00640
10	Human Health and Social Work Activities	0.00629
11	Financial and Insurance Activities	0.00590
12	Water Supply; Waste Management, Wastewater Treatment, and Recycling	0.00458
13	Mining and Quarrying	0.00443
14	Construction	0.00423
15	Information and Communication	0.00390
16	Electricity and Gas Supply	0.00373
17	Real Estate Activities	0.00232

From table 3, it is shown that Agriculture, Forestry, dan Fisheries sector has the highest Employment Multiplier Effect among the other sectors. This indicates that Agriculture, Forestry, dan Fisheries sector generates the highest labour market if there is an increase in its final demand. Furthermore, in every one-million-rupiah increase of Agriculture, Forestry, dan Fisheries sector final demand generates approximately 26.63 new employment opportunities.

From the analysis above, it is clear that Agriculture sector can be considered as the backbone of national employment. The agricultural sector in Indonesia is characterized by the dominance of small-scale and family-based farming, labour-intensive cultivation practices, and the seasonal demand for workers during planting and harvesting periods. In addition, the continuity of local value chains—such as traditional markets, household-scale processing, and supporting services—absorbs a considerable share of additional labour.

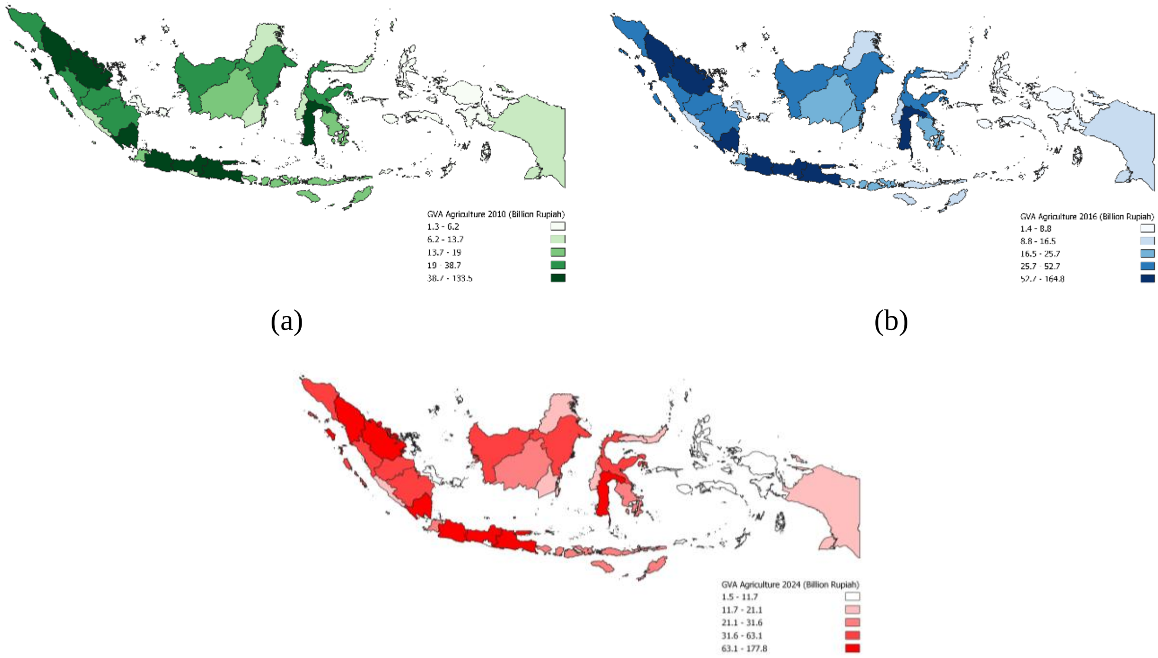
Table 4. GVA and intermediate input ratio (percentage)

No	Industries	GVA Ratio	Intermediate Input
1	Food Crop Agriculture	80.79	19.21
2	Seasonal and Perennial Horticultural Crops, and Others	81.91	18.09
3	Seasonal and Perennial Plantations	78.12	21.88
4	Livestock	66.50	33.50
5	Agriculture Services and Hunting	77.08	22.92
6	Forestry and Logging	86.97	13.03
7	Fisheries	85.16	14.84

However, this sector is the source of livelihood of most Indonesia vulnerable population such as small farmers, traditional fishermen, and rural women. This can be concluded from table 4, its shown that GVA and intermediate input ratio of the agriculture, forestry, and fisheries sector each have the ratio above 66 percent. This means more than 66 percent of these sectors' output are consumed directly by the national citizens as the final consumption. Several industries such as food crop and fisheries industries are consumed directly by the total population in the amount of more than 80 percent indeed.

3.2. The Impact of Production Factor Quality on the Agricultural Sector in Indonesia

After looking at the role of the agricultural sector, the discussion continued with the determinants of agricultural sector output. Before getting into the model, figure 3 shows the value added of the agricultural sector in each province from 2010 to 2024. It can be seen that there has been an increase in added value, with provinces such as Central Java, West Java, East Java, South Sulawesi, North Sumatra, and Riau dominating compared to other provinces. Meanwhile, provinces whose economies are not based on the agricultural sector have low output, such as DKI Jakarta, Gorontalo, Maluku, North Maluku, and West Papua.



(a) (b)

(c)

Figure 3. Agricultural sector output development by province in (a) 2010, (b) 2016, and (c) 2024

In the context of general economic theory, the level of economic output is determined by two primary factors: labour and capital. In the agricultural sector, the adoption of modern technology and the enhancement of resource management through the implementation of effective strategies can lead to a notable increase in productivity, particularly when coupled with the strategic utilization of skilled labour. Additionally, capital in the form of investment and access to agricultural credit have been demonstrated to play a significant role in increasing production capacity and agricultural yields. Consequently, the interplay between labour quality and capital can exert a substantial influence on agricultural sector productivity. The following text is intended to provide a comprehensive overview of the subject matter.

In order to demonstrate the impact of labour and capital quality on agricultural sector output, the utilization of an inference model is essential. Prior to estimation, model selection is conducted. The following table 5 illustrates the outcomes of evaluating the selected panel models. In light of these findings, the Fixed Effect Model was selected for further analysis.

Table 5. Panel model selection testing

Test	Statistics	p-value
Hausman	2228.2	0.0000***
Chow	0.58476	0.9887
Lagrange-Multiplier	2230.3	0.0000***

Note:
* Significant at 10%
** Significant at 5%
*** Significant at 1%

Furthermore, the results of various diagnostic tests of the FEM model are shown in table 6. The findings of the test results suggest the presence of several assumptions within the model that are problematic. Consequently, the utilization of the FEM model for the interpretation of the output is deemed inappropriate. Consequently, there is a necessity for more robust modelling to address the existing problems. The Driscoll and Kraay [1] estimator was selected for model estimation due to its specialized design for producing reliable estimates of statistical uncertainty, also referred to as "well-calibrated" estimates, in panel data regression models. This estimator is particularly suited for scenarios where errors are not independent across cross-sectional units but are instead correlated [2].

Table 6. Diagnostic test finding

Asumptions	Test	p-value	Decision
Autocorrelation	Breusch-Godfrey Test	0.0000^{***}	Serial correlation exists
Cross Sectional Dependence	Pesaran CD test	0.0000^{***}	Cross sectional dependence exists
Heteroscedasticity	Breusch-Pagan LM test	0.0000^{***}	Heteroscedasticity exists
Normality	Jarque-Berra Test	0.0000^{***}	Residuals aren't normally distributed

Note:
* Significant at 10%
** Significant at 5%
*** Significant at 1%

Subsequent to the handling of model violations, model interpretation can be performed. The output of the robust FEM model is presented in table 7. As demonstrated in the following table, it is evident that all variables exert an influence at multiple levels.

Table 7. Estimation of robust fixed effect model

Variable	Coefficient	Std.Error
ln(Lab)	-0.4606^{***} (0.0017)	0.1464
ln(Inv)	0.0019^{***} (0.0012)	0.0006
ln(Cred)	0.0087^{*} (0.0533)	0.0045
ln(Hum)	3.4399^{***} (0.0000)	0.3274
ln(Lab)*ln(Hum)	0.1087^{***} (0.0018)	0.0347

Note: the sign () indicates the p-value
* Significant at 10%
** Significant at 5%
*** Significant at 1%

The coefficient value for the labour variable is -0.4606, indicating that a 1 percent increase in energy intensity results in a 0.4606 percent decrease in agricultural sector output, assuming that other variables remain constant. This outcome can be attributed to suboptimal labour productivity in the agricultural sector, which is characterized by the influx of older workers, leading to an overall decline in output [5]. Furthermore, an increase in labour without a concomitant increase in quality may be a contributing factor to the decline in the added value of the agricultural sector. This observation is reinforced by the positive effect of the Human Development Index (HDI) and its favourable interaction with labour.

The estimated value of the human resource quality variable is 3.4399. This value indicates that a one-percent increase in the Human Development Index (HDI) will result in 3.4399 percent growth in agricultural sector output, under the assumption that other variables remain constant. This finding aligns with the conclusions of studies conducted by [3]. Conversely, the estimated interaction between labour and the Human Development Index is 0.1087, indicating that an increase in agricultural labour will result in a 0.1087 percent increase in sector output, under the assumption that other variables remain constant. The enhancement of labour quality is a pivotal factor in this regard, as it facilitates the adoption of advanced technologies and the implementation of more efficient agricultural practices, which, in turn, result in an increase in agricultural sector output [6]. Furthermore, Skilled labour also improves the management of scarce resources such as land and water while reducing input waste, thereby raising overall sectoral value added [4]. This is a critical factor in increasing the overall added value of the agricultural sector.

The succeeding discussion will address the extent to which capital, represented by the investment and credit variables, affects the agricultural sector economy. The estimated investment value of 0.0019 indicates that a 1 percent growth in investment in the agricultural sector will increase the added value of the sector by 0.0019 percent, under the assumption of ceteris paribus. The direction of this influence aligns with the findings reported [11] in their research. Investment is frequently regarded as a pivotal catalyst for fostering growth and advancement within the agricultural sector [12]. The influx of capital into the agricultural sector has the potential to facilitate the acquisition of novel technologies, upgraded infrastructure, and human resource training, thereby enhancing productivity and efficiency [13]. Consequently, this has the secondary effect of increasing agricultural output.

The second capital variable is credit, estimated to have a value of 0.0087. This implies that a 1 percent growth in credit in the agricultural sector will result in an output growth of 0.0087 percent, under the assumption that all other variables remain constant. This condition aligns with the findings reported in the research conducted [14]. The provision of credit facilitates access to adequate financing, thereby enabling farmers to procure quality agricultural inputs, including seeds, fertilizers, agricultural machinery, and technologies that can enhance productivity and efficiency [15]. The enhanced accessibility of credit has the potential to mitigate financial impediments experienced by small and medium-sized farmers, thereby empowering them to adopt agricultural innovations that augment crop yields and diminish reliance on manual labour [16]. Furthermore, credit extended to the agricultural sector can facilitate the development of agricultural infrastructure, including the construction of irrigation systems, storage facilities, and transportation access. These investments can contribute to the reduction of agricultural waste and the enhancement of market accessibility. Consequently, agricultural credit emerges as a pivotal instrument in fostering the advancement of the agricultural sector.

4. Conclusion

From the Input–Output analysis it is proven that agriculture, forestry, and fisheries exhibit strong multiplier effects, particularly in labour absorption and household income formation, highlighting the sector’s capacity to drive inclusive growth. However, a large proportion of agricultural output is directly consumed by households, indicating that much of its economic potential remains confined within final consumption rather than stimulating wider intersectoral linkages.

Results from the panel model further demonstrate that the quality of production factors significantly affect the sector’s output. Increasing labour without any improvements in quality cause a negative impact on agricultural output, while enhancements in agricultural labour quality as reflected by the interaction between Labor and Human Development Index generate substantial positive effects. Likewise, capital variables, represented by investment and credit, positively influence agricultural value added, underscoring the importance of financial access and technological adoption.

Overall, these results emphasize that strengthening the agricultural sector’s contribution to national growth requires not only enhancing its intersectoral linkages but also improving the quality of its production factors. Policies aimed at developing skilled agricultural labour, expanding access to credit and investment, and promoting technology adoption are essential for transforming Indonesia’s agriculture into a more productive, resilient, and growth-inducing sector.

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