

Dynamic model in analyzing Indonesia's agricultural sector's macroeconomic performance

Wahyudin^{1,*}, Syamsurijal Tan², Junaidi², Zulgani², Faradina Zevaya²

¹ Statistics Bureau of Indonesia (Badan Pusat Statistik), Mataram 83116, Indonesia

² Department of Economics, Universitas Jambi, Jambi 36361, Indonesia

* **Corresponding author:** Wahyudin, wahyudin@bps.go.id

CITATION

Wahyudin, Tan S, Junaidi, et al. (2024). Dynamic model in analyzing Indonesia's agricultural sector's macroeconomic performance. *Journal of Infrastructure, Policy and Development*. 8(8): 5661. <https://doi.org/10.24294/jipd.v8i8.5661>

ARTICLE INFO

Received: 4 April 2024

Accepted: 29 May 2024

Available online: 7 August 2024

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Abstract: Indonesia, an emerging archipelagic nation, possesses abundant natural resources spanning marine, land (including forests and water sources), and diverse biological riches. The agricultural sector emerges as a pivotal driver of growth across the country, exhibiting extensive distribution. Consequently, there is an urgent imperative for comprehensive research to bolster and optimize the performance of this sector. This study aims to meticulously analyze and scrutinize macroeconomic variables aimed at enhancing Indonesia's agricultural sector. Through the utilization of a dynamic panel model, the study zeroes in on crucial variables: economic growth in the agricultural sector, farmer terms of exchange, human development index, population density, inflation, average daily wages, and lagged economic growth data from each province in Indonesia. The best model for dynamic panel testing, employing both First Difference Generalized Method of Moments (FD-GMM) and Generalized Method of Moments System (SYS-GMM) approaches, is identified as the SYS-GMM model. This model exhibits unbiased and consistent estimation, as evidenced by the Arellano-Bond (AB) test and Sargan test results. The analysis conducted using this selected model reveals notable findings. Lagging agricultural sector performance, human capital measured by the Human Development Index (HDI), and farmers' exchange rates are found to significantly and positively influence the economic growth of the agricultural sector. Conversely, inflation exerts a significant and negative impact on sectoral growth. However, wage levels and population density do not demonstrate a significant partial effect on the economic growth of the agricultural sector.

Keywords: agricultural sector; dynamic model; SYS-GMM Model; Indonesia

1. Introduction

Indonesia is a developing country characterized by its archipelagic geography and endowed with abundant natural resources, particularly in terms of marine resources, land resources encompassing forests, water resources, and the diverse biological wealth they contain. These natural riches serve as capital in the country's development, especially in the economic sphere. One area that can be developed and optimized is the agricultural sector. The agricultural sector in Indonesia continues to significantly contribute to the country's economy and remains a priority in Indonesia's development programs. Agricultural development plays a crucial role in ensuring food supply and security, providing employment, contributing foreign exchange through agricultural exports, and more. This, in turn, impacts the growth of the agricultural sector and enhances the livelihoods of farming communities. Agriculture also acts as a catalyst for development by supplying raw materials, food, absorbing labor, and increasing the purchasing power of communities for other sector products. Naturally, development is supported by a robust agricultural sector both in terms of supply and

demand. A strong agricultural sector, viewed from both the supply and demand perspectives, fosters linkages with other economic activities (Kuncoro, 2010).

Recognizing the significant importance of the agricultural sector in the economy, particularly in terms of food supply and security, it is hoped that the government will pay greater attention to the growth of this sector. However, the dynamics of agricultural sector development are not as straightforward as expected. This is due to various challenges faced by farmers themselves, including issues related to capital, workforce quality, technology, agricultural product pricing, political situations, and more (Rusliyadi et al., 2018). Certainly, this should be a consideration and concern for the government when aiming to develop the agricultural sector and simultaneously elevate the standard of living for the community.

The development of economic growth in the agricultural sector depicted in **Figure 1** shows a declining trend over the years. In 2018, the agricultural sector experienced a growth rate of 3.88 percent, which then decreased to 3.61 percent in the following year, 2019. Subsequently, in 2020 and 2021, during the COVID-19 pandemic, there was a significant impact on the national economy, which inevitably affected the agricultural sector in Indonesia. The pandemic's economic policy uncertainty had profound implications for nearly all sectors of the global economy (Al-Thaqeb et al., 2022). The repercussions of the COVID-19 pandemic extended beyond the agricultural sector, influencing various other sectors and reshaping the world's economy and politics throughout history (Ceylan et al., 2020). This was partly due to the demand shock caused by COVID-19 in the global agricultural market. However, the impact of COVID-19 demonstrated a slight reduction in direct greenhouse gas emissions from agriculture, around 1%, or approximately 50 million tons of carbon dioxide in 2020 and 2021 (Elleby et al., 2020). During 2020 and 2021, the economic growth of the agricultural sector in Indonesia further decelerated to 1.77 percent and 1.87 percent, respectively. This deceleration in agricultural sector growth significantly affected other components contributing to overall Indonesian economic growth.

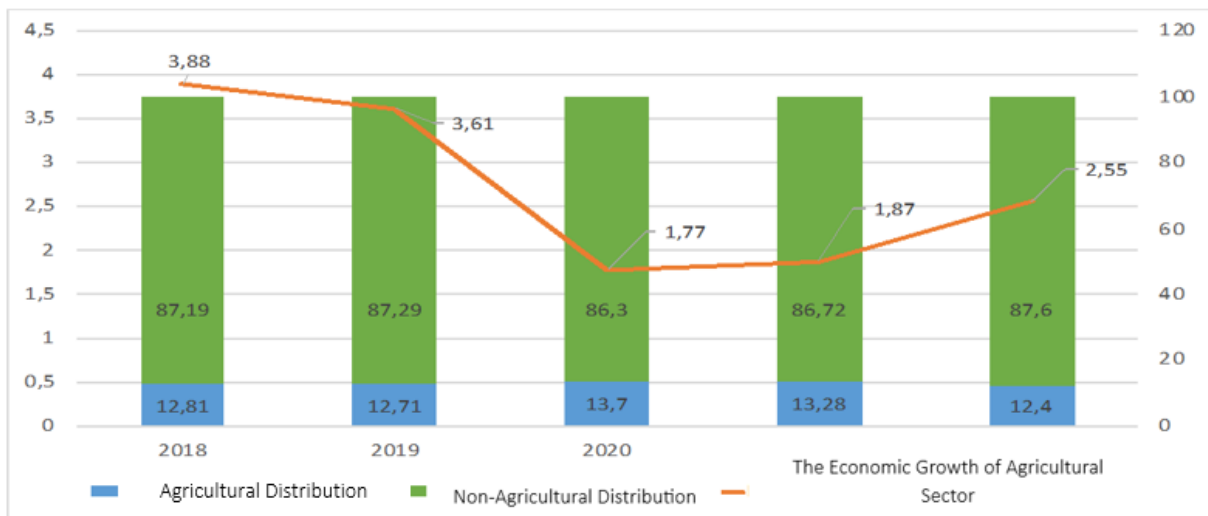


Figure 1. Agricultural economic growth and inflation in 2018–2022 (percent).

Source: Central Statistics Bureau (processed).

Figure 1 also illustrates the development of the agricultural sector's distribution in Indonesia's economy. Observing the years from 2018 to 2022, the distribution of the agricultural sector displays considerable fluctuations. In 2018, the agricultural sector's distribution was recorded at 12.81 percent, showing an increase in distribution in 2020 and 2021, reaching 13.27 percent and 13.28 percent respectively. It's noteworthy that these increments occurred amid Indonesia facing the COVID-19 pandemic from 2020 to 2021. This implies that while Indonesia was under the strain of the COVID-19 pandemic, which impacted growth across various economic sectors, the agricultural sector contributed an increased share to Indonesia's economy. Research conducted in Canada by Gray (2020) the economic condition in Canada during the pandemic led to increased prices or inflation in several food commodities. This was due to disruptions or slowdowns in the transportation sector, leading to high demand. The hindered distribution of food commodities resulted in inflation in various regions due to inadequate supply despite high demand. Inflation, being one of the benchmarks for measuring people's purchasing power, always receives special attention from the government for management (Roncaglia de Carvalho et al., 2018). A similar situation occurred in Turkey based on Makalesi's (2020) study findings the sluggishness of Turkey's economy due to the pandemic affected sectors like trade and transportation, hindering the distribution and trade of agricultural products. Consequently, there was a surge in food inflation in the country, impacting the income of farmers as their agricultural products couldn't be marketed. This steep rise in inflation will undoubtedly press down on the purchasing power of Indonesian society, particularly farmers in Indonesia. Hence, it's crucial for both local and central governments to control inflation by setting inflation targets through managing the supply and demand of various goods, including agricultural products (E. O. Svensson, 2014). This is crucial to consider as another challenge faced by farmers relates to prices, especially the prices of agricultural commodities or agriculture-based industrial products for export, such as fish and shrimp, coffee, betel nuts, Crude Palm Oil (CPO), and processed rubber prices. Fluctuations in export commodity prices in the international market significantly affect the development of these sectors, ultimately impacting the agricultural sector's role in the Gross Domestic Regional Product (PDRB) and the welfare levels of farmers. This is evident in the fluctuations of the Farmers' Exchange Rates (NTP), both generally and within each sub-sector.

The agricultural sector, which is a leading sector in Indonesia's growth, needs to be strongly considered by the government to robustly support Indonesia's growth. In the research of Chandio (2016) in Pakistan, it explains the importance of the agricultural sector's performance in driving a country's growth. Chandio's research results also indicate the necessity of enhancing Human Resources (HR) and Information Technology (IT) to improve the agricultural sector's performance. According to Sertoglu and Ugural (2017) the country that can enhance its long-term economic growth is the one capable of improving the quality of its agricultural sector's growth. Sertoglu's research highlights the positive impact of agricultural output on economic growth and recommends that governments and policymakers start diversification efforts and increase budget allocations for the agricultural sector. These various studies underscore the importance of enhancing the quality of agricultural sector performance as a booster for a country's growth.

The agricultural development program essentially comprises efforts to facilitate, serve, and encourage the development of competitive, inclusive, sustainable, and decentralized agribusiness systems and enterprises to enhance community welfare. There are several reasons why agriculture is crucial: (1) Its significant and diverse resource potential, (2) substantial contribution to GDP, (3) a substantial portion of the population relies on the agricultural sector for livelihood, (4) acting as a growth base in rural areas. Arifin (2013) asserts that agricultural development serves as a source of income and employment, a producer of food products, a driver of industrialization, a contributor to national foreign exchange earnings, and a market for products and services outside the agricultural sector. Based on Enu (2014) research titled “Analysis of the agricultural sector of Ghana and its economic impact on economic growth,” the study aims to determine the impact of the agricultural sector on Ghana’s economic growth and the influence of various agricultural sub-sectors on Ghana’s economic growth. Enu’s research uses the Ordinary Least Squares (OLS) methodology to estimate the impact of each agricultural sector on GDP growth. The results of the study show that agricultural output has a significant positive impact on Ghana’s growth.

The enhancement of agricultural sector development serves multiple functions in improving food security, uplifting the welfare of low-income or impoverished populations, particularly those living in rural areas, preserving the environment, and simultaneously playing a role in bolstering economic growth. Hence, there is a need for agricultural sector development strategies capable of transforming the lives of communities, especially farmers, to uplift them from poverty. This is expected to contribute to the growth of Indonesia’s economy, ultimately ensuring the attainment of agricultural sector development goals (Harsono et al., 2023). In several studies related to the agricultural sector, there is a regional nature that largely employs panel data models or Ordinary Least Squares (OLS) as conducted Kassie (2018) and Nurhab (2022) in the previous researches. The utilization of both OLS and panel data models remains static, whereas many economic variables are dynamic. Panel data analysis more aptly captures this dynamism through dynamic panel data regression. In employing dynamic panel modeling, there exists a lag in the dependent variable, which correlates with the error. Consequently, estimations using OLS or static panel methods yield biased and inconsistent estimators. To address this issue, dynamic panel data models can be estimated using the Generalized Method of Moments (GMM) approach. Sadoon et al. (2019) suggested the utilization of instrumental variable estimation methods. The results yield unbiased and consistent estimators but are not yet efficient. Subsequently, the Anderson and Hsiao instrumental variable method, developed by Arellano and Bond, recommends an approach called the Arellano-Bond GMM method. This method is capable of producing estimators that are unbiased, consistent, and efficient (Sebki, 2021).

The welfare of farmers is now receiving more tangible attention from the government. This was evidenced in 2023, in article 53 subparagraph E of Law No. 28 of 2022 concerning the government’s implementation of the State Budget for the Fiscal Year 2023, which aims for quality development targets, including the enhancement of the Farmers’ Exchange Rates. The improvement of the agricultural sector stands as one of the national development and economic growth objectives. Building upon the aforementioned context, the research issue here pertains to

analyzing macroeconomic variables' impact on the performance of the agricultural sector in Indonesia. Therefore, this research is structured to obtain a more comprehensive, dynamic, and accurate depiction concerning the macroeconomic variables' impact on the performance of the agricultural sector in Indonesia. The macro variables used include the Farmers' Exchange Rates, Human Development Index (HDI), Inflation, wage levels, and population size on the growth of the agricultural sector in Indonesia using a dynamic panel model approach.

Importantly, the study underscores the substantial impact of lag in the agricultural sector on its own growth, emphasizing the need for a nuanced exploration of the spatial implications of sectoral growth in each region. This prompts a call for further research development, particularly in the context of Indonesia as an archipelagic nation, advocating for the incorporation of regions into the model and macroeconomic variables to facilitate a more comprehensive analysis. This paper is organized as follows: In the next section, we delve into the literature review, providing a comprehensive overview of previous research and theoretical frameworks related to the macroeconomic performance of the agricultural sector. Following this, the materials and methods section outlines the data sources, the dynamic panel model used, and the methodological approach for analyzing the impact of various macroeconomic variables. The results and discussion section then presents the findings from the analysis, interpreting the significance and implications of the results in the context of Indonesia's agricultural sector. Finally, the conclusion section summarizes the key findings, discusses the broader policy implications, and offers recommendations for future research and policy directions to enhance the performance and growth of Indonesia's agricultural sector.

2. Literature review

2.1. The concept of agricultural development

The agricultural sector in economic development is crucial because a significant portion of the population in poor countries depends on it for their livelihoods. If planners truly prioritize the well-being of their people, the only way is by enhancing the welfare of the majority who live in the agricultural sector. The role of the agricultural sector in economic development consists of several aspects: (1) increasing food availability/surplus food for domestic consumption, (2) releasing surplus labor to the industrial sector, (3) serving as a market for industrial products, (4) increasing domestic savings, (5) boosting trade (source of foreign exchange), and (6) improving the welfare of rural populations (Jhingan, 2000). Arifin (2013) states that the development of the agricultural sector serves as a source of income and employment opportunities, produces food products, drives industrialization, contributes to the country's foreign exchange earnings, and serves as a market for products and services outside the agricultural sector. In the context of food security, the development of the agricultural sector can increase food availability and improve access to or purchasing power for food products. Increasing the productivity of food crops through superior varieties, increasing livestock and fisheries production (aquaculture and marine fisheries) has proven capable of addressing hunger issues. Tambunan (2003) stated that the linkages of the agricultural sector in driving output growth are not only related

to production but also to consumption or income and investment linkages. The agricultural sector has three functions: first, as a source of investment for the non-agricultural sector, where surplus funds in the agricultural sector become a source of investment for other sectors; second, it acts as a source of raw materials or inputs for other sectors, particularly agro-industry and trade; and third, through increased market demand for outputs, it serves as a source of production diversification in other economic sectors. Adam Smith's theory of growth emphasizes the economic growth process through the impact of capital accumulation and labor productivity. Smith also analyzes two aspects of economic growth: (1) the growth of total output and (2) population growth. The Neo-classical growth theory presents a different perspective from previous theories, viewing it from the supply side. The Neo-classical Solow growth model focuses on four variables (Romer, 1996): output (Y), capital (K), labor (L), and knowledge or the effectiveness of labor (A), as follow:

$$Y_t = F(K_{(t)}, A_{(t)}L_{(t)}) \quad (1)$$

The Neo-Classical economic growth theory has many variations, but it is generally based on the production function developed by Charles Cobb and Paul Douglas, now known as the Cobb-Douglas production function. This function, also known as the exponential production function, can be expressed by the following equation:

$$Q = AL^\alpha K^\beta \quad (2)$$

where:

Q = Total Production

A = Total Productivity

K = Capital

L = Labor

The parameters α and β , which represent the output elasticity with respect to each input, are constant.

2.2. A contribution of farmers' exchange rate in the agricultural sector

The Farmers' Exchange Rate (NTP) is a crucial indicator in the agricultural sector that reflects the welfare level of farmers. NTP is calculated as the ratio of the price index received by farmers to the price index paid by farmers. An NTP greater than 100 indicates that farmers are experiencing a surplus, while an NTP below 100 indicates that farmers are incurring losses. The contribution of NTP to the growth of the agricultural sector includes the following: (1) Prosperous farmers are more likely to invest in better agricultural technology, which in turn can boost agricultural productivity. (2) Increased income for farmers, indicated by a high NTP, can lead to greater investment in the agricultural sector, such as investments in agricultural infrastructure, training for farmers, and research and development. (3) Prosperous farmers tend to have higher purchasing power, which can increase the demand for goods and services in rural areas and drive local economic growth. (4) Farmers with stable and sufficient income from their agricultural output are more likely to adopt sustainable farming practices, which contribute to the long-term growth of the agricultural sector. (5) NTP can serve as an evaluation tool for the effectiveness of government policies in the agricultural sector.

Moreover, the plantation-based sectors, particularly the food and beverage industry (CPO processing industry) and the rubber industry, play a significant role in the economies of various regions in Indonesia. A study using Miyazawa's Input-Output Model and the Foster-Greer-Thorbecke Poverty Index Analysis reveals that while the percentage of poverty (P0) in the plantation sub-sector is lower than in other agricultural sub-sectors, the poverty depth index (P1) and the poverty severity index (P2) are higher (Hardiwan et al., 2019). This indicates that although fewer people are in poverty, those who are experience more severe poverty. The study also highlights that policies promoting downstream processing in the rubber industry and oil palm replanting can significantly impact output, value added, labor, and income in the plantation-based sectors, thereby increasing the income of poor households.

2.3. A concept of human development index

The Human Development Index (HDI) is an indicator used to measure the progress of human development in a region or country. HDI provides a general overview of the welfare level and quality of life of the population in a given area. The impact of HDI on the growth of the agricultural sector includes the following: (1) Higher education levels and better health improve the quality of the labor force in the agricultural sector. (2) Better education enables farmers to understand and implement technological innovations in agriculture, which can enhance agricultural productivity. (3) Improved education and communication technology facilitate farmers' access to market information, commodity prices, and weather forecasts, helping them make better decisions in their agricultural activities. (4) Increased education and environmental awareness through human development can aid in the more sustainable management of natural resources, such as the more efficient and environmentally friendly use of land and water. According to United Nations Development Program (2024), the HDI was developed to highlight that the true measure of a country's development should focus on people and their capabilities, rather than solely on economic growth. The dimensions in the HDI are: (1) long and healthy life with its indicators being life expectancy at birth, and the dimension index is life expectancy index, (2) knowledge with its indicators being expected years of schooling and mean years of schooling, and the dimension index is education index, (3) a decent standard of living with its indicators being Gross National Income (GNI) per capita based on purchasing power parity (PPP \$), the dimension index is GNI index.

2.4. Inflation in the agricultural sector

Inflation is the general and sustained increase in the prices of goods and services in an economy over a certain period. Inflation is measured using the Consumer Price Index (CPI) or the Producer Price Index (PPI). High inflation can reduce the purchasing power of the population. The impact of inflation on the growth of the agricultural sector includes the following: (1) High inflation leads to increased production costs, which can reduce farmers' profit margins and their ability to reinvest in agriculture. (2) High inflation decreases consumer purchasing power, which in turn reduces the demand for agricultural products. (3) High inflation is usually accompanied by high interest rates, resulting in higher borrowing costs for farmers

and hindering investment in the agricultural sector. (4) Decline in the Farmers' Exchange Rate (NTP), inflation affecting the prices of goods and services purchased by farmers can alter the NTP. If inflation on input goods is higher than on agricultural outputs, the NTP will decrease. The impact of inflation on the agricultural sector can be observed from the research by Zyl (1986) from 1973 onwards, South Africa experienced double-digit inflation, with the prices of agricultural producers' outputs rising more slowly than the prices of inputs. This led to decreasing profitability and purchasing power parity for agricultural products, increasing debt and risk, and weakening agriculture's competitive position in international markets. Inflation in input prices creates cash flow problems for farmers, necessitating high levels of operational management and conservative financial strategies. Individual farmers might counteract the effects of input price inflation by increasing productivity and reducing costs. However, the current competitive structures could potentially accelerate input price inflation if productivity increases and cost reductions occur across the agricultural sector as a whole. Solutions will be driven by general economic policy, with more effective competition and increased effective demand through accelerated urbanization offering potential, at least in theory.

2.5. A concept of wage level in the agricultural sector

Wage levels refer to the amount of compensation workers receive in the form of salaries or wages for the work they have performed. Wage levels can be influenced by various factors such as education level, skills, experience, labor demand and supply, as well as government policies related to minimum wages. The impact of wage levels on the growth of the agricultural sector includes the following: (1) Competitive wage levels can increase worker motivation and productivity. Workers who feel valued with fair wages tend to have a more efficient and high-quality work ethic, which in turn increases agricultural output. (2) Higher wage levels can attract more skilled and educated labor to the agricultural sector. (3) Increased wages in the agricultural sector can enhance workers' purchasing power, positively impacting the rural or local economy. (4) Higher wages encourage farmers to invest more in technology that can reduce reliance on manual labor, thereby improving efficiency and productivity (University of Hawaii System, 2018).

2.6. An effect of population density in the agricultural sector

The population is the total number of people occupying a particular area at a given time. Population growth is measured through birth rates, death rates, and migration. A large population can impact various economic and social aspects, including the agricultural sector. The influence of the population on the growth of the agricultural sector includes the following: (1) a high population leads to increased demand for food, prompting the agricultural sector to boost its production, (2) a large population provides more labor for the agricultural sector, (3) population growth, especially in rural areas, leads to the fragmentation of agricultural land as it is divided among heirs, this fragmentation can reduce production efficiency and economies of scale in agriculture, (4) an increase in the population can reduce labor in the

agricultural sector as many people choose to move to cities in search of better job opportunities (Arvianti et al., 2019).

In addition to the general effects of population density on agriculture, specific regions such as Jambi Province have shown potential for developing food crops-based and horticulture-based villages as growth centers. A study by Junaidi et al. (2020) analyzed the potential of these villages in Jambi Province and found that out of 1399 villages, 96.71 percent were primarily engaged in the agricultural sector, with a significant portion being food crops-based and horticulture-based. The study highlighted that 95.66 percent of these villages were either developing or already developed, with nearly half having non-agricultural Micro, Small, Medium Enterprise (MSMEs). This indicates a great potential for these villages to become growth centers, leading to increased economic activity and improved living standards for the local population.

Development policies implemented across Indonesia since the New Order era have driven significant transformations in demography, regional paradigms, growth base sectors, and growth actors. A study analyzing these policies found that central government demographic policies and plantation development programs have led to substantial changes in land cover, rural development, and economic growth in the country's biodiversity-rich regions (Rustiadi et al., 2023). The study observed positive trends in macro development indicators such as the Human Development Index (HDI), educational levels, Gross Regional Domestic Product (GRDP) per capita, and the proportion of the tertiary sector in GRDP. These changes were primarily driven by the trade and motorized-vehicle repair sectors. Additionally, the expansion of oil palm plantations has significantly altered the landscape. At the village level, there has been an increase in infrastructure and diversity of economic activities, with notable shifts in rural typology, including an increase in urban villages and villages specializing in oil palm plantations or other industrial crops.

2.7. Contribution of this paper

This paper makes several significant contributions to the existing literature on the economic growth of the agricultural sector in Indonesia. Firstly, it utilizes dynamic panel data models to analyze the impact of macroeconomic variables on agricultural growth, offering a more nuanced understanding compared to the static models used in previous studies. This approach allows for the examination of lagged effects and dynamic relationships, providing more robust and reliable results.

Secondly, this study includes recent data from 2020 to 2022, capturing the unique impacts of the COVID-19 pandemic on the agricultural sector. The pandemic has introduced unprecedented challenges and changes in economic conditions, which are crucial to understanding the current and future dynamics of the sector. By incorporating this recent data, the study offers timely insights that are highly relevant for policy-making in the post-pandemic era.

Thirdly, the findings highlight the significant positive impact of farmers' exchange rates and human development (measured by the Human Development Index) on the economic growth of the agricultural sector. These insights emphasize the importance of stable exchange rates and investments in human capital as key drivers

of agricultural productivity and growth. This provides a clear direction for policymakers to focus on these areas to enhance sectoral performance.

Furthermore, the study identifies inflation as a significant negative factor affecting agricultural growth, underscoring the need for effective inflation control measures. This highlights the importance of maintaining economic stability to foster a conducive environment for agricultural development.

Lastly, the study proposes comprehensive policy recommendations that encompass measures to stabilize exchange rates, enhance human capital, control inflation, and invest in rural infrastructure and innovation. These recommendations are designed to create a supportive environment for sustainable agricultural growth, contributing to broader economic development goals such as food security and poverty reduction.

By addressing these aspects, this paper not only fills existing gaps in the literature but also provides actionable insights for enhancing the economic performance of Indonesia's agricultural sector in a post-pandemic world.

3. Materials and methods

This study utilizes secondary data from the Central Statistics Agency. The time period covered in this research spans from 2020 to 2022, encompassing 34 research objects that include all provinces in Indonesia. Hence, the total observation units in this study amount to 102 observations. Researchers find that using the last 3 (three) years and 34 provinces is sufficient for conducting dynamic panel data regression research, in line with the statement provided by Hansen (1999) and Verbeek (1999) whereas studies on panel data modeling combine time series and cross-sectional aspects, a minimum of 30 observations has been deemed sufficient to yield a good model. The variables used include Farmers' Exchange Rates (NTP), Human Development Index (HDI), Inflation, wage levels, and population density.

3.1. Analysis method

The analysis method employed in this study is dynamic panel regression processed using Stata 14 software and the Geoda Application to aid in visualizing panel data.

3.2. Panel data regression model

The panel data regression model can be conducted using three approaches, namely, Common Effect Model, Fixed Effect Model, and Random Effect Model. Common Effect Model in this model, the time and individual dimensions are not considered, and it is also assumed that C behavior uses the Ordinary Least Squares approach (OLS) (Zevaya et al., 2023). The CEM model is stated as follows (Amaliah et al., 2020):

$$y_{it} = \beta_0 + X_{it}\beta + u_i + u_{it} \quad (3)$$

Fixed Effect Model is one way to account for cross-sectional unit heterogeneity in panel data regression models is by allowing for differentiated intercepts while maintaining constant slopes. The Fixed Effect Model (FEM) model is stated as follows:

$$y_{it} = \beta_0i + X_{it}\beta + u_i + u_{it} \quad (4)$$

Random Effect Model (REM) also referred to as the Error Component Model (ECM), it is stated as follows:

$$y_{it} = \beta_0 + X_{it}\beta + u_i + u_{it} \quad (5)$$

In this model, μ_i is considered as a random variable with an average of μ_0 . So, the intercept can be written as $\mu_i = \mu_0 + e_0$, where e_0 is an error with a mean of zero and a variance σ_e^2 . Thus, the equation can be written as follows:

$$y_{it} = u_0 + X_{it}\beta + u_{it} + \varepsilon_i \quad (6)$$

$$y_{it} = u_0 + X_{it}\beta + u_{it} + w_{it} \quad (7)$$

with $w_{it} = u_{it} + \varepsilon_i$.

3.3. Dynamic panel model

In this research, we will apply dynamic panel data regression modeling, which is based on the relationships among economic variables, many of which are dynamic in nature. The analysis can be used as a dynamic model in relation to the analysis of dynamic adjustments. This dynamic relationship is characterized by the presence of lagged dependent variables among the regressor variables. The method of moments approach can be used to address inconsistent estimators. Blundell (2000) suggests a Generalized Method of Moments (GMM) approach. The GMM approach is one of the popular methods. There are at least two reasons underlying this choice. First, GMM is a common estimator and provides a more useful framework for comparison and assessment. Second, GMM offers a simpler alternative to other estimators, especially compared to maximum likelihood.

However, the GMM estimator is not without its shortcomings. Some of these weaknesses include: (i) The GMM estimator is asymptotically efficient in large sample sizes but less efficient in finite sample sizes, and (ii) this estimator sometimes requires several programming implementations, hence necessitating software that supports the application of the GMM approach (Blundell, 2000).

There are two commonly used types of GMM estimation procedures to estimate autoregressive linear models, namely:

1) First-differences GMM (FD-GMM or AB-GMM)

To attain consistent estimations, a specific approach involves conducting a first-difference on equations to eliminate individual effects. The AB-GMM estimator might exhibit bias in small samples. This occurs when the lag level of a correlated series weakly correlates with the subsequent first-difference, resulting in weak instruments available for the first-difference equation. Blundell (1998) indicates that the AB-GMM estimator might face limitations due to bias in small samples, especially when the available observation periods are relatively limited. This emphasizes the need for caution before applying this method to estimate autoregressive models with a relatively small number of time series.

2) System GMM (SYS-GMM)

Utami (2019), the fundamental idea behind the use of the system GMM method is to estimate a system of equations in both first-differences and levels, where the instruments used at the level are lagged first-differences of the series. Lubis (2016) emphasizes the importance of utilizing initial conditions to produce efficient estimators for dynamic panel data models when T is small. One approach involves

creating a dynamic panel data autoregressive model without exogenous regressors as follows:

$$y_{it} = \delta y_{i,t-1} + u_i + v_{it} \quad (8)$$

with $E(\mu_i) = 0$, $E(v_{it}) = 0$, $E(\mu_i v_{it}) = 0$, in which $i = 1, 2, \dots, N$; $t = 1, 2, \dots, T$. In this case, Blundell et al. (1998) focused on $T = 3$. Note that this regression can be obtained from the above equation evaluated at time $t = 2$ by subtracting both sides of the equation, namely:

$$\Delta y_{i2} = (\delta - 1)y_{i,1} + u_i + v_{i2} \quad (9)$$

Blundell and Bond link the bias and imprecision of the first-difference GMM estimator with the issue of weak instruments, characterized by the concentration parameter. Based on the supporting theories presented, the model equation is formulated to address the issues in this study, which is:

$$\text{PDRBP}_{it} = \beta_0 + \beta_1 \text{PDRBP}_{it-1} + \beta_2 \text{NTP}_{it} + \beta_3 \text{IPM}_{it} + \beta_4 \text{UPAH}_{it} + \beta_5 \text{INF}_{it} + \beta_5 \text{POP}_{it} + \varepsilon_{it} \quad (10)$$

Notification:

PDRBP_{it} = The economic growth of agricultural sector

PDRBP_{it-1} = Lag of the economic growth of agricultural sector

NTP = Farmer's exchange rate

IPM (HDI) = Human Development Index

UPAH = The wage rate of farmers in each region

INF = Inflation

POP = Population Density, km/person

To estimate the parameters of the dynamic panel data model in the equation above, the first difference generalized method of moments (FD-GMM) will be initially employed. The validity of the instruments used will be assessed based on the results of the FD-GMM estimation. If they fail to meet the validity criteria, the SYS-GMM approach will be applied to address instrument validity issues in the FD-GMM framework. Testing the instrument validity in the FD-GMM approach can be done using the Sargan test. The Sargan test for overidentifying restrictions serves as a method to detect instrument validity problems. The null hypothesis for this test asserts that there are no issues with instrument validity (valid instruments), indicating that these instruments are not correlated with the errors in the FD-GMM equation. Through the Sargan test, it will be determined whether FD-GMM or SYS-GMM is the more suitable model for this study.

4. Results and discussion

The agricultural sector has become one of the leading sectors, contributing 12.2 percent to the total national GDP recorded in 2022. The significant contribution of the agricultural sector presents an opportunity for the government to enhance the national GDP.

In **Figure 2**, the roles of each sub-sector in shaping the agricultural sector in the Gross Domestic Product (GDP) of Indonesia in 2022 are depicted. Based on the above figure, it indicates that the plantation sub-sector has the largest distribution, accounting for 30 percent of the total GDP of the agricultural sector in Indonesia. This implies that the gross value added from the plantation sector makes a significant contribution to the economy in the agricultural sector. Besides the plantation sub-sector, the food

crops sub-sector is the second-largest contributor, accounting for 21 percent. Therefore, Indonesia has become a developing country capable of independently meeting the food needs of its population. This extraordinary value addition is a remarkable advantage and a promising prospect for Indonesia to enhance growth in this sector. The above figure also illustrates the substantial value added in the fisheries sub-sector, supporting the GDP of the agricultural sector in Indonesia with a contribution of 19 percent to the total agricultural sector GDP. Therefore, it is important for the three main sub-sectors to be given attention, improved, and developed to support the country's economic growth, especially in the agricultural sector. Enhancing output and added value through various strategic government programs serve as a solution and have a positive impact on the country's economic growth (Saleh et al., 2023a).

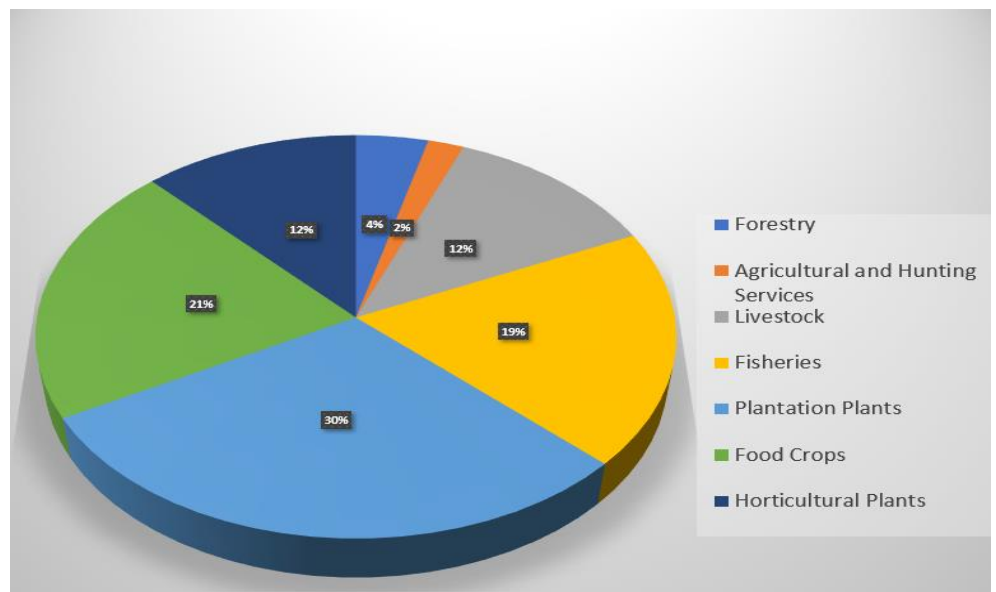


Figure 2. The contribution of the agricultural sub-sector to the agricultural sector in the 2022 National GDP.

Source: Central Statistics Bureau (processed).

The Net Farmers' Income (NFI) is often used as an indicator of farmers' well-being in Indonesia and is derived from the ratio of the index received by farmers to the index paid. Therefore, if the index received by farmers has a value above 100, it means that our farmers still have a surplus in managing their agricultural sector (Saleh et al., 2023). Based on **Figure 3**, it shows the Net Farmers' Income (NFI) in Indonesia according to provinces. The highest net farmers' income is found in the Riau, West Kalimantan (Kalimantan Barat), and Jambi provinces, each amounting to 144.9, 141.34, and 135.08, respectively. There are 28 provinces with NFI above 100, and there are still 5 provinces with NFI below 100, namely West Java (Jawa Barat), Banten, Yogyakarta Special Region, Bali, and East Nusa Tenggara (Nusa Tenggara Timur). Therefore, it is a task for local governments to improve the net farmers' income in these five provinces because having NFI below 100 implies that the communities working in the agricultural sector in these provinces may not be prosperous. When compared to the national NFI of 107.33, there are still 19 provinces below the national NFI.

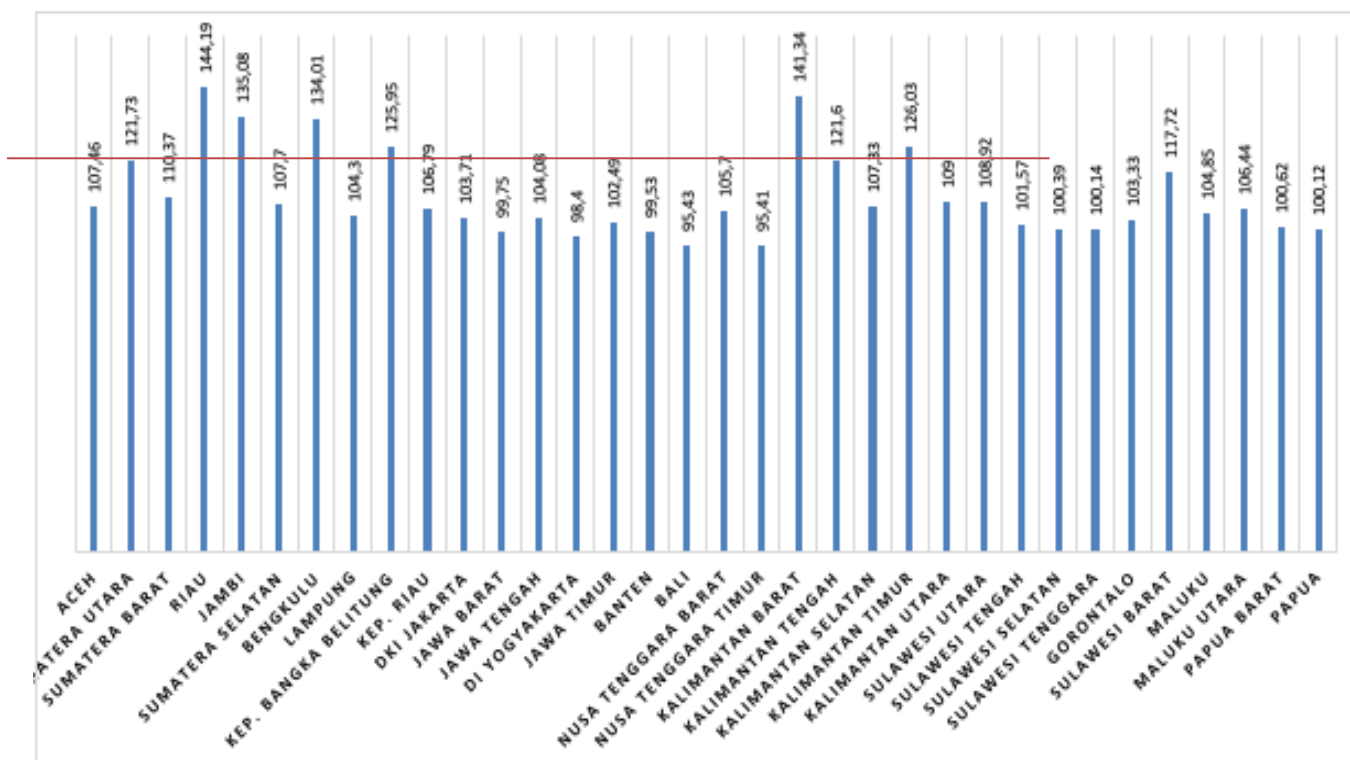


Figure 3. Farmer exchange rates in Indonesia according to provinces in 2022.

Source: Central Statistics Bureau (processed).

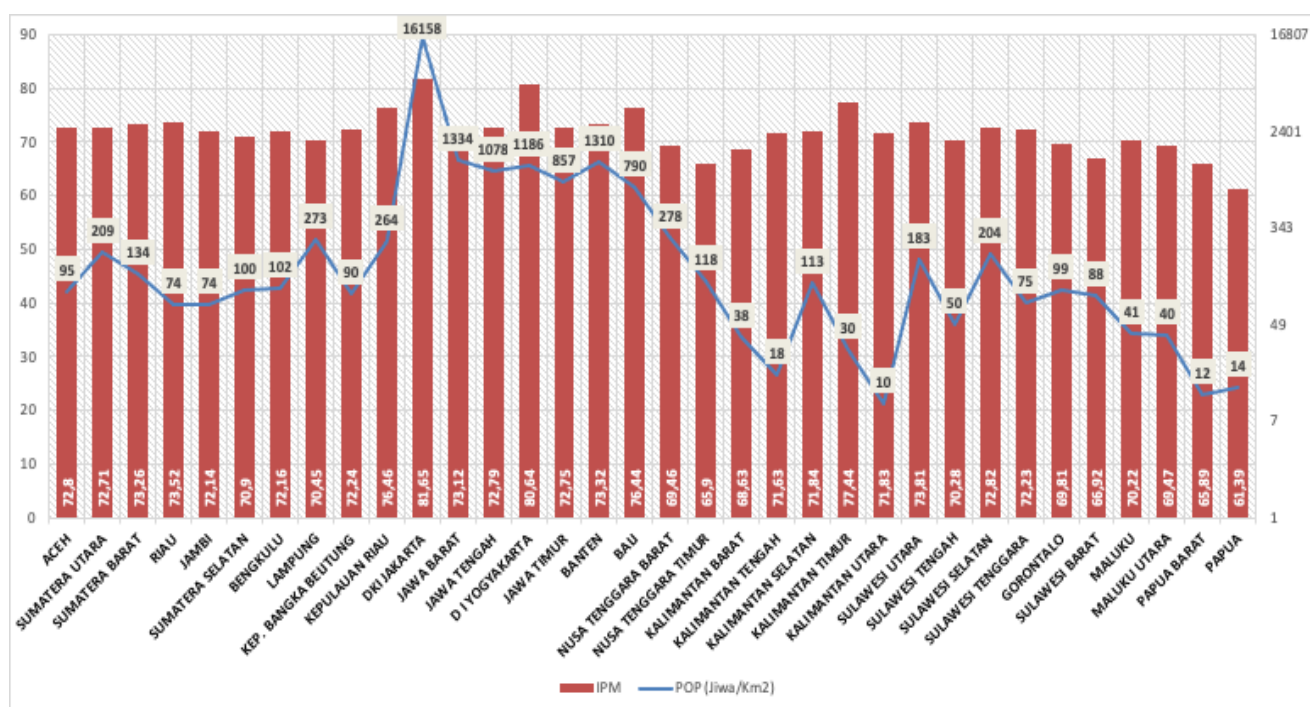


Figure 4. Population density and human development index in Indonesia by province in 2022.

Source: Central Statistics Bureau (processed).

The Human Development Index (HDI) in Indonesia in the year 2022 averaged at 71.92 points, while the national HDI itself was 72.91. There are 24 provinces with HDI below the national average and only 10 provinces with HDI above the national average. The provinces with the highest HDI are the special capital region (DKI) of

Jakarta, Yogyakarta Special Region, and East Kalimantan (Kalimantan Timur) with respective HDI values of 81.65, 80.64, and 77.44. HDI is a crucial indicator for measuring success in efforts to enhance the quality of human life. It explains how the population can access the benefits of development in terms of income, health, education, and more. Therefore, HDI serves as a vital indicator in assessing the quality of human capital in a region (Biares, 2018). **Figure 4** shows that there are three provinces with the lowest HDI: East Nusa Tenggara (Nusa Tenggara Timur), West Papua (Papua Barat), and Papua, where the human capital quality is in the 60's range.

Figure 4 also depicts the population density in Indonesia by province. Based on the above depiction, it shows that DKI Jakarta is the province with the highest population density, reaching 16,158 people/square kilometer. The next most densely populated provinces are West Java (Jawa Barat) and Banten, with 1334 people/square kilometer and 1310 people/square kilometer, respectively. The population density of an area has an impact on the quality of life of its residents. In the study by Wafiq (2021), it was noted that the negative impact caused by population density on the environment leads to a decrease in the quality of the environment in that area. Fithria (2017), in her research, also states that the impact of population density in an area includes an increase in energy consumption, both in the form of electricity and fuel.

Certainly, the high population density in a region becomes the government's responsibility to fulfill the needs of the population in that area, both in terms of food and non-food requirements. Regarding the Human Development Index (HDI), it indicates that the highest HDI is found in DKI Jakarta, Yogyakarta Special Region, and East Kalimantan (Kalimantan Timur), with values of 81.65, 80.64, and 77.44, respectively. Meanwhile, the lowest HDI is in Papua, West Papua (Papua Barat), and East Nusa Tenggara (Nusa Tenggara Timur). This indicates the uneven distribution of human capital development in Indonesia. Various programs to enhance human resources need to be promoted to improve the quality of human capital in Indonesia. (Appiah et al., 2019). Enhancing human capital or the Human Development Index (HDI) is a mandatory strategy for the government to boost the national economy, especially in the agricultural sector. Improving the HDI will increase the added value of agricultural products and enhance the overall quality of these agricultural products. (Bashir et al., 2018).

In **Figure 5**, it illustrates the development of changes in the Consumer Price Index (Inflation) in Indonesia from 2018 to 2022. In the last 5 years, inflation in Indonesia has moved fluctuatively, reaching its highest peak at 5.51 percent in 2022. High and uncontrollable inflation is undoubtedly a significant issue for a country. High inflation diminishes the purchasing power of both the general public and farmers in the agricultural sector, affecting their ability to meet living expenses and sustain their farming activities. Therefore, the issue of inflation must be controlled to mitigate its impact on the economic growth of a country (Lessons, 2021). The trend in the average hourly wage in Indonesia shows a fluctuating pattern as well. In 2018, it was Rp. 15,275, experiencing a substantial increase in 2020 and 2021, reaching Rp. 17,696 and Rp. 18,089, respectively. Rofik et al. (2018) mentioned in his study that the relatively high annual inflation rate led to a significant rise in wage levels. High wage levels also indicate an improvement in the socio-economic development of the country.

Increasing income or wages undoubtedly enhances the income and welfare of the population (Iksan and Arka, 2018).



Figure 5. Inflation and average hourly wages in Indonesia 2018–2022.

Source: Statistics Bureau (processed).

5. Discussion

Dynamic panel modeling analysis

The first step undertaken in estimating this research involves conducting dynamic panel data regression using the first-difference (FD-GMM) approach. Subsequently, if the model in the first stage does not meet the criteria for the best GMM model, namely being unbiased, valid, and consistent, the next step is to proceed with SYS-GMM estimation. In the estimation results presented in **Table 1**, the SYS-GMM model has fulfilled the criteria for the best model.

Table 1. FD-GMM and SYS-GMM dynamic panel modeling estimation results.

Variable	FD-GMM	SYS-GMM
$PDRBP_{t-1}$	0.324	0.001*
NTP	0.110	0.019
IPM	0.023*	0.025*
UPAH	-0.018*	0.387
INF	-0.446	-0.008*
POP	-0.764	-0.892
Constanta	0.025*	0.000*
AB Test		
$m1$	0.0392*	0.0208*
$m2$	0.2178	0.4729
Sargan Test		
Chi2	12.6451	18.7348
Prob > Chi2	(0.023)*	(0.344)

Note: *) Significant $\alpha = 5\%$.

This is indicated based on the Sargan test results, where the null hypothesis (H0) in the Sargan test states that there is no issue with the validity of instruments (valid instruments), meaning that the instruments are correlated with errors in the FD-GMM equation. In the FD-GMM model, the Sargan test result is 0.023, which is greater than 0.05, indicating a rejection of H0. This implies that the SYS-GMM model is better than the FD-GMM model.

Then, to assess the consistency of the estimation results generated from the FD-GMM and SYS-GMM models, an autocorrelation test will be conducted using the Arrelano-Bond statistics $m1$ and $m2$. Consistency is indicated by a significant value for the $m1$ statistic and a non-significant value for the $m2$ statistic, Firdaus (2011). From **Table 1**, the results of processing the FD-GMM and SYS-GMM models show that the $m1$ values for each model are significant at the 5% level, and the $m2$ values are not significant at the 5% level. This means that both models are consistent in producing model estimates. However, since the Sargan test indicates that the SYS-GMM model is the best model, meaning it is unbiased, valid, and consistent in estimation.

After the calculation and testing of the best model, the dynamic panel SYS-GMM model was obtained with the summary tabulation results as follows:

Table 2. SYS-GMM dynamic panel modeling estimation results.

Variable	Coefficient	Standar error	Z	P-value
PDRBP _{t-1}	0.4740430	1.2355317	2.24	0.001*
NTP	0.1803807	0.3240373	1.74	0.019*
IPM	1.5338320	3.7886490	0.66	0.025*
UPAH	0.1801629	0.2214078	0.69	0.387
INF	-0.5465704	0.1899218	-1.21	-0.008*
POP	-2.1265810	0.7821352	-4.56	-0.892
Constant	0.6509112	0.2607257	4.86	0.000*
Sargan test	-	-	-	-
Chi2	18.73480	-	-	0.344

Note: *) Significant $\alpha = 5\%$.

Based on **Table 2** in the selected dynamic panel model. namely the SYS-GMM dynamic panel model. the estimation results indicate that the lag of agricultural sector economic growth significantly and positively influences the growth of the agricultural sector economy. Additionally. other significant variables include the farmers' exchange rate and the Human Development Index. both of which have a positive impact on the economic growth of the agricultural sector. Furthermore. the inflation rate has a significant negative impact on the economic growth of the agricultural sector. Based on **Table 2** and the results of processing the best SYS-GMM model. the model equation can be formulated as follows:

$$\widehat{PDRBP}_{it} = 0.6509112 + 0.4740430PDRBP_{t-1} + 0.1803807NTP_{it} + 1.5338320IPM_{it} + 0.1801629UPAH_{it} - 0.5465704INF_{it} - 2.1265810POP_{it} + \epsilon_{it} \quad (11)$$

Based on the output results of the processing depicted in **Table 2** above, it can be seen that the economic growth model of the agricultural sector in Indonesia using the dynamic panel model SYS-GMM approach is positively influenced by its lag, which is 0.4740430. This means that a 1 percent increase in the lag of agricultural sector growth will result in a 0.4740430 percent increase in the growth performance of the agricultural sector for the following year.

The results of dynamic panel estimation also indicate that the Farmers' Terms of Trade (NTP) has a positive and significant relationship with the economic growth of the agricultural sector, recorded at 0.1803807. This means that a 1-point increase in NTP will drive an increase in the growth performance of the agricultural sector by 0.1803807 percent in Indonesia. This aligns with the research conducted by Firmansyah et al. (2022), NTP has a positive and significant impact on economic growth and directly enhance the welfare of farmers in Indonesia. The influence of farmers' welfare on enhancing a country's economic growth is also emphasized by Hossain et al. (2019), which shows a parallel perspective where farmer welfare will have a positive impact on a country's growth.

The Farmers' Terms of Trade (NTP) is one of the benchmark indicators for the well-being of farmers in Indonesia, where this indicator is formed by comparing the index received with the index paid by farmers. From the concept of NTP, it is evident that if the received index is greater than the paid index, it means that farmers have a surplus or can be considered prosperous, and vice versa. Therefore, with this indicator, both the central and regional governments prioritize preparing strategic programs to enhance the well-being of farmers in Indonesia (Harsono et al., 2023). Certainly, with the improvement in the welfare of farmers, there is alignment with the increase in farmers' income, which can drive an improvement in their purchasing power to enhance agricultural inputs and output. This increase in output and the quality of raw materials will directly enhance the performance of economic growth in the agricultural sector in Indonesia.

Furthermore, another significant macroeconomic variable is human capital or the Human Development Index (HDI), recorded at 1.5338320. This human capital variable has a positive and significant impact on the growth performance of the agricultural sector in Indonesia. With the increase in HDI in a region, it will undoubtedly enhance productivity in that area, leading to increased output and promoting well-being in that region. The importance of human capital development is also emphasized by Trianggara (2016) as a benchmark for overall development performance, with development dimensions formed through three basic dimensions: long and healthy life, knowledge, and a decent standard of living. The improvement in human capital will also enhance the utilization of technology in the agricultural sector in Indonesia. With adequately skilled and up-to-date human resources among farmers, there will be an increase in innovations in the field of agriculture, allowing for easy adaptation to the global economy (Kumar and Kumar Singh, 2021). This is also consistent with the research conducted by Baihaqi (2017) and Savitri (2017) where the improvement in human capital or HDI can increase the output in a region, which certainly has a direct impact on economic growth, especially in the agricultural sector. Wijaya (2021) In the results of the study, it is stated that the Human Development Index (HDI) significantly supports the economic growth of a country

and is a prominent variable in the hypothesis testing. Theoretically and scientifically, this aligns with the idea that an increase in human capital enhances the effectiveness and quality of output, thereby increasing the value added to a product. This increase in value added will undoubtedly drive economic growth in a country, especially in the agricultural sector. Therefore, practically, the findings of this research highlight the need for the government to pay attention to the equitable improvement of HDI or human capital in every region, particularly in the agricultural sector. The enhancement of human resource quality in the agricultural sector will undoubtedly elevate the quality of agricultural products in Indonesia, making them eligible for export markets and increasing the country's economy (Habib et al., 2019).

The spatial SYS-GMM panel modeling also indicates that the variable of the growth rate of prices or inflation (INF) has a negative and significant impact on the economic growth of the agricultural sector. This means that a 1 percent increase in prices or inflation will decrease the growth rate of the agricultural sector by 0.5465704 percent. The rise in the prices of consumer goods (inflation) will undoubtedly reduce the purchasing power of the population, both in meeting personal needs and in their businesses (Roncaglia de Carvalho et al., 2018). This is also consistent with the research conducted by Azis (2021). In their study, the impact of an increase in prices in a region can suppress the purchasing power of the population in meeting the raw material needs of industries or businesses. Certainly, if this inflationary effect is not controlled, it will directly affect the welfare of farmers and the growth of economic output, especially in the agricultural sector. Therefore, it becomes a separate task for each country to determine its inflation targets or control inflation within the country, both through the supply and demand for goods and services (E. O. Svensson, 2014) or through various inflation control programs.

This is also consistent with the research conducted by Manullang et al. (2023) Stating that inflation control policies are crucial in maintaining the purchasing power of the community and ensuring the increase in output for the economic growth of a region. Mishchenko (2009), in the study of his research on the impact of inflation on economic growth, he puts forth the results indicating that inflation significantly impedes economic growth. The same statement is conveyed by Azam Khan (2018) in his research on inflation conducted in five Asian countries. His research indicates that inflation has a negative and significant impact on economic growth. According to Azam Khan, an effective mix of macroeconomic policies needs to be designed to control inflation and promote the processes of growth and economic development; thereby, largely enhancing social welfare. The results of the dynamic panel modeling using SYS-GMM, where inflation has a negative and significant relationship with the growth of the agricultural sector in Indonesia, align with previous theories and research. Therefore, it is crucial for both local and central governments to pay attention to this strategic variable, which is inflation. It is essential for the government to establish and control the threshold of inflation to maintain the stability of the country's economy (Adaramola, 2020; Hoang Tien, 2021). Based on the author's findings, it highlights the crucial role of the government in managing price fluctuations and controlling inflation, both through maintaining the supply of goods in circulation and regulating the amount of money in circulation.

The estimation results from the best dynamic panel model, in a partial sense, indicate that the average wage level of agricultural sector workers is not significant in influencing the growth of the agricultural sector. This suggests that the wage level, which is one form of expenditure in the production process, does not have a significant impact on the value-added output for the agricultural sector. This means that, in the dynamic panel model, the influence of the average hourly wage has a very small and insignificant effect. Research by Dewi (2020), which also suggests the lack of influence of wage variables on economic growth. Similarly, population density has an insignificant impact on the development of the agricultural sector. The population density of a region certainly has its own economic impact on the area, both in terms of the abundance of labor or sources of human capital, which must be supported by existing public facilities (Peterson, 2017). For population density in this study, it still does not show a significant impact on the economy, especially in the development of the agricultural sector. Therefore, population density (POP) still does not have a direct impact on the development of the agricultural sector in Indonesia.

6. Conclusion

The findings indicate several significant factors influencing the economic growth of the agricultural sector. Lagged economic growth within the sector has a notable positive impact on subsequent growth, highlighting the importance of sustained progress. Moreover, policies supporting favorable farmers' exchange rates and advancements in human development positively contribute to agricultural sector expansion. Conversely, inflationary pressures pose a significant challenge, exerting a negative influence on sectoral growth. Interestingly, the average wage level of agricultural workers and population density do not emerge as significant determinants of sectoral growth. These insights underscore the need for targeted policies to sustain agricultural sector growth, encompassing measures to stabilize exchange rates, enhance human capital, and mitigate inflationary pressures, while also considering labor dynamics and broader economic development concerns. To sustain agricultural sector growth, targeted policies are essential to address key challenges and leverage opportunities within the sector. These policies should encompass a multifaceted approach aimed at promoting stability, innovation, and inclusivity. Firstly, maintaining stable and favorable exchange rates for farmers is crucial to enhance competitiveness in global markets. Secondly, investing in human development initiatives, including education and skill development, can improve productivity and efficiency among agricultural workers. Controlling inflationary pressures through monetary and fiscal measures is also vital to ensure price stability and encourage investment. Additionally, aligning wage policies with sectoral growth objectives while promoting fair labor practices can enhance productivity and attract skilled labor. Furthermore, investing in rural infrastructure, research and development, and access to finance can foster innovation, improve market access, and enhance productivity across the agricultural value chain. Strengthening market institutions and value chains is also critical to improving market access and transparency for farmers, enabling them to capture more value from their produce. By implementing these targeted policies, governments can create an enabling environment for sustained agricultural sector

growth. contributing to food security. poverty reduction. and overall economic development.

This study has several limitations that should be addressed in future research. Firstly. the analysis is based on data from 2020 to 2022. which may not capture long-term trends and structural changes in the agricultural sector. Future studies could extend the analysis period to provide a more comprehensive view. Additionally. the study focuses on a limited set of macroeconomic variables. Including additional variables such as climate change impacts. technological adoption rates. and international trade dynamics could provide a more holistic understanding of the factors affecting agricultural growth.

The study employs dynamic panel data models. which. while robust. have limitations in terms of efficiency and consistency in small sample sizes. Future research could explore alternative modeling approaches or hybrid models to validate and expand upon these findings. Furthermore. while the study provides valuable policy recommendations. empirical validation of these policies through pilot programs or case studies could strengthen the evidence base for policy-making.

Author contributions: Conceptualization, W and ST; methodology, W and J; software, W and J; validation, ST, J and Z; formal analysis, W and J; investigation, W; resources, W; data curation, W; writing—original draft preparation, W and FZ; writing—review and editing, FZ; visualization, W; supervision, ST, J and Z; project administration, W; funding acquisition, W. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: Statistics Bureau of Indonesia and Universitas Jambi.

Conflict of interest: The authors declare no conflict of interest.

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