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IMPACT OF COVID-19 PANDEMIC ON INDONESIA'S AGRICULTURAL SUBSECTORS: AN ARDL APPROACH

Purpose. *The research aims to study the effect of the Covid-19 pandemic on aggregate agricultural production and agricultural production per subsector, where the agricultural sector is divided into five subsectors, namely food crops, horticulture, plantations, livestock and fisheries.*

Methodology / approach. *The Autoregressive Distributed Lag (ARDL) method is applied in this work. Using ARDL equations with restricted test cointegration, it generates both short-term and long-term models simultaneously. The analysis moves on to estimate the long-term and short-term models of (i) the impact of the Covid-19 pandemic on total agricultural production and (ii) the impact of the pandemic on agricultural production per subsector.*

Results. *In general, the Covid-19 pandemic had a negative but insignificant effect on Indonesia's agricultural production. The effect of the Covid-19 pandemic on agricultural production (GDP) varies significantly from one subsector to another. The negative effect was in the food crops, horticulture and fisheries subsectors, but this negative effect was significant only for food crops. The pandemic had a positive effect on the plantation crops and livestock subsectors, but the positive effect was significant only for the livestock subsector. Based on the Error Correction Term (ECT) value, the speed of agricultural subsectors to return to long-run equilibrium is not the same.*

Originality / scientific novelty. *Until now, research on the impact of the Covid-19 pandemic on agriculture has been based on the assumption that the agricultural sector is a homogeneous system. This study examines the agricultural sector by decomposing it into subsectors including food crops, horticulture, plantations, livestock, and fisheries. The results show that each subsector responds differently to shocks (due to the Covid-19 pandemic). As far as we can observe, this study is the first to decompose subsectors for Indonesia. In addition, studies related to the influence of the Covid-19 pandemic on agriculture using a dynamic econometric approach (using time series data) are still limited.*

Practical value / implications. *The Covid-19 pandemic had an impact on production due to an increased unemployment and decreased purchasing power, which reduced demand for products from the food crops, horticulture, and livestock subsector, which in turn caused a decrease in production. Research results help the government in determining the best course of action to support the food crops, horticulture, and fisheries subsectors in the event that the Covid-19 pandemic creates unfavourable conditions. Future research proposals include: (i) a study of how the production function in the agricultural subsector can be used to estimate production in the event of unforeseen circumstances like the Covid-19 pandemic or an economic downturn; and (ii) a study of how the type of fiscal stimulus affects production in agricultural subsectors to determine the type of assistance based on the dominance of subsectors in a particular region.*

Key words: *agricultural economics, Covid-19, ARDL approach, agricultural subsector, Indonesia's agriculture, agricultural production.*

1. INTRODUCTION

The sources of economic crises are becoming increasingly diverse, not only from the economic sphere itself, but also from the spread of viruses that cause death and economic contraction through the emergence of various types of flu that attack animals and humans [1; 2; 3]. Between 1901 and 1990 (in 90 years), there were 11 global economic crises, but in the last 30 years (1991–2019), there were 18 economic crises, and 11 of them occurred during the 21st century (2001–2019) [4]. For Indonesia, natural disasters as a source of economic shocks must also be taken into account, given the high frequency of volcanic eruptions, earthquakes, floods, and droughts [5; 6]. During the economic crisis in Indonesia in 1998 and 2008, agriculture became the main support of the Indonesian economy as a provider of employment (a source of income) for those who experienced layoffs in the urban formal sector [7]. The Covid-19 pandemic only had a small effect on agricultural production in Indonesia [8]. In particular, the pandemic had a negative but insignificant effect [4].

This research aims to study the effect of the Covid-19 pandemic on Indonesia's agricultural production. Specifically, this study identifies (i) the effect of the Covid-19 pandemic on aggregate agricultural production and (ii) the effect of the Covid-19 pandemic on agricultural production per subsector, where the agricultural sector is grouped into five subsectors, namely food crops, horticulture, plantations, livestock, and fisheries. There is a hypothesis that the production behaviour of agricultural subsectors varies in response to crisis conditions (Covid-19 pandemic), so aggregate analysis cannot be assumed to represent the situation of the five subsectors (assuming agriculture is homogeneous). This study uses dynamic econometric analysis that uses time series data to generalise conclusions for long-term forecasting. To the best of our knowledge, there are no research results related to the effect of the Covid-19 pandemic on Indonesia's agricultural production per subsector using a dynamic econometric approach (using time series data).

2. LITERATURE REVIEW

The effect of the Covid-19 pandemic on the agricultural subsector differs among countries. Covid-19 caused the income of horticultural farmers in the United States, Norway, and China to decline [9], and there was an overstock of horticultural products in China and Ethiopia [10; 11], and farmers who cultivated grapes, apples, and oranges suffered losses [12]. The impact of lockdown policies on the food sector in the countries of Ghana, Mali, Ivory Coast, Burkina Faso, Liberia, Niger, Sierra Leone, Benin, and Togo, as well as in Guinea, Mauritania, Gambia, and Guinea-Bissau, led to disruption of grain procurement for traditional mills [13], while in Indonesia, restrictions on activities affecting the food sector [4] as well as food processing activities [14–17]. The pandemic caused some households to stop agricultural production activities in some areas of Ethiopia. Movement restrictions led to a lack of labor, limited access to agricultural inputs, and a lack of transportation and markets for agricultural products [18].

Covid-19 caused a decline in the income of oil palm farming households so that access to basic needs and other goods was limited and the income of tea, coffee, rubber and cardamom producers decreases [19; 20]. Covid-19 caused a decline in the production and income of farmers in Costa Rica [21] and the welfare of small farmers [22], it also affected the livestock sector [23–25] and harmed livestock producers [26] and the number of fish catches in the country of Portugal decreased compared to before the Covid-19 pandemic [27] and adversely affected low-income fishers in Malawi [28] and harmed fisheries sector stakeholders in developing countries [29]. Workers in the urban informal sector were forced to close their businesses and return to the village to engage in agricultural production managed by family or relatives as reported [30] in India. This phenomenon is known in Pacific Island countries as deurbanisation [31].

During the Covid-19 period, agricultural production and marketing of agricultural products were relatively strong against the pandemic, but the food industry and food and beverage services (culinary) experienced a negative influence [29]. Various studies report that the disruption of the Covid-19 pandemic on agricultural production in developing countries, especially Asia, is relatively small [4; 8; 30; 32]. Covid-19 caused global GDP to fall by 7.2 % [33] and caused shocks to real gross domestic product (GDP) in both developed and developing countries [34]. Covid-19 also caused China's GDP to decline by 6.8 % in 2020 and economic losses from the agrifood system to reach 7 % of added value [35] and [36] explained that the relationship between GDP per capita and Covid-19 cases is negative, meaning that the higher the GDP per capita, the lower the Covid-19 cases. The demand-side shock to agricultural products due to Covid-19 caused a decrease in the price of meat and milk by 7–18 % and 4–7 %, respectively, in the international market, so that economic growth decreased [37].

Based on a review of previous academic literature relevant to this study, the following gaps in the research on the impact of the Covid-19 pandemic on agricultural production and economic growth to date can be identified: (i) the research was conducted using cross-section data; therefore there is very limited potential for generalisation, and (ii) although agriculture has at least five subsectors with distinct socioeconomic production characteristics and marketing-related product features, the analysis is conducted under the assumption that the agricultural sector is homogeneous. For example, fishery and livestock products require fast transportation to keep them fresh for consumers, so the two-week quarantine provision at the port as part of the health protocol to prevent the spread of Covid-19 is very detrimental to this subsector. Meanwhile, plantation products such as palm oil, rubber, coffee, and cocoa are generally marketed as semi-finished processed products or consumer goods that can be stored longer, so quarantine is not an issue for these subsector products. Therefore, an important research question remains about the impact of the Covid-19 pandemic on Indonesian agricultural production in general and its individual subsectors.

3. METHODOLOGY

We used 40 quarters of quarterly data covering the years 2013 through 2022, 12 of which include observations during the COVID-19 pandemic (quarters 1 of 2020 through 4 of 2022). The Dummy Variable (DUM) with a value of one for the first quarter 2020 to the fourth 2022 and zero for the first quarter 2013 to the fourth 2019 is used to simulate the Covid-19 pandemic. All data were converted into logarithmic form and expressed in billions of Indonesian Rupiah (IDR) at 2010 = 100 constant pricing. The "Indonesian Financial Economic Statistics" that Bank Indonesia (Indonesia's Central Bank) publishes monthly serves as the data source.

This study used the Autoregressive Distributed Lag (ARDL) approach [38–42]. ARDL is a dynamic econometric model approach based on OLS (ordinary least square). This model is known to be superior for small samples and does not require that the variables are stationary in the same order as long as they are stationary at order zero (level) i.e. I(0), or order one (first derivative) i.e. I(1) [43; 44; 39]. To determine whether the variables are stationary, the unit root test is used, if variables are not stationary, then [45]: (i) the behaviour under study is limited to the observed period. Thus, each variable is a unique occurrence that is unlikely to generalise to future times, making it of limited use in forecasting, (ii) the analysis will produce spurious/nonsense regressions.

The Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) unit root test, an expansion of the Dickey-Fuller test, are the two most often used unit root tests. Serial correlation and heteroscedasticity from the ADF test are corrected by the PP test [45; 46] The Phillips-Perron unit root test is more reliable in error correction models, according to [47; 48]. The unit root is tested in this study using ADF and PP as proof that the variables are stationary.

Through a straightforward transformation, the ARDL model may provide a dynamic Error Correction Model (ECM) that incorporates short-run dynamics brought on by shocks and long-run equilibrium. Due to these benefits, ARDL cointegration tests have lately been growing in popularity and are often applied, as evidenced by the work of [49–51]. The ARDL dependent test approach, according to [44], delivers rapid and reliable findings when there is a single equation cointegration relationship between the variables. It is confirmed that the set of variables has an Error Correction Term (ECT), which is the amount of time it takes for it to return to its long-run equilibrium following a short-run shock if they are cointegrated.

Equation (1) presents the long-term relationship between agricultural GDP and household consumption, investment, and government spending during the Covid-19 pandemic:

$$LAgri_t = \alpha_0 + \alpha_1\, LConsum_t + \alpha_2\, LInvest_t + \alpha_3\, LGov_t + DUM + \varepsilon_t. \quad (1)$$

The ARDL model from equation (1) is formulated in equation (2) as follows:

$$LAgri_t = \sum_{i=1}^{p} \beta i\, \Delta LAgri_{t-i} + \sum_{j=1}^{q} \beta j\, \Delta LConsum_{t-j} + \sum_{k=1}^{r} \beta k\, \Delta LInvest_{t-k} + \sum_{l=1}^{s} \beta k\, \Delta LGov_{t-l} + DUM + \varepsilon_t, \quad (2)$$

where p, q, r, s are the optimal lags of each variable, and ε_t is the error. Bound test cointegration is used to check the existence of cointegration (long-run relationship) between at least two variables, namely the dependent variable and one or more independent variables. ARDL with bound test cointegration produces short-run and long-run models simultaneously as equation (3):

$$LAgri_t = \alpha_0 + \alpha_1\, LConsum_t + \alpha_2\, LInvest_t + \alpha_3\, LGov_t + \sum_{i=1}^{p} \beta i\, \Delta LAgri_{t-i} + \sum_{j=1}^{q} \beta j\, \Delta LConsum_{t-j} + \sum_{k=1}^{r} \beta k\, \Delta Invest_{t-k} + \sum_{l=1}^{s} \beta l\, \Delta LGov_{t-l} + DUM + \varepsilon_t. \quad (3)$$

The existence of a cointegration relationship is evaluated from the results of the F-statistic test which tests the null hypothesis of no cointegration:

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = 0$, with the alternative H_1: $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq 0$.

If the F-statistic is higher than the upper critical limit, cointegration is present. If the F-statistic value is below the lower critical limit, cointegration does not exist. If the F-statistic value is between the upper and lower critical limits, cointegration between the variables cannot be concluded [44; 51; 52; 53]. If cointegration exists, the study can move forward by estimating the long-run and short-run models in accordance with equation (4):

$$\Delta LAgri_t = \alpha_0 + \sum_{i=1}^{p} \beta i\, \Delta LAgri_{t-i} + \sum_{j=1}^{q} \beta j\, \Delta LConsum_{t-j} + \sum_{k=1}^{r} \beta k\, \Delta LInvest_{t-k} + \sum_{l=1}^{s} \beta l\, \Delta LGov_{t-l} + DUM + \psi\, ECT_{t-1} + \varepsilon_t, \quad (4)$$

where ψ is the ECT coefficient, which determines how quickly the system returns to long-term equilibrium if a shock to the system occurs.

The steps in equations (1) to (4) were repeated but the LAgri variable is replaced with LFood, LHorti, LPlant, LLivestc, or LFish. To test the model's suitability, an autocorrelation test is conducted using the Breusch-Pagan-Godfrey F-test and a model stability test using the CUSUM and CUSUM Square tests.

Based on Figure 1, the unit root test is conducted using Augmented Dickey-Fuller and Philips-Perron. If both ADF and PP results indicate stationary at the level [I(0)] or [I(1)], the estimation continues with the ARDL model.

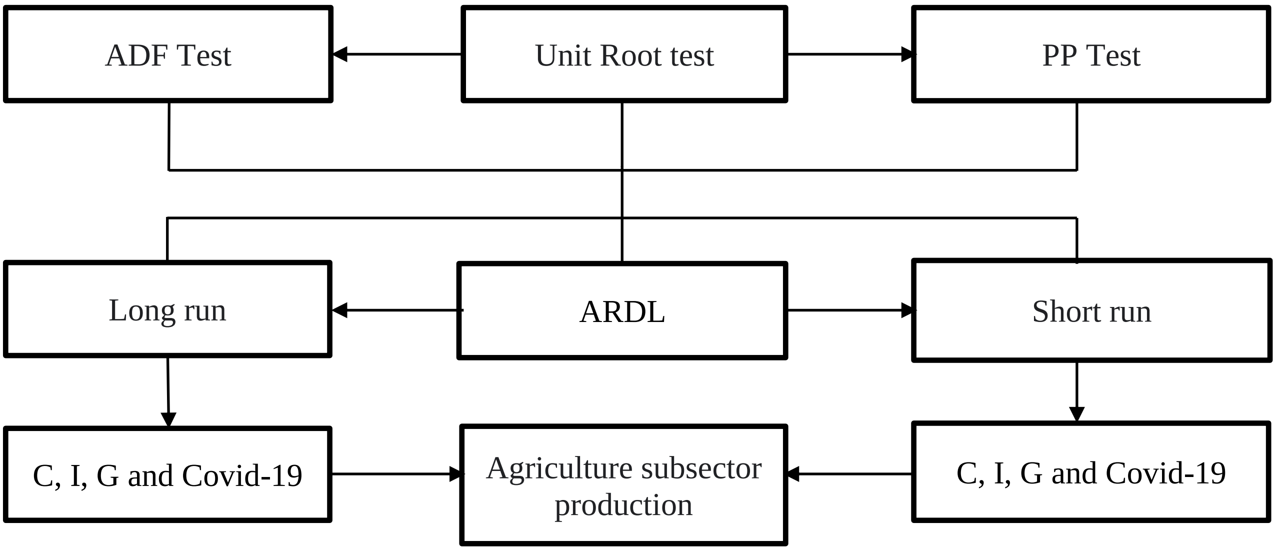

Figure 1. Conceptual framework of the study

Source: authors' research.

In the presence of cointegration, both long-run and short-run relationships are estimated. The long-run estimation assesses the impact of household consumption, investment, government expenditure, and Covid-19 variables on the production of the subsectors such as food crops, horticulture, plantations, livestock, and fisheries. Additionally, the short-run estimation uses an ECM to evaluate the effect of household consumption, investment, government expenditure, and Covid-19 variables on the production of the agricultural subsectors.

4. RESULTS

Firstly, this section provides an overview of the development of agriculture both in aggregate and within each subsector, specifically focusing on food crops, horticulture, plantations, livestock, and fisheries during the Covid-19 pandemic. Following this, the analysis delves into examining the correlation between agriculture and the production of food crops, horticulture, plantations, livestock, and fisheries using the ARDL approach. The ARDL approach involves several steps, including the unit root test, co-integration test, and long-term as well as short-term estimation.

4.1. Indonesian agriculture during the Covid-19 pandemic. It is observed that Indonesia's agricultural output follows seasonal patterns, with peak production typically occurring in the third quarter of the year, followed by a decline in the first quarter, and a subsequent rise back towards the peak (as shown in Figure 2). Upon further analysis, it becomes evident that the food crops and plantation subsectors exhibit substantial fluctuations, primarily driving the observed seasonal patterns, whereas the livestock and fisheries subsectors are less affected by such seasonality (as depicted in Figure 3). Interestingly, the Covid-19 pandemic does not seem to significantly impact the observed seasonality, as there is no discernible difference in the pattern of production fluctuations before and after the pandemic.

The agriculture sector in Indonesia is one of sectors that the pandemic severely impaired. Although the number of Covid-19 cases has declined sharply since 2021 compared to the previous two years due to the Indonesian government's targeted policies, it has had a negative impact on Indonesia's economic performance, especially on the production and productivity of the agricultural sector [54].

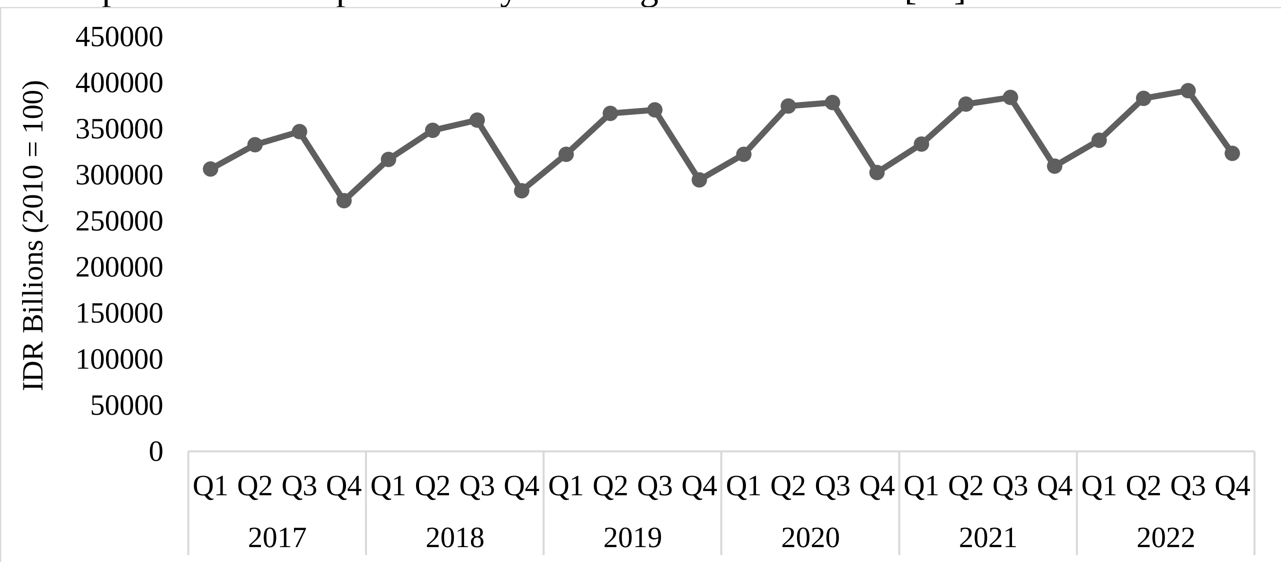

Figure 2. Development of Indonesia's agricultural GDP, 2017–2022
Source: authors' calculation.

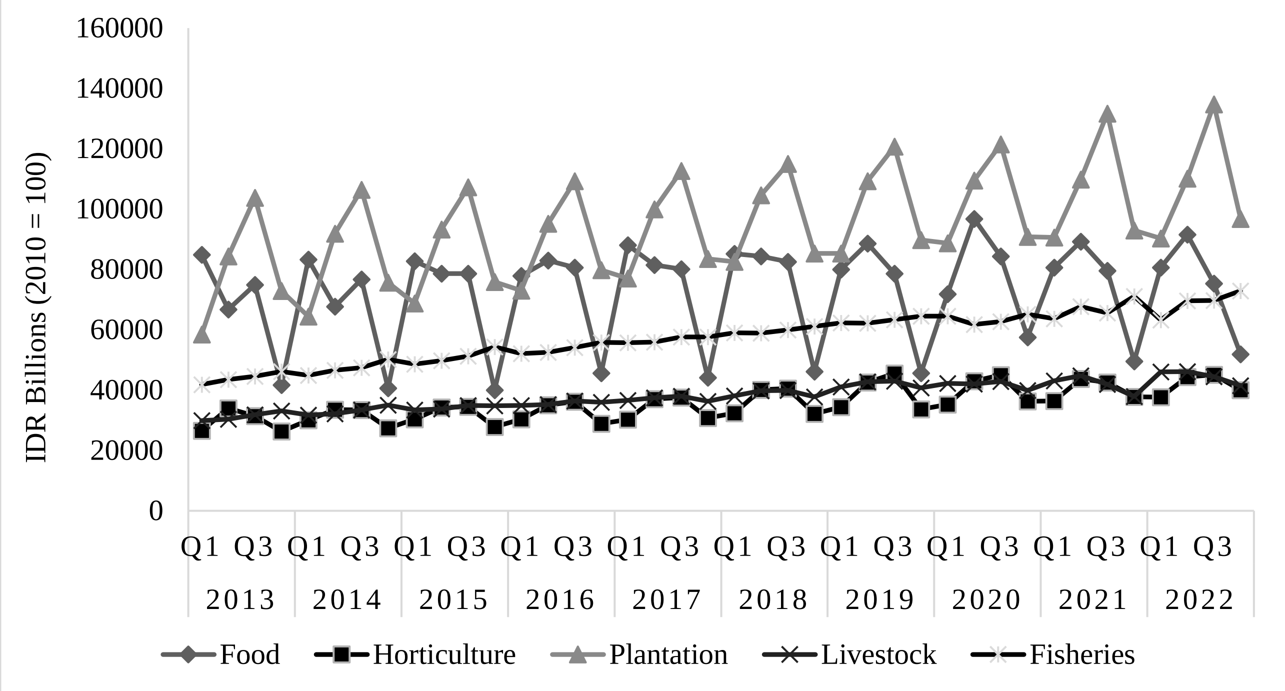

Figure 3. Development of Indonesia's agricultural GDP by subsectors, 2017–2022

Source: authors' calculation.

By analysing the GDP growth per quarter (quarter-on-quarter) over the last 10 years, the seasonal nature of agricultural production becomes evident. Specifically, food crops, plantations, and horticulture consistently showcase negative growth in every fourth quarter and demonstrate positive growth in the first quarter of the subsequent year. In contrast, fluctuations in livestock and fisheries production are not as consistent, with negative growth observed in various quarters such as the first, second, or fourth. Surprisingly, the Covid-19 pandemic, spanning from the first quarter of 2020 to the fourth quarter of 2022, did not appear to disrupt the pattern of fluctuations in the production of food crops, horticulture, and plantations.

The impact of the Covid-19 pandemic is evident in the slight changes in fluctuations observed in the livestock and fisheries production. While there was only one quarter with negative growth each year before the pandemic, during 2020–2022, two quarters showed negative growth.

In terms of cumulative annual growth (year-on-year), the plantation subsector showed more resilience to the crisis, as it only showed negative growth once, namely in the first quarter of 2022. On the other hand, the horticulture, livestock, and fisheries subsectors are more vulnerable. Before Covid-19, they consistently reported production growth (except for horticulture in the first quarter of 2017), but during the pandemic, they experienced more challenges, with livestock recording negative growth in five quarters (year-on-year), fisheries in four quarters, and horticulture in two quarters.

Nevertheless, when considering the aggregate indicator, the agricultural sector as a whole showed negative growth once in the last 10 years, specifically in the first quarter of 2020, with a minimal contraction of -0.02 % (year-on-year) growth.

4.2. Indonesia's agricultural subsectors growth during the Covid-19 pandemic. The effect of the Covid-19 pandemic on the GDP growth of Indonesia's agricultural subsector is estimated using the ARDL model, which is an error correction model approach. For this reason, the first step is to check whether the variables used are stationary through a unit root test. The purpose of the unit root test in the ARDL framework is to ensure that the variables are stationary at the level [I(0)] or the first differentiation [I(1)]. This study uses two test tools, namely Augmented Dicky-Fuller and Phillips-Perron, respectively, with intercept without trend and intercept with trend. All variables are stationary at the first level or differentiation (Table 1), thus fulfilling the requirement to continue the analysis using the ARDL model.

Table 1

Unit Root Test result

Variable		Augmented Dicky-Fuller		Phillips-Perron	
		Constant	Constant, trend	Constant	Constant, trend
Level I(0)	LAgri	-4,8007***	-8,7569***	-4,6952***	-7,0914***
	LFood	-1,7667	-3,1407	-8,7655***	-13,4453***
	LHorti	-0,5824	-1,2978	-4,0105***	-7,6927***
	LPlant	-2,3935	-1,8931	-5,4869***	-11,1592***
	LLivestc	-1,3074	-2,2491	-1,9792	-4,9664***
	LFish	-2,6832*	-4,7813***	-1,4627	-4,7224***
	LConsum	-1,5301	-3,6106	-1,5499	-3,5099*
	LInvest	-1,3232	-1,9892	-1,4456	-3,8284**
	LGov	-1,2829	-1,3511	-7,5766***	-20,0601***
First Difference I(1)	Δ LAgri	-8,9928***	-9,6247***	-15,2379***	-29,6382***
	Δ LFood	-41,6752***	-41,1339***	-20,3628***	-20,1186***
	Δ LHorti	-21,0572***	-20,7733***	-10,6804***	-10,4934***
	Δ LPlant	-40,0341***	-42,2563***	-9,0168***	-8,7986***
	Δ LLivestc	-11,0590***	-11,1266***	-10,4661***	-12,4569***
	Δ LFish	-7,2279***	-8,0551***	-18,4827***	-23,0526***
	Δ LConsum	-9,1284***	-9,1018***	-12,0348***	-17,2963***
	Δ LInvest	-2,2741	-2,2733	-9,2182***	-9,3934***
	Δ LGov	-3,8288***	-3,8802**	-26,5145***	-26,0066***

Note. *, ** and *** are significant at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.
Source: authors' computation using EViews 10.

Based on the results presented in Table 2, the cointegration test indicates that the five agricultural subsectors exhibit cointegrating GDP subsector equations. The F-bound test value of above 5.455 exceeds the upper critical limit value for a 99 % confidence level ($\alpha = 0.01$), suggesting a significant relationship between the independent and dependent variables. However, it's worth noting that each agricultural subsector had a different optimal lag.

Long-run results from Table 3 indicate that household consumption, investment lag two periods, and dummy lag first period positively affect agriculture sector growth, whereas agricultural production first lag, government expenditure and dummy variable negatively affects it. The Covid-19 pandemic had a negative but insignificant effect on Indonesia's agricultural production.

Table 2

ARDL cointegration test results

Estimated model		Optimal lag length	F-bound test	Decision
LAgri	LConsum, LInvest, LGov, DUM	(1,0,2,2,1)	317.7827	Cointegration
LFood	LConsum, LInvest, LGov, DUM	(1,0,1,2,1)	20.0537	Cointegration
LHorti	LConsum, LInvest, LGov, DUM	(1,0,2,2,1)	9.7686	Cointegration
LPlant	LConsum, LInvest, LGov, DUM	(2,1,2,2,1)	58.1891	Cointegration
LLivestc	LConsum, LInvest, LGov, DUM	(2,1,2,0,0)	16.2955	Cointegration
LFish	LConsum, LInvest, LGov, DUM	(2,3,2,2,3)	8.5395	Cointegration

Source: authors' computation using Eviews 10.

Household consumption is the main growth driver, while investment has a positive but insignificant effect, as presented in Table 3.

Table 3

Estimation results of short-term and long-term of aggregate agricultural production

ARDL Regression Dependent variable: LAgri, ARDL (1,0,2,2,1)			ECM Regression Dependent variable: Δ LAgri		
Independent variable	Coefficient	t-statistic	Independent variable	Coefficient	t-statistic
LAgri(-1)	-0.0172	-0.5251	Δ LInvest	0.2665	1.6331
LConsum	0.3671	2.0995**	Δ LInvest(-1)	-0.5796	-4.7464***
LInvest	0.2665	1.0705	Δ LGov	-0.4085	-16.8497***
LInvest(-1)	0.1071	0.4093	Δ LGov(-1)	0.3071	13.0254***
LInvest(-2)	0.5796	3.0771***	Δ DUM	-0.0114	-0.9647
LGov	-0.4085	-9.8537	ECT	-1.0175	-47.5372***
LGov(-1)	-0.4399	-9.4505	R^2 = 0.9888		
LGov(-2)	-0.3071	-9.6731			
DUM	-0.0114	-0.7995			
DUM(-1)	0.0561	4.0751***			
R^2 = 0.9661 F-stat = 76.9979*** F-stat Breusch-Pagan-Godfrey Serial Correlation LM test = 0.9707 (p = 0.4900) Passed the CUSUM and CUSUM of square stability test (p = 0.05)					

Note. *, ** and *** are significant at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

Source: authors' computation using Eviews 10.

The results of the estimation of short-term and long-term equations for the production of each subsector, as in equation (4), are presented in Tables 4, 5, 6, 7, and 8. The analysis concluded that the effect of the Covid-19 pandemic on agricultural production (GDP) varies greatly between one subsector and another. Negative effects are observed in the food crops, horticulture, and fisheries subsectors, but these negative effects are only significant in food crops. The pandemic positively affects the plantation crops and livestock subsectors, but the positive effect is only significant in the livestock subsector. If, overall, adjustments to shocks in the agricultural sector are oscillatory (ECT has an absolute value greater than one) [4], analysis by subsector reveals that this oscillatory nature only exists in the plantation crops and livestock subsectors, in both of which the pandemic has a positive effect. Food crops produced in the dryland farming system were not fully affected by the Covid-19 pandemic, as it was not too closely linked to the modern market for inputs and marketing. Indeed, the mixed farming system is a semi-subsistence farming system whose primary orientation is to provide food for villagers [54].

There are differences in the role of household consumption, investment, and government spending on agricultural production growth by subsector. For food crops production, household consumption is the driver of growth. Meanwhile, investment and household consumption positively and significantly affect growth for the horticulture subsector despite being insignificant. Investment drives the growth of plantation production and livestock production. Investment has a positive and significant effect on these two subsectors in the short and long-term.

In contrast to the other four subsectors, where government expenditure does not affect growth, in the fisheries subsector, government expenditure is the driving factor for growth (positive and significant effect). Meanwhile, household consumption and investment will only have a positive effect after one or two periods (one or two quarters), and even then, it must be simultaneously with other variables. Because partially, the influence of these two variables is not significant.

There is extensive cultivation of staple crops including rice, corn, and soybeans, and farmers can respond by modifying their production per growing season [55]. For Indonesia, the Covid-19 pandemic has negatively and significantly affected production in the short term. Likewise, the production system adjusts at a rate of 61.18 % to return to its long-term equilibrium (adjustment takes seven weeks) after experiencing disruption due to the pandemic (Table 4).

Table 4

Estimation results of short-term and long-term of food crops production

ARDL Regression Dependent variable: LFood, ARDL (1,0,1,2,1)			ECM Regression Dependent variable: Δ LFood		
Independent variable	Coefficient	t-statistic	Independent variable	Coefficient	t-statistic
LFood(-1)	0.3882	1.4757	Δ LInvest	-1.8212	-3.9951***
LConsum	1.3559	2.7842***	Δ LGov	-1.2940	-19.3290***
LInvest	-1.8212	-1.8341*	Δ LGov(-1)	0.3533	4.2749***
LInvest(-1)	1.7868	2.4254**	Δ DUM	-0.0719	-2.1779**
LGov	-1.2940	-12.7165***	ECT	-0.6118	-11.9083***
LGov(-1)	-0.4507	-1.9174*	R^2 = 0.9738		
LGov(-2)	-0.3533	-3.7319***			
DUM	-0.0719	-1.8155*			
DUM(-1)	0.1274	3.2906***			
R^2 = 0.9360 F-stat = 38.3896*** F-stat Breusch-Godfrei Serial Correlation LM test = 0.0975 (p = 0.3062) Passed the CUSUM and CUSUM of square stability test (p = 0.05)					

Note. *, ** and *** are significant at p < 0.1, p < 0.05, and p < 0.01, respectively.
Source: authors' computation using Eviews 10.

Horticultural crops such as vegetables and fruits are mostly annual, labor intensive, and require significant capital, especially for pest and disease control. Because of their labour-intensive production processes and perishable nature – two elements that are directly impacted by the mobility restriction – the production of fruits and vegetables would be interrupted. The production process will be delayed by restrictions on the on-time distribution of pesticides [55]. This condition is fully visible in Indonesia's horticultural production, where in the short term, investment has a positive and significant effect on production, and the Covid-19 pandemic has a negative effect despite being insignificant. The horticultural production system adjusts to short-term shocks at a rate of 74.98 % towards its long-term equilibrium. The horticultural production system requires nine weeks to return to its long-term equilibrium (Table 5).

Table 5

Estimation results of short-term and long-term of horticultural production

ARDL Regression Dependent variable: LHorti, ARDL (1,0,2,2,1)			ECM Regression Dependent variable: Δ LHorti		
Independent variable	Coefficient	t-statistic	Independent variable	Coefficient	t-statistic
LHorti(-1)	0.2502	0.9923	Δ LInvest	0.5676	2.1299**
LConsumum	0.2189	0.7649	Δ LInvest(-1)	-0.8329	-3.7735***
LInvest	0.5676	1.1477	Δ LGov	-0.3913	-9.7470***
LInvest(-1)	-0.4775	-1.1684	Δ LGov(-1)	0.1772	2.9665***
LInvest(-2)	0.8329	2.7887***	Δ DUM	-0.0019	-0.1005
LGov	-0.3913	-5.4926***	ECT	-0.7498	-8.3346***
LGov(-1)	-0.3805	-4.4805***	R^2 = 0.9264		
LGov(-2)	-0.1772	-2.3109**			
DUM	-0.0019	-0.0830			
DUM(-1)	0.0469	1.9456*			
R^2 = 0.9343 F-stat = 38.3896*** F-stat Breusch-Godfrei Serial Correlation LM test = 1.2414 (p = 0.9075) Passed the CUSUM and CUSUM of square stability test (p = 0.05)					

Note. *, ** and *** are significant at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.

Source: authors' computation using Eviews 10.

Given that cooking oil is an essential food item in Indonesia and that the government regulates its price, the government of Indonesia implemented an export embargo on CPO and its derivative products beginning on April 28, 2022, in order to prevent increasing scarcity in the nation [56]. Therefore, the COVID-19 pandemic's beneficial impact on plantation productivity is indirectly brought about by the demand side, as the price of Indonesian plantation products increased significantly between 2020 and 2022 as a result of supply chain disruptions and the Russia-Ukraine war. This situation is illustrated in the ECM regression analysis of plantation subsector production, which in the short-term is capital intensive (investment has a positive and significant effect on production), and the Covid-19 pandemic has a positive and significant effect on production in the short-term (Table 6).

Table 6

Estimation results of short-term and long-term of plantation production

ARDL Regression Dependent variable: LPlant, ARDL (2,1,2,2,1)			ECM Regression Dependent variable: Δ LPlant		
Independent variable	Coefficient	t-statistic	Independent variable	Coefficient	t-statistic
LPlant(-1)	-0.1647	-1.0651	Δ LPlant(-1)	0.8324	15.6521***
LPlant(-2)	-0.8324	-7.7027***	Δ LConsum	-0.1399	-1.3417
LConsum	-0.1399	-0.8850	Δ LInvest	1.2506	7.6922***
LConsum(-1)	0.2135	1.4557	Δ LInvest(-1)	-0.8771	-7.4321***
LInvest	1.2506	5.6536***	Δ LGov	-0.1271	-1.7176*
LInvest(-1)	-0.5599	-2.0791**	Δ LGov(-1)	0.2042	3.1042***
LInvest(-2)	0.8771	5.3275***	Δ DUM	0.0189	1.8319*
LGov	-0.1271	-1.2856	ECT	-1.9971	20.4685***
LGov(-1)	-0.0244	-0.2342	R^2 = 0.9923		
LGov(-2)	0.2042	-2.4842**			
DUM	0.0189	1.5159			
DUM(-1)	0.0349	2.7173**			
R^2 = 0.9880 F-stat = 172.1197*** F-stat Breusch-Godfrei Serial Correlation LM test = 0.3313 (p = 0.7214) Passed the CUSUM and CUSUM of square stability test (p = 0.05).					

Note. *, ** and *** are significant at p < 0.1, p < 0.05, and p < 0.01, respectively.
Source: authors' computation using Eviews 10.

As an importing country, Indonesia is experiencing severe shortages in the beef market. Demand for broiler meat has increased sharply, leading to high price fluctuations. When beef prices increased by 60 %, broiler meat increased by 74 % [57].

Table 7

Estimation results of short-term and long-term of livestock production

ARDL Regression Dependent variable: LLivestc, ARDL (2,1,1,0,0)			ECM Regression Dependent variable: Δ LLivestc		
Independent variable	Coefficient	t-statistic	Independent variable	Coefficient	t-statistic
LLivestc(-1)	0.1122	0.8453	Δ LLivestc(-1)	0.6706	5.8461
LLivestc(-2)	-0.6706	-4.7300***	Δ LConsum	-0.0936	-0.8302
LConsum	-0.0936	-0.5520	Δ LInvest	1.0449	6.5646***
LConsum(-1)	0.2030	1.2480	Δ LInvest(-1)	-0.6179	-5.9890
LInvest	1.0049	4.2732***	ECT	-1.5584	-10.7346***
LInvest(-1)	-0.3815	-2.2461**	R^2 = 0.7994		
LInvest(-2)	0.6179	4.3957***			
LGov	-0.1270	-3.8313***			
DUM	0.0364	4.8835***			
R^2 = 0.9513 F-stat = 60.7905*** F-stat Breusch-Godfrei Serial Correlation LM test = 0.0347 (p = 0.9659) Passed the CUSUM and CUSUM of square stability test (p = 0.05)					

Note. *, ** and *** are significant at p < 0.1, p < 0.05, and p < 0.01, respectively.
Source: authors' computation using Eviews 10.

Broiler farming, which is capital-intensive, requires a relatively short production period (about 40 days) so that producers can react to market situations quickly. This situation is demonstrated by the livestock production system in Indonesia, where both the Covid-19 epidemic and investment have positive and noteworthy effects on productivity with elasticity exceeding unity. The impact of the pandemic on error correction regression does not show a link between the short- and long-term (Table 7).

As a poor community, the fisher community receives various support in the framework of social safety nets, such as basic food and direct cash assistance, as well as grants to secure business continuity within the framework of the national economic recovery program. Of the five subsectors observed, government spending has a positive and significant effect on production only in the fisheries subsector. Although not significant, the Covid-19 pandemic harms production, and this negative effect is seen in the short term (Table 8).

Table 8

Estimation results of short-term and long-term of fishery production

ARDL Regression Dependent variable: LFish, ARDL (2,1,1,0,0)			ECM Regression Dependent variable: Δ LFish		
Independent variable	Coefficient	t-statistic	Independent variable	Coefficient	t-statistic
LFish(-1)	-0.0263	-0.1451	Δ LFish(-1)	-0.6414	-6.9359***
LFish(-2)	0.6414	3.7765***	Δ LCons	-0.1230	-1.3290
LConsum	-0.1230	-0.9189	Δ LCons(-1)	-0.3018	-2.7216**
LConsum(-1)	0.0371	0.3180	Δ LCons(-2)	-0.1488	-1.7121
LConsum(-2)	0.1530	1.3465	Δ LInvest	-0.4079	-2.4981**
LConsum(-3)	0.1488	1.3735	Δ LInvest(-1)	-0.3165	-2.4786**
LInvest	-0.4079	-1.7595	Δ LGov	0.1244	5.9325***
LInvest(-1)	0.2654	1.0163	Δ LGov(-1)	0.0878	4.4938***
LInvest(-2)	0.3165	1.5854	Δ DUM	-0.0074	-0.9464
LGov	0.1244	3.9954***	Δ DUM(-1)	-0.0579	-5.0453***
LGov(-1)	0.0014	0.0317	Δ DUM(-2)	-0.0401	-3.3780***
LGov(-2)	-0.0878	-3.3279***	ECT	-0.3849	-8.0029***
DUM	-0.0074	-0.7835	R^2 = 0.8554		
DUM(-1)	-0.0414	-2.7035**			
DUM(-2)	0.0177	0.9367			
DUM(-3)	0.0401	2.6665**			
R^2 = 0.9900 F-stat = 123.7519*** F-stat Breusch-Godfrei Serial Correlation LM test = 1.3268 (p = 0.2985) Passed the CUSUM and CUSUM of square stability test (p=0.05)					

Note. *, ** and ***are significant at $p < 0.1$, $p < 0.05$, and $p < 0.01$, respectively.
Source: authors' computation using Eviews 10.

Long-run results from Table 8 indicate that fishery production lag two periods, household consumption lag one periods, investment lag one periods, and government expenditure positively affect fishery production, whereas dummy variable negatively affects it. In the long-term, the impact of Covid-19 on fish production will be reduced by 0.30 %. In the short term, the impact of Covid-19 on fish production decreased by 0.007 %.

5. DISCUSSION

According to our results (see Table 3), there is a difference in the impact of Covid-19 on agricultural output in terms of the long run and short run. The sign of the dummy variable at the optimum lag is positive and significant while the sign of the dummy variable is negative but not significant in the short run. In the long run, Covid-19 increases agricultural output by 0.05 % while in the short run it decreases by 0.01 %. A 1 % cent increase in investment causes agricultural production to increase by 0.57 %. The sign of the ECT of the agricultural sector is negative, as expected, with a value of -1.0175 or 101.75 %, which is the time needed to return to long-term equilibrium after experiencing a short-term shock of more than 12 weeks.

Numerous research findings that the disruption of the Covid-19 pandemic on agricultural production in developing countries, especially Asia, is relatively small [4; 8; 30; 32]. In contrast to production, exports of agricultural products experienced negative growth in six out of 12 quarters during the Covid-19 pandemic due to the disruption of port operations [58]. Thus, trade barriers such as the closure of borders and port quarantine for two weeks affected Indonesia's exports, even for non-perishable goods such as CPO (crude palm oil) and crumb rubber. Therefore, various studies report that disruptions to agriculture are more in the supply chain rather than production [4; 9; 33; 55; 59; 60]. The resilience of Asian agrifood systems during Covid-19, found that the pandemic generated major social and economic crises in many countries in Asia, exposing institutional, social, and economic vulnerabilities and aggravating existing food insecurity and poverty. Covid-19 revealed the vulnerabilities of modern agricultural and food economies [61].

The Covid-19 impact increases the production of plantation subsector in terms of long run and short run (see Table 6). The sign of the dummy variable at the optimum lag in the long run and short run is positive and significant. In the long run, Covid-19 has an impact on increasing plantation production by 0.03 % while in the short run it increases by 0.018 %. A 1 % increase in investment causes agricultural production to increase by 0.87 %. The sign of the ECT of the negative horticulture subsector is as expected with a value of -1.9971 or 199.71 %, which is the time required to return to long-term equilibrium after experiencing a short-term shock of more than 24 weeks.

Palm oil production dominates Indonesia’s plantation subsector. Before the Covid-19 pandemic (2019), as the world’s top palm oil producer, Indonesia produced 51.8 million tons of CPO, with a domestic consumption of 16.7 million tons, while the rest was exported with an export value of USD 14.7 million. CPO and its derivatives contribute 8 % of Indonesia’s export value [56; 62–64]. Mobility restrictions to prevent the spread of COVID-19, including a two-week quarantine at ports, have crippled sea transportation [58; 65]. Similarly, palm oil production in Indonesia is relatively non-stop because it is carried out in large open areas, which allows workers to maintain personal distance from each other during their work. In terms of demand, as cooking oil and food ingredients, domestic consumption remains high, especially with the provision of biodiesel production with a high proportion of vegetable oil sources (B-30, meaning bio-diesel of 30 % vegetable oil, i.e., CPO) [66].

In the last five years before Covid-19, world CPO production and demand were relatively stable. However, transportation barriers have sharply increased the price of CPO, especially as CPO is also a staple food in India and China (the most populous countries) as cooking oil and food ingredients. Russia's invasion of Ukraine on February 24, 2022, which prevented Ukraine, a major producer of sunflower oil, from exporting its goods, worsened the issue [67]. As a result, buyers of sunflower oil switched to buying palm oil, which caused a sharp increase in the price of CPO globally [68]. The opening of trade with the operation of sea transportation has boosted Indonesia's CPO exports with the subsequent impact of domestic scarcity, so the price of cooking oil has increased sharply.

The sign of the dummy variable at the optimum lag in the long run is positive and real (see Table 7). In the long run, Covid-19 has an impact on increasing the production of the livestock sector by 0.03 %. An increase in investment at lag optimum by 1 % causes livestock sector production to increase by 1.004 %. The sign of the ECT of the negative livestock subsector is as expected with a value of -1.5584 or 155.84 %, which is the time needed to return to long-term equilibrium after experiencing a short-term shock of more than 19 weeks.

Indonesia's population growth and increasing per capita income have increased the demand for animal products such as meat, milk, and eggs. Generally, 45 % of domestic production can only meet beef consumption. About 90 % of cattle production is based on a system of small farms where livestock production is a side business. On the other hand, poultry meat production is able to meet the demand. In Indonesia, a Muslim country, chicken meat is used instead of beef (in contrast to non-Muslim countries, where pork is a significant alternative for beef) [69; 70].

Indonesia imports meat and slaughters cattle and live feeders to meet the beef deficit. Covid-19 has caused turmoil in producing countries' meat industry/livestock subsector. Crowding, noise, and density of workplace density characterise the meat processing industry. In addition, the working environment is humid and cold, which facilitates the spread of the virus. Therefore, the meat processing industry is very vulnerable to the spread of Covid-19. The meat industry had to be temporarily shut down in the US, Canada, Brazil, and EU nations due to reports of Covid-19 outbreaks in several countries [71; 72]. Transportation limitations for domestic and international distribution due to mobility restrictions and supply chain disruptions at ports added supply-side disruptions brought on by the shutdown of the processing industry [65].

The Covid-19 impact decreases the production of fisheries subsector both in the short term and in long-term (see Table 8). The sign of the dummy variable at the lag optimum in the long run is negative and not significant. In the short term and long-term, Covid-19 has an impact on decreasing the production of the fisheries sector by 0.007 %, an increase in investment in the lag optimum of the fisheries sector by 1 % causes the production of the fisheries sector to increase by 0.26 %. The sign of the ECT of the negative livestock subsector is as expected with a value of -0.3849 or 38.49 %, which is the time needed to return to long-term equilibrium after experiencing a short-term shock of more than 5 weeks.

As an archipelagic country with an area of 70 % oceans, Indonesia has great economic potential in the fisheries and marine sector (estimated IDR 3000 trillion). Only 10 % of the potential can actually be achieved, though [73]. In contrast, coastal villages in Indonesia are more commonly described as being poor or extremely poor [74; 75]. Indonesian fishing is dominated by small-scale fisheries, which makes it more vulnerable to shocks [76]. Mobility restrictions and stay-at-home advisories suppressed demand for fishery products with seafood restaurants' closure. Exports were hampered by quarantine restrictions at international ports, especially for fresh fish [55]. Fishermen had to cut back on their fishing frequency as a result of uncertain product marketing, which decreased productivity [77].

This study revealed that agricultural subsectors responded differently to the Covid-19 pandemic. None of the subsectors is directly affected, but rather the induced result of the demand side due to decreased purchasing power and disruptions in distribution channels that result in product prices increasing sharply, resulting in increased output value and increasing production of substitute goods for the commodity in question. The patterns are: (i) mobility restrictions to the closure of business activities have led to unemployment and decreased purchasing power [78; 58; 29] so that demand for consumer goods decreases which is responded by producers by reducing output as it unfolds in the food crops subsector, where the Covid-19 pandemic had a negative and significant effect on production, (ii) mobility restrictions have hampered the distribution of production factors (especially pesticides and fertilisers), so that the production of the horticultural subsector is not optimal. On the other hand, fruits and vegetables that are the output of this subsector require rapid distribution to reach consumers in a fresh condition so that post-harvest disturbances will encourage farmers to reduce production to reduce the risk of loss. Thus, the Covid-19 pandemic had a negative but insignificant effect on the production of the horticulture subsector. Meanwhile, in the fisheries subsector, disruptions in the distribution of production led to the closure of seafood restaurants, prompting fishermen to reduce the frequency of fishing, leading to a drop in production (the Covid-19 pandemic has a negative but insignificant effect on the production of the fisheries subsector), and (iii) for products that rely on international markets for both exports and import sources, the Covid-19 pandemic has a positive effect on production but with different mechanisms.

In the plantation subsector (in this case, palm oil), distribution disruptions in the form of closing international entrances to quarantine provisions for two weeks caused a scarcity of goods in the world market, that's why prices rose sharply. The output value will increase even though production does not change, resulting in the positive effect of the Covid-19 pandemic on the production of the plantation subsector, but this effect is not significant. Meanwhile, for imported products such as beef, skyrocketing prices due to the disruption of distribution channels led to domestic production growth for imported commodity substitution goods, so the Covid-19 pandemic had a positive and significant effect on production for the livestock subsector.

The varying impacts of the Covid-19 pandemic on the production of agricultural subsectors and the occurrence of negative induction on consumption and positive induction on production for different subsectors resulted in the effectiveness of fiscal intervention/fiscal stimulus carried out by the government to increase purchasing power through various assistance in the framework of social safety nets is limited in its positive impact [79]. So, depending on the agricultural subsectors in each region (coastal areas, rice paddy areas, plantation areas, or horticulture areas), the composition of assistance will vary. Because a crisis like the Covid-19 pandemic is not a black swan but rather something that will undoubtedly happen again in the same or a different form [80; 81].

Based on the lag optimum in the long run, Covid-19 has a positive impact on increasing food production, horticultural production, plantation production, and livestock production. During the Covid-19 period, investors invested in food crops, horticulture and plantation subsectors. On the other hand, Covid-19 has a negative impact on fisheries production, therefore the government needs to increase spending with fiscal policy. In the short term, Covid-19 has a negative impact on the production of food crops subsector, horticulture subsector, and fisheries subsector. Therefore, the government needs to implement fiscal policy.

6. CONCLUSIONS

This study emphasises the importance of examining the impact of the Covid-19 pandemic on agricultural production in Indonesia, both in aggregate and per subsector, because the production behaviour of each subsector can vary in dealing with the crisis. This study uses dynamic econometric analysis with time series data, an approach that has not been widely applied in previous studies, to provide more accurate insights and long-term predictions. In aggregate, the Covid-19 pandemic has a negative impact on agricultural production, but this impact is insignificant. The following discrepancies in the impact of the Covid-19 pandemic on the production of various subsectors are revealed by the breakdown of the agriculture sector into five subsectors: the Covid-19 pandemic has a negative and significant effect on production in the subsector of food crops, but this negative effect is not significant in the horticulture sector, positive but not significant in the subsector of plantations, positive and significant in the subsector of livestock, and negative but not significant in the subsector of fisheries. There are differences in the role of household consumption, investment, and government spending on agricultural production growth by subsector. The output of the food crops is mainly influenced by household consumption. At the same time, investment has a positive and significant effect on the production in the plantation and livestock subsectors, while in the fisheries subsector, government spending is the main driver of production growth. Therefore, investors should be encouraged to invest in the food crops subsector, horticulture subsector and plantation crops subsector. The government need to implement fiscal policy in the fisheries subsector.

7. LIMITATIONS AND FUTURE RESEARCH

This study has limitations. Ideally, the production estimation model is derived from the production function, where output is a function of inputs consisting of natural resources, capital, and labor. However, since such data is unavailable quarterly per agricultural subsector, production is approached through the demand side. Whereas, the scope of study based on closed economy. The future research agenda is to find out the effect of export variables and the type of fiscal stimulus on the production of agricultural subsectors so that in the future, the Government of Indonesia can determine the type of assistance based on the dominance of agricultural subsectors in one region. Therefore, depending on the agricultural subsectors in each region (coastal areas, rice paddy areas, plantation areas, or horticulture areas), the composition of assistance will vary.

Conflicts of interest: the authors declare no conflict of interest.

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