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# EXAMINING THE CONTRIBUTION OF AGRICULTURAL SUB-SECTORS TO AGRICULTURAL GDP IN THE ASEAN COUNTRIES USING A PANEL DATA APPROACH

**S.M. Ahammad[1*], F.S. Tania[1] and M.S. Islam[2]**
[1]Department of Accounting, Faculty of Business Studies, Hajee Mohammad Danesh Science and Technology University, Dinajpur, [2]Institute of Business Administration, University of Rajshahi, Bangladesh
[*]Corresponding Author: Email: mostak@hstu.ac.bd, Cell Phone: +8801712083786
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**ABSTRACT**
Using a panel data framework, this study looks at the changing relationship between agriculture production and four major agricultural sub-sectoral outputs in seven Association of Southeast Asian Nations (ASEAN) countries from 1961 to 2016. The data was obtained from the Food and Agriculture Organization (FAO) of the United Nations dataset. It uses panel unit root tests and panel co-integration analysis to figure out how the variables are related. In addition, the long-run co-integration coefficient parameters are estimated to detect the existence of long-run relationships to measure the effect of responses between agricultural GDP and four major agricultural sub-sectoral outputs. Most of the panel unit root results show that there is a long-run co-integrating relationship among the variables. So, there is a possible long-run co-integrating relation among the variables. The empirical results of panel co-integration analysis revealed that the long-run equilibrium relationship among the variables is not positive but statistically significant, indicating the existence of long-run co-movement among the variables. The long-run equilibrium results support the idea that agriculture production is fully dependent on the sub-sectors. In addition, among all the sub-sectors, the cereals sub-sector shows poor results, which indicates a comparatively lower contribution to agriculture production. The food sub-sector shows the most significant results in all seven ASEAN countries, which indicates that the contribution of the food sub-sector is very high compared to other sub-sectors.

**Keywords:** ASEAN, DOLS, FMOLS, Panel co-integration

## INTRODUCTION

Agriculture is the most important part of an economy because it meets people's basic needs and is where most of the raw materials for industrialization come from. Agriculture is important to international trade, transportation, the building industry, household income, and economic growth, especially in developing countries. Numerous countries' GDPs are directly impacted by the agricultural industry. Those nations whose GDP is not directly affected by the agriculture sector indirectly rely on it to feed their citizens. So, for the balanced growth of the economy, the agricultural sector must not be neglected. The agriculture sector likewise confronts difficulties in maintaining a consistent per capita agricultural GDP. These issues can lead to population growth, reductions in arable land, and changes in agricultural practices, all of which have an effect on climate change.

These obstacles may have unanticipated effects on the agricultural expansion of the economy. Using the panel data method, this study explores the relationship between agricultural GDP and the contributions of various subsectors in ASEAN (Association of Southeast Asian Nations) countries. The seven ASEAN nations under consideration are the Philippines, Brunei Darussalam, Thailand, Burma, Indonesia, and Malaysia.

In the ASEAN region, agriculture has played and continues to play an essential role. It is a vital engine of social, inclusive growth, a significant source of export profits, a provider of food for its population, and a generator of direct and indirect employment through agriculture-related, value-added enterprises. Others have highlighted the significance of both exports and food security requirements (e.g., Thailand and Vietnam).

After looking at how important the agriculture sector and its sub-sectors are, the study looked at how the sub-sectors of agriculture affect agricultural GDP in the ASEAN countries listed above.These countries were chosen based on how much they produce in agriculture and how much their subsectors add to their gross domestic product.This study will help people understand how much the agriculture sector and its sub-sectors work together and how much agriculture production depends on the growth of its sub-sectors.Over the years, a lot of research has been done on how well the agriculture sector is doing.Using secondary data from 2001 to 2015, Chandio *et al.* (2015) examined the contribution of agricultural sub-sectors' growth rates to Pakistan's agriculture GDP growth rate. Using the Ordinary Least Square (OLS) approach, the model parameter was estimated. The data analysis revealed a favourable and statistically significant contribution to the agriculture GDP growth rate. Chandio et al. (2016) focused on the performance of agricultural sub-sectors: an analysis of the sector-by-sector contribution to agriculture GDP in Pakistan from 1998 to 2015. Using ordinary least squares (OLS), an econometric technique, the model parameters were estimated. For this reason, the study considered agriculture's GDP as well as a number of independent factors, including major and minor crops, livestock, and forests. According to the empirical findings, agricultural sub-sectors contribute positively and substantially to the agricultural GDP. Jehangir et al. (1998) attempted to investigate the production of major crops in Pakistan. The study concluded that the production of important crops such as wheat, rice, sugarcane, cotton, and maize can be boosted by employing modern agricultural techniques.

Wongwachara and Minphimai (2009) analyzed GDP data to determine the production gap, cycles, and growth for ASEAN nations. This analysis shows that the projected Phillips curve relationship between the output gap and inflation in ASEAN countries is insignificant. Ahmed and Amjad (1984) evaluated the significance of agricultural development for the growth of other sectors in Pakistan, including the industrial sector and the manufacturing sector. Moyenuddin (2015) studied the contribution of Bangladesh's agricultural, industrial, and service sectors to economic growth using data from 1980 to 2013. The time series data are stationary at the first difference according to the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. According to the co-integration study, each economic sector has a strong, positive, and statistically significant linear association with economic growth.

Rezitis and Ahammad (2017) evaluated the dynamic link between energy consumption and the three most important sectoral outputs (agriculture, manufacturing, and services) in thirteen South and Southeast Asian nations using a panel data framework from 1971 to 2012. Using panel co-integration analysis, the long-term connection between the variables was investigated. In addition, the panel vector error correction model (PVECM) and impulse response functions (IRFs) were used to investigate the short-run and long-run directions of causation and the effect of responses between energy consumption and the three sectoral outputs. Zhaheer (2013) analysed the development of the agriculture sector in Pakistan from 1950 to 2010, including its issues and potential remedies. The major and minor crop (from 1980 to 2010), livestock, fisheries, and forestry (from 2005 to 2010) subsectors of the sector are also investigated. TFP from 1970 to 2010 is also evaluated to determine overall agricultural productivity. The findings indicate that the growth of the agriculture industry has fluctuated over the past six decades, with its best performances occurring in the 1960s and 1980s. Fan et al. (2010) analysed China's agricultural boom and its economic effects. They discovered, among many other positive effects, a significant contribution of agricultural growth to economic growth.

All of the aforementioned studies were done to assess the contribution of the growth rate of agricultural subsectors to the growth rate of agriculture's GDP. However, from the above studies, it is clear that agriculture sub-sectors play a vital role in agricultural GDP growth. This study attempts to analyze the relationship between agriculture production and its sub-sectoral output in a panel data framework by including additional variables, namely cereals, crops, food, and livestock from seven ASEAN nations.

## METHODS AND DATA

### Methodology

This study aims to investigate the relationship between agriculture production and four selected sub-sectoral contributions in seven ASEAN countries. The empirical methods used in this study include panel unit root tests (e.g., Harris and Tzavalis (1999), Im et al. (2003), Levin et al. (2002), and Breitung (2001)) to determine the stationary features of the variables under investigation. Second, to determine the presence of cointegration, panel co-integration tests, such as Pedroni (1999), are executed. Third, the estimation of long-run co-integration parameters is carried out based on the studies by Pedroni (1999). Note that the estimates were derived using RATS 8.2 econometric software and followed Doan's (2012) study.

### Panel unit root analysis

This study uses various unit root tests to check the stationary of the variables. A large portion of the broad unit root tests utilizes the accompanying general structure:

$$\Delta y_{it} = \rho_i y_{i,t-1} + \sum_{L=1}^{p_i} \theta_{i,L} \Delta y_{i,t-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \qquad m = 1,2,3 \qquad (1)$$

where Δ is the first difference operator, *p* is the lag length, $d_{mt}$ is a vector of deterministic variables and $\alpha_{mt}$ is the corresponding vector of coefficients for models *m*=1, 2, 3 and 4. $\rho_i = 0$ shows that the procedure has a unit root for individual *i*, while $\rho_i < 0$ demonstrates a stationary procedure.

In this study, the order of variable integration is determined using four distinct panel unit root tests. The first is the LLC test developed by Levin *et al.* (2002), the second is the HT test developed by Harris and Tzavalis (1999), the third is the IPS test developed by Im *et al.* (2003), and the fourth is the Breitung test developed by Breitung (2000).

**Levin, Lin and Chu Test**

The Levin, Lin and Chu (1993) tests are abbreviated by LLC henceforth. Their results have only been recently published in Levin, Lin and Chu (2000). According to LLC, since $\rho_i$ is fixed across *i* the alternative hypothesis is that they $\rho_i$ are identical and negative.

**Harris and Tzavalis Test**

The Harris and Tzavalis Test, labelled HT, is a similar but simpler test, described by Harris and Tzavalis (1999). This also has a null hypothesis of unit root versus an alternative hypothesis with a single stationary value. It is designed to be applied to data sets that are relatively short in the time (T) dimension of the panel.

**Im, Pesaran and Shin Test**

Im, Pesaran and Shin test was developed by Im *et al.* (2003), unlike Levin, Lin and Chu and Harris and Tzavalis, they allow the more general alternative hypothesis that the $\rho_i$ can vary and the null hypothesis implies that all individual series have a unit root, i.e. $\rho_i = 0$ for all *i*, while the alternative hypothesis indicates that some of the series are stationary, i.e. $\rho_i < 0$ for some *i*.

**Breitung Test**

Breitung Test developed by Breitung (2003), proposes an alternative set of procedures to Levin, Lin and Chu with a similar null hypothesis of a unit root that uses unbiased estimators rather than bias-corrected ones.

**Panel Co-integration Analysis**

A panel co-integration test was developed by Pedroni (1999). The two sets of tests for co-integration were developed by Pedroni (1999, 2000) which include seven statistics. The first set is a panel within a dimension that has four statistics (panel *v*-statistic, panel *ρ*- statistic, panel *PP*- statistic, panel *ADF*-statistic) and, a second set is a group between dimensions which includes (group *PP*- statistic, group *ADF*- statistic). Panel *v*-statistic, panel *ρ*- statistic, panel *PP*- statistic and panel *ADF*- statistic indicates the panel variance statistic, panel rho statistic, panel Phillips and Peron test and augmented Dickey-Fuller *t*-statistic respectively. The panel co-integration analysis is used to test the existence of the long-run relationship between agriculture production and the four agricultural sub-sectors outputs (cereals, crops, food and livestock).

**Long-run equilibrium relationship**

Based on multiple research by Pedroni (2000, 2001, 2004, and 2007), the current work applies two estimators to estimate the long-run parameters of the co-integration relationships. Fully Modified Ordinary Least Squares (FMOLS) were used for the initial estimation, which was created by Phillips and Hansen (1990) and modified by Hansen (1992). The second estimator is the Dynamic Ordinary Least Squares (DOLS) model, which was proposed by Stock and Watson (1993).

**Data**

The data set used is yearly data on the logarithm of the per capita agriculture production and sub-sectoral contribution (cereals, crops, food, and livestock) of seven ASEAN countries, i.e. Philippines, Brunei Darussalam, Thailand, Myanmar, Indonesia, Vietnam, and Malaysia, by using secondary data obtained from Food and Agriculture Organization of the United Nations (FAO) data. The 56 years of data from 1961 to 2016 were obtained from the FAOSTAT statistical dataset (http://faostat.fao.org). The country data were arranged according to their level of contribution to agriculture as well as agricultural sub-sectors. In this study, agriculture is the major sector, and four sub-sectors are selected: cereals, crops, food, and livestock. The multivariate panel data approach includes- lnAGR = The natural logarithm of agriculture production, lnCER = The natural logarithm of cereals sub-sector, lnCRO = The natural logarithm of crops sub-sector, lnFOO = The natural logarithm of food sub-sector, lnLVK = The natural logarithm of livestock sub-sector.

## RESULTS AND DISCUSSION

### Panel unit root test results

The panel unit root test results are presented in Table 1 and Table 2. Table 1 shows the results of the Levin, Lin and Chu (LLC) test and the Breitung test. Table 2 shows the results of the rest of the two-panel unit root tests, i.e., the Harris and Tzavalis (HT) test and the Im, Pesaran, and Shin (IPS) test, respectively. Here in the table, the variables lnAGR, lnCER, lnCRO, lnFOO, lnLVK indicate the level of agriculture, the level of cereals, the level of crops, the level of food, and the level of livestock. Accordingly, ΔlnAGR, ΔlnCER, ΔlnCRO, ΔlnFOO, ΔlnLVK represent the first difference in agriculture, the first difference in cereals, the first difference in crops, the first difference in food, and the first difference in livestock, respectively. The majority of panel unit root test outcomes tend not to reject the null hypothesis of a panel unit root for the levels of the variables.

Specifically, according to Levin, Lin and Chu (LLC) test most of the results fail to reject the null hypothesis for the level variables. Maximum results indicate a tendency to fail to reject the null hypothesis of a panel unit root for the levels of the variables, as determined by the Breitung test. In table 2, both of the tests Harris and Tzavalis (HT) and Im, Pesaran, and Shin (IPS) indicate that all of the panel unit root results for the levels of the variables show a tendency of failing to reject the null hypothesis of panel unit root.

On the contrary, all of the panel unit root test results for the first difference indicate the rejection of the null hypothesis of the panel unit root of the variables in support of the alternative of stationary first differences of the variables.

**Table 1.** The results of the Panel unit root LLC and Breitung tests

| Variables level and in 1st differences | LLC Test | | | Breitung test | | |
|---|---|---|---|---|---|---|
| | None | Constant | Constant and Trend | None | Constant | Constant and Trend |
| lnAGR | 14.86(1.00) | 0.59(0.72) | 0.21(0.58) | 11.16(1.00) | 9.48(1.00) | -0.79(0.21) |
| lnCER | 7.15(1.00) | -0.78(0.22) | 1.95(0.97) | 6.39(1.00) | 4.99(1.00) | -2.01 (0.02) |
| lnCRO | 12.40(1.00) | 0.28(0.61) | 0.63(0.73) | 9.70(1.00) | 8.36(1.00) | -1.53(0.06) |
| lnFOO | 14.12(1.00) | 0.22(0.59) | 0.83(0.80) | 10.86(1.00) | 9.17(1.00) | -0.96(0.17) |
| lnLVK | 6.78(1.00) | 0.32(0.62) | 1.35(0.91) | 6.26(1.00) | 4.84(1.00) | -2.51(0.01) |
| ΔlnAGR | -7.44(0.00) | -8.38(0.00) | -5.71 (0.00) | -6.13(0.00) | -7.18(0.00) | -9.62 (0.00) |

| | | | | | | |
|---|---|---|---|---|---|---|
| ΔlnCER | -15.15(0.00) | -14.82(0.00) | -11.40(0.00) | -10.45(0.00) | -10.94(0.00) | -12.10(0.00) |
| ΔlnCRO | -8.34(0.00) | -10.92(0.00) | -7.95(0.00) | -6.10(0.00) | -9.79(0.00) | -11.36(0.00) |
| ΔlnFOO | -9.56(0.00) | -9.08(0.00) | -8.23(0.00) | -7.38(0.00) | -7.06(0.00) | -11.05(0.00) |
| ΔlnLVK | -9.12(0.00) | -4.98(0.00) | -2.22(0.01) | -7.54(0.00) | -7.57(0.00) | -8.51(0.00) |

Note: Δ is the 1st difference operator. Numbers in parentheses are *p*- values

**Table 2.** Results of Panel Unit root HT tests and IPS tests

| Variables level and in 1st differences | HT test | | | IPS test | |
|---|---|---|---|---|---|
| | None | Constant | Constant and Trend | Constant | Constant and Trend |
| lnAGR | 0.84(0.80) | 2.36(0.99) | -0.99(0.16) | 3.48(0.10) | -0.22(0.41) |
| lnCER | 0.38(0.65) | 0.78(0.76) | 0.49(0.69) | 1.41(0.92) | -0.36(0.36) |
| lnCRO | 0.68(0.75) | 2.15(0.98) | -0.94(0.17) | 2.49(0.10) | -0.69(0.24) |
| lnFOO | 0.84(0.80) | 2.22(0.99) | -1.42(0.08) | 3.05(0.10) | 0.30(0.62) |
| lnLVK | 1.08(0.86) | 2.32(0.99) | -0.37(0.37) | 2.65(0.10) | -0.79(0.21) |
| ΔlnAGR | -82.20 (0.00) | -43.84(0.00) | -26.56(0.00) | -8.43(0.00) | -7.08(0.00) |
| ΔlnCER | -11.36(0.00) | -50.54 (0.00) | -31.06(0.00) | -11.97(0.00) | -10.94(0.00) |
| ΔlnCRO | -79.56(0.00) | -42.89(0.00) | -25.84(0.00) | -10.91(0.00) | -9.90(0.00) |
| ΔlnFOO | -84.22(0.00) | -45.32(0.00) | -27.46(0.00) | -8.69(0.00) | -10.09(0.00) |
| ΔlnLVK | -83.88(0.00) | -43.75(0.00) | -26.37(0.00) | -7.43(0.00) | -5.97(0.00) |

Note: Δ is the 1st difference operator. Numbers in parentheses are *p*- values.

Consequently, based on the panel unit root analysis, it is possible to conclude that the variables are integrated in order one, i.e. I(1). Subsequently, the next step of the empirical analysis is to examine the co-integration of the variables being investigated.

**Panel co-integration test**

The panel co-integration test results presented in Table 3 were obtained with and without the inclusion of time dummies. Here are seven test statistics in the table: panel v-statistic, panel ρ-statistic, panel pp-statistic, panel Adf-statistic, group ρ-statistic, group pp-statistic, and group Adf- statistic. The p-values of seven test statistics indicate significance at the 1% and 5% levels.The statistics are asymptotically significant as standard normal. Significantly, the majority of the test statistics reject the null hypothesis of no co-integration between the variables. When time dummies are included, four out of seven test statistics (panel pp-statistic, panel Adf-statistic, group pp-statistic, and group Adf-statistic) reject the null hypothesis of no co-integration among the variables under examination. When time dummies are not included, five out of seven test statistics (panel p-statistic, panel pp-statistic, panel Adf-statistic, group pp-statistic, and group Adf-statistic) reject the null hypothesis of no co-integration between the variables under examination. The majority of significant results are negative but statistically significant. These results demonstrate the existence of a long-term correlation between the variables in both analyses.

**Table 3.** Panel Co-integration Test

| Variables | Panel (Within dimension) | | | | Group (Between dimension) | | |
|---|---|---|---|---|---|---|---|
| | *v*-statistic | *ρ*-statistic | *PP*-statistic | *ADF*-statistic | *ρ*-statistic | *PP*-statistic | *ADF*-statistic |
| Co-integration Test- With Time Dummies | | | | | | | |
| ln*AGR*, lnCER, lnCRO, lnFOO, lnLVK *constant* | -0.14 | -0.67 | -3.28** | -2.90** | 0.05 | -3.44*** | -3.01** |
| Co-integration Test- Without Time Dummies | | | | | | | |
| ln*AGR*, lnCER, lnCRO, lnFOO, lnLVK *constant* | 1.09 | -2.31** | -3.84*** | -3.80*** | -1.57 | -3.95*** | -3.93*** |

Note: *** and ** indicate statistical significance at 1% and 5% level of significance, respectively. The statistics are asymptotically significant as standard normal.

**Long-run equilibrium relationship**

Panel Fully-Modified Ordinary Least Squares (FMOLS) and panel Dynamic Ordinary Least Squares (DOLS) estimators were used to determine the long-run equilibrium connection. Table 4 displays the panel FMOLS and panel DOLS results for long-term elasticity. Examining the empirical results reveals that the FMOLS and DOLS estimators produce results that are very similar in terms of the magnitude and statistical significance of the parameter estimations, both for the entire panel and for individual countries. Table 4 presents the estimated parameters of seven Southeast Asian countries, i.e., the Philippines, Brunei Darussalam, Thailand, Myanmar, Indonesia, Vietnam, and Malaysia. The third row of Table 4 represents the estimated parameters of the co-integration vector corresponding to the full panel, that is, the whole group of seven ASEAN countries. Though all the coefficients of the full panel are not positive, but they are statistically significant at the 1% level of significance. The estimates of the full-panel FMOLS indicate that a 1% increase in cereals sub-sector output increases agricultural GDP by 0.03%; a 1% increase in crop sub-sector output increases agricultural GDP by 0.39%; a 1% increase in food sub-sector output increases agricultural GDP by 0.48%; and a 1% increase in livestock sub-sector output increases agricultural GDP by 0.13%. The estimates of the full-panel DOLS indicate that a 1% increase in cereals sub-sector output decreases agricultural GDP by -0.01%; a 1% increase in crop sub-sector output increases agricultural GDP by 0.41%; a 1% increase in food sub-sector output increases agricultural GDP by 0.52%; and a 1% increase in livestock sub-sector output increases agricultural GDP by 0.09%.

The results of the panel FMOLS and DOLS estimators for long-run elasticity are provided in Table 4 below.

**Table 4.** Panel co-integration coefficients of Seven ASEAN countries

| Variables | Panel FMOLS | | | | | Panel DOLS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Intercept | lnCER | lnCRO | lnFOO | lnLVK | Intercept | lnCER | lnCRO | lnFOO | lnLVK |
| lnAGR (Full Panel) | -0.01*** (-9.65) [0.00] | 0.03*** (4.66) [0.00] | 0.39*** (27.85) [0.00] | 0.48*** (26.55) [0.00] | 0.13*** (15.98) [0.00] | -0.05*** (7.61) [0.00] | -0.01*** (-3.65) [0.00] | 0.41*** (40.99) [0.00] | 0.52*** (32.45) [0.00] | 0.09*** (26.18) [0.00] |
| lnAGR (Philippines) | -0.01*** (-5.32) [0.00] | 0.01 (0.10) [0.32] | 0.51*** (11.88) [0.00] | 0.49*** (10.85) [0.00] | 0.14*** (7.90) [0.00] | 0.03*** (6.28) [0.00] | 0.01** (2.65) [0.01] | 0.20*** (5.59) [0.00] | 0.73*** (14.68) [0.00] | 0.05*** (4.48) [0.00] |
| lnAGR (Brunei Darussalam) | 0.01 (0.56) [0.57] | -0.03* (-1.81) [0.07] | 0.12*** (2.84) [0.00] | 0.96*** (10.79) [0.00] | 0.05 (0.65) [0.52] | -0.52*** (-0.84) [0.00] | 0.01 (0.75) [0.46] | 0.22*** (3.30) [0.00] | 0.77*** (5.26) [0.00] | 0.11 (1.10) [0.27] |
| lnAGR (Thailand) | -0.03*** (-8.94) [0.00] | -0.01 (-0.75) [0.45] | 0.61*** (17.26) [0.00] | 0.27*** (6.40) [0.00] | 0.21*** (9.54) [0.00] | 0.06 (1.20) [0.23] | 0.01 (0.59) [0.56] | 0.67*** (12.40) [0.00] | 0.15*** (2.85) [0.00] | 0.15*** (27.37) [0.00] |
| lnAGR (Myanmar) | 0.01*** (3.30) [0.00] | 0.03 (1.55) [0.12] | 0.13** (2.42) [0.02] | 0.68*** (25.08) [0.00] | 0.03** (2.58) [0.01] | 0.06*** (8.50) [0.00] | -0.02** (-2.44) [0.01] | -0.67* (-1.97) [0.05] | 1.08*** (32.98) [0.00] | 0.00 (0.28) [0.78] |
| lnAGR (Indonesia) | -0.01*** (-2.85) [0.00] | 0.05*** (3.36) [0.00] | 0.09* (1.76) [0.08] | 0.81*** (12.09) [0.00] | 0.05* (1.74) [0.08] | 0.07*** (10.82) [0.00] | -0.02*** (-3.10) [0.00] | 0.42*** (6.30) [0.00] | 0.52*** (6.43) [0.00] | 0.06*** (6.16) [0.00] |
| lnAGR (Vietnam) | -0.01*** (-3.64) [0.00] | 0.05*** (4.18) [0.00] | 0.30*** (10.74) [0.00] | 0.48*** (16.91) [0.00] | 0.08*** (4.29) [0.00] | 0.00 (0.18) [0.86] | -0.09*** (-10.07) [0.00] | 0.57*** (28.12) [0.00] | 0.44*** (26.48) [0.00] | 0.08*** (11.43) [0.00] |
| lnAGR (Malaysia) | -0.03*** (-8.64) [0.00] | 0.08*** (4.80) [0.00] | 0.99*** (26.79) [0.00] | -0.35*** (-11.88) [0.00] | 0.35*** (15.59) [0.00] | -0.08*** (-4.00) [0.00] | 0.02*** (2.86) [0.00] | 0.86*** (54.99) [0.00] | -0.06*** (-2.82) [0.00] | 0.19*** (18.46) [0.00] |

Note: Numbers in parenthesis are the absolute values of t-statistics while those in brackets are p-values. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively

The FMOLS and DOLS estimations of individual nations reveal that the effects of the subsectors' output (cereals, crops, food, and livestock) are statistically significant and favourable in the majority of countries. The FMOLS estimator of agriculture production shows negative results in two countries, i.e., Brunei Darussalam and Thailand, for the cereals sub-sector, and most of them are less significant. The crops sub-sector responds positively to agriculture production in all countries, and most of them are statistically significant. Most of the results of the food sub-sector are positive except for Malaysia, and all are statistically significant. Finally, the livestock sub-sector shows positive results in agricultural production, but only four countries—the Philippines, Thailand, Vietnam, and Malaysia—show the most significant results. Individual countries like Malaysia and Vietnam indicate highly significant results. Another notable matter in the case of the FMOLS model is that except for cereals, the other three sub-sectors, i.e., crops, food, and livestock, show maximum positive results as well as statistically significant output in all seven ASEAN countries.

In the instance of DOLS, country-specific estimators imply that all individual nations' agriculture production responds negatively in Myanmar, Indonesia, and Vietnam to the cereals subsector output, and most of them are less significant. All individual countries respond positively to the crop sub-sectoral output except Myanmar, where agriculture production responds negatively, and all of them show statistically significant results except Myanmar. The high responses of the agriculture production of all countries are to the food sector's output. Here, all the sub-sectoral output is highly significant, and only Malaysia responds negatively to agriculture production. Finally, the livestock sub-sector responds positively in all seven countries except two, i.e., Brunei Darussalam and Myanmar, whose output is not statistically significant, while other countries' output is highly significant. Here, Indonesia and Malaysia show highly significant results in all sub-sectors. According to the sub-sectoral output of food and crops, sub-sectors indicate the most significant results.

## CONCLUSION

The study examined the relationships and effects between agriculture production and its major sub-sectoral output (cereals, crops, food, and livestock) in seven ASEAN countries, i.e., the Philippines, Brunei Darussalam, Thailand, Myanmar, Indonesia, Vietnam, and Malaysia, for the period 1961–2016 using a panel data approach. These seven countries have been selected since they convey a very strong agricultural and economic contribution to the region. Keeping in mind that the time covered by the data is 56 years for each of the seven ASEAN countries, Pedroni's test was used to test for panel unit root test, panel co-integration analysis, and long-run equilibrium relationships.

The majority of panel unit root results tend not to reject the null hypothesis of a panel unit root for the variable levels. In contrast, all panel unit root results imply a rejection of the null hypothesis of a panel unit root of the first differences of the variables in favour of the alternative hypothesis of stationary first differences of the variables. It is conceivable to conclude that the variables are integrated based on the results of the panel unit root analysis, which hints at the existence of a possible long-run co-integrating relation among the variables, such as lnAGR, lnCER, lnCRO, lnFOO, and lnLVK. So, there is a correlation between agriculture and all the mentioned sub-sectors.

The panel co-integration analysis reveals that the long-run equilibrium relationship between agriculture and its sub-sectors (cereals, crops, food, and livestock) is not positive, but most of them are statistically significant, indicating the existence of long-run co-movement among the variables.

Particularly without time dummies, results are more significant compared to time dummies' results. However, from this test, we can say that there exists a correlation between agriculture production and the sub-sectors mentioned above.

Panel co-integration of the co-efficient represents the long-run co-movements among the variables of the full panel and individual countries of agriculture and its sub-sectors. The panels Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) show the empirical results, which indicate the long-run elasticity relationship between co-integrated variables and co-integrating vectors under consideration. It reveals that the maximum co-efficient responds positively, and most of them are statistically significant, which indicates that most of the sub-sectors respond positively to agriculture production in seven ASEAN countries.

Finally, policymakers may gain a better understanding of the relationship between agriculture production and the four sub-sectoral outputs (cereals, crops, food, and livestock) in the seven ASEAN countries thanks to the empirical findings of the current study (the Philippines, Brunei Darussalam, Thailand, Myanmar, Indonesia, Vietnam, and Malaysia). The dynamic long-run relationships between agriculture production and the four sub-sectoral outputs in the present study indicate that the sub-sectors have a significant impact on overall agriculture production. More emphasis should be given to the cereals sub-sector as it shows poor output compared to other sub-sectors. However, agricultural sectoral growth is necessary to achieve stable economic growth worldwide.

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