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# Towards sustainable agricultural development and food security in East Asia: The role of broad money and banking credits

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# Towards sustainable agricultural development and food security in East Asia: The role of broad money and banking credits

**Abstract:** The existing literature has extensively explored the role of financial development in boosting agricultural output. However, there is a lack of empirical research on the effects of broad money and banking credits on food production in East Asian countries. This study addresses this gap by examining the relationship between financial variables and agriculture in selected East Asian economies from 1995 to 2019, focusing on food security. Our findings indicate that increases in broad money and financial sector credit significantly enhance long-term food security by 0.216% and 0.846%, respectively. Additionally, we observed positive correlations between food security and agricultural inputs: a 1% increase in agricultural land, fertilizer use, and renewable energy adoption improves food security by 0.219%, 0.049%, and 0.146%, respectively. Robustness checks and Granger causality tests further validate these results. This study underscores the critical role of financial resources and agricultural inputs in food security and calls for a reassessment of credit systems to mitigate any adverse effects. These findings provide important insights for policymakers aiming to strengthen food security in East Asia.

**Keywords:** Agricultural development, Broad money, Food security, Food production, East-Asian economies



## 1. Introduction

Access to sufficient food is essential for maintaining optimal health and well-being. The global population's increasing food demands can be met if the agricultural sector is adequately funded (Wang et al., 2024). Agroforestry and biodynamic farming are among the new agricultural practices that represent the future of farming. They optimize resource use and minimize productivity loss by reducing negative environmental impacts (Yin et al., 2024; Chen and Li, 2024). However, food security has been greatly affected by climate change in recent years (Khalfaoui et al., 2024). It's evident that there is a pressing need: decision-makers should give importance to consider both agriculture and the environment at the same time. Access to financial resources is the key to implementing sustainable agricultural practices (Gregory et al., 2005). As financial

conditions deteriorate and geopolitical tensions rise in less developed countries, the weakness of agricultural production will undoubtedly lead to a more complex situation (Özdemir, 2023). Consequently, the optimal utilization of financial resources should cover investments in agriculture and rural development more, as well as improved access to financial services for small-scale farmers (Fan et al., 2023). Moreover, understanding the benefits of different financial mechanisms is crucial for effective food system activities. According to Clapp (2019), investment patterns in agricultural production have changed significantly in recent years. Investment dynamics in the food and agriculture industries are shifting, with investments increasingly going to equity funds. As a result, investors' interest in traditional commodities and agricultural lands has been declining. Besides, according to a 2019 report published by the European Investment Bank (EIB), factors such as low-profit margins and long-term returns discourage investors from innovating and taking risks. The progress of environmental impact reduction investments has been negatively affected by these outcomes (EIB, 2019). For this reason, policies to support farmers should make it easier for them to get loans (Jiang et al., 2023).

Precision agriculture has the potential to improve sustainable agricultural practices through advanced technologies significantly. Integrating financial development with technological advancements in agriculture could create a synergistic effect, enhancing agricultural productivity (Stafford, 2000; Zhang et al., 2002; Gebbers & Adamchuk, 2010). Consequently, the nexus between financial factors, such as broad money, financial credit, banking credit, and precision agriculture, is vitally important. By securing adequate financing, farmers can enhance their agricultural practices with cutting-edge techniques (Lai et al., 2017; Raifu and Aminu, 2019). However, access to agricultural finance varies significantly within and among countries. Factors like location, gender, and market orientation influence access to finance (IFAD, 2015). Therefore, development organizations such as the UN, World Bank, and IMF should prioritize increasing the availability of these financial products especially in developing countries to support food security. Undoubtedly, achieving the goal of the Sustainable Development Goal (SDG) objective of eradicating hunger by the year 2030 presents a formidable undertaking. It is anticipated that a substantial population of approximately 600 million individuals will continue to experience food insecurity by the year 2030 (FAO, 2023). Therefore, it is vitally important that international organizations should intensify their efforts to facilitate the transformation of agri-food systems and

effectively utilize them to achieve the targets outlined in SDG-2. This crucial scenario also emphasizes the need for more investment in and availability of agricultural finance to address the current impacts and establish sustainable food production systems. In the year 2022, a substantial population of approximately 783 million individuals experienced the condition of hunger (FAO, 2023). This figure denotes a notable escalation of 122 million people when compared to the pre-pandemic year of 2019. These organizations must allocate financial resources toward implementing strategies that effectively ensure food security and stability for all (Vivacqua, 2023). By collaborating with those international bodies, governments can ensure the financial mechanisms that are aligned with national food security goals and sustainable development objectives.

East Asia is highly vulnerable to climate-related hazards like sea level rise, floods, and droughts. Japan, for instance, has faced more frequent extreme weather events, such as the 2018 Typhoon Jebi, causing significant agricultural damage. Extreme precipitation events are expected to increase by the end of the 21st century (Japan Meteorological Agency, 2018). Therefore, Japan has been investing in climate-smart technology and advanced irrigation to bolster agricultural resilience (Takimoto, 2021). Similarly, South Korea's rice production is highly sensitive to variations in rainfall and temperature (Rizwanullah et al., 2023). Additionally, South Korea ranks among the most climate-vulnerable nations (Cui et al., 2009). Therefore, understanding how financial tools like broad money and banking credit can enhance food security is essential for effective policy-making (OECD, 2017; Islam & Kieu, 2021). In other words, financial support is crucial for advancing agricultural practices and ensuring sustainability. This study investigates the connection between financial variables and key agricultural factors, such as fertilizer use, agricultural land, sustainable energy practices, and rural population demographics with food production. In this context, the research question is how financial development affects food security in certain East Asian countries. The goal is to understand how credit supply and agricultural inputs work together to influence Asia's food security in the long term.

The rest of this study is structured as follows: Section 2 outlines the theoretical framework, while Section 3 offers a comprehensive review of the existing literature, Section 4 provides the data and model used, Section 5 discusses the findings, and Section 6 concludes the study with a conclusive summary.

**2. Theoretical framework**

An increase in agricultural productivity can lead to producing more food on less land. which is crucial for food security. Policymakers can enhance global food security by creating effective strategies based on investigating how various systems can improve profitability throughout the entire agriculture and food system. These strategies include but are not limited to investing in agriculture and rural development, increasing access to financial resources for small-scale farmers, and risk management tools to mitigate the effects of CC and other unforeseen challenges on agricultural output and food availability (Farooq et al., 2023; Hu et al., 2021). Nonetheless, agriculture frequently lacks sufficient funding due to government allocation towards other areas or ineffective spending. Entrepreneurs may also be hesitant to invest in agriculture because they perceive it to be riskier and more expensive than other sectors. Yet, the food and agriculture sectors demand significantly increased funding to support farmers, small-scale producers, and agrifood companies in accessing financial services in the era of CC. According to Narayanan (2016), in order to address long-term challenges and reduce economic risks, small-scale producers in volatile agricultural markets need to utilize state-of-the-art tools and take advantage of broad market opportunities. This may be because numerous small-scale farmers lack official business structures and encounter inadequate support from agricultural laws and regulations.

An increase in broad money enhances the lending capacity of financial institutions. This situation leads to an expansion in the supply of credit and theoretically improves overall accessibility to credit. This liquidity, when translated into credit for the economy, provides both individuals and businesses with greater access to resources to finance their projects. Therefore, an expanding supply of broad money typically leads to greater availability of credit, making it more accessible. More credit options can provide more financial support during market uncertainty and safeguard against unpredictable events. Timely access to financial funds is crucial for farmers and agribusiness companies to maintain the supply conditions and plan for future production. For instance, farmers can modernize their operations and stay competitive in today's agricultural marketplace if they have the opportunity to access suitable financing options such as microcredits, smart input subsidies, and guarantee funds (Agbodji and Johnson, 2021; Farooq et al., 2023). Agricultural loans offered by banks to farmers could be categorized into three main groups to meet their financial needs, as shown in Figure 1. The first category, business loans, is designed to finance farmers' daily operations and production

processes. These credits may be offered under different names depending on the various production activities; For example, it is privatized as a "crop production loan" for those engaged in crop production, and as a "livestock business loan" for those engaged in animal husbandry. Business loans are generally short-term, given at the beginning of the season, and expected to be repaid at the end of the harvest. The second category is post-harvest loans. These loans are designed to meet the cash needs of farmers in case they do not sell the harvested products immediately or until they collect their receivables if they have sold the products on credit. Banks provide advance financing to farmers based on the net receivable amount, by calculating the interest, commission, and other costs that will occur in this process. For products placed in licensed warehouses, these loans can also be obtained by using warehouse receipts as collateral. The third and final category is investment loans. These loans provide the financing that farmers and agricultural entrepreneurs need for larger-scale investments such as new field purchases, greenhouse installations, tractors, or other machinery purchases. Investment loans are generally medium or long-term and may require solid collateral. This guarantee can be provided by guarantees such as mortgages or pledges, and the maturity of the loan may vary depending on the nature of the project. These loan types allow farmers and agricultural sector entrepreneurs to meet a wide range of financing needs, starting from daily operational expenses to large-scale investments. Thus, in addition to increasing sustainability and productivity in the agricultural sector, it contributes to the general economic growth of the sector (Driedger et al., 2016; Gesualdo et al., 2024).

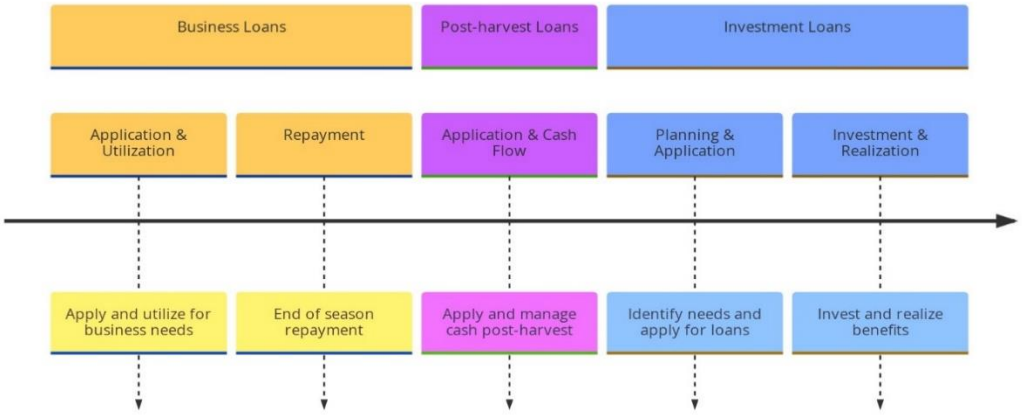


***Figure 1:*** *Agricultural Loans Roadmap.*

Food industries rely significantly on agricultural inputs. Consumption of fertilizer is a crucial factor in agricultural productivity, and agricultural productivity is the foundation of food production (Rehman et al., 2017). Nevertheless, the changing patterns of temperature levels in Asia forced countries to put restrictions on agricultural exports to prevent shortages, leading to an increase in global food prices. If we address these issues for Asian countries, we must also consider the challenges associated with food security and agriculture within the context of Asia's ongoing urbanization. Estudillo et al. (2022) argued that the agricultural sector is under pressure due to the expanding population in Asia. As a result of agricultural output losses caused by climate change, it is crucial to thoroughly analyse the availability of financial resources in the Asian agricultural industry. Asia's growing urban population requires not only higher agricultural productivity but also a comprehensive understanding of the allocation of financial resources in this rapidly changing environment (ABD, 2021). Therefore, our study focuses on examining the significant effects of broad money supply and domestic credit on food security. Understanding the interaction between these financial factors is important to improve food production methods and ensure food security. Additionally, we consider the importance of using renewable energy to improve sustainable agricultural practices. Adopting renewable energy technologies has the potential to reduce the environmental footprint of agriculture while improving food security over time (Chopra et al., 2022). Finally, since changes in rural demographics might have a significant impact on the agricultural sector with significant consequences on agricultural activities, we will also consider the rural population as a demographic variable.

## 3. Literature review

The progress of agriculture is enhanced by the development of finance, particularly through financial inclusion and agricultural credit. This progress, in turn, contributes to the accomplishment of food security. Recent academic research has found that various types of financial and banking credit can positively impact the growth of agricultural productivity. The literature contains numerous studies that explore the nexus between agricultural credit, financial inclusion, agricultural production values, and agricultural growth. Mahapatra and Jena (2023) examined how agricultural credit disbursement affected cereal, millets, and rice crops in Odisha from 2000-01 to 2019-20, using autoregressive distributed lag (ARDL) models for analysis. The study confirmed a

significant long-term relationship between agricultural credit and yields, indicating that crop loans had a positive long-term impact on total cereal and rice yields but not millet yields. On the other hand, term loans had negative long-run effects on the yields of all three crops, especially rice. In the short term, both crop and term loans are seen to affect cereal yield negatively. This study demonstrates that determining the right type of loan is critical since loans might affect agricultural output differently in the short and long term. Nascimento et al. (2022) evaluated the role of rural financing on agricultural output in Brazil and found a positive long-term nexus between agricultural output and agricultural-related loans. The estimated long-run elasticity indicates that a 1% increase in rural credit leads to a 0.44% increase in agricultural GDP. the study affirms that rural credit can be beneficial towards the enhancement of the agricultural sector, and therefore driving the growth of the economy. Anh et al. (2020) in Vietnam, and Rehman et al. (2019) in Pakistan, investigated how credit or loan provisions significantly affect various agricultural performances.

Other studies investigated the relationship between crop production, food security, and credit availability in regions where agriculture is the main sector. For instance, Seven and Tumen (2020) identified a positive correlation between agricultural loans and productivity and showed that doubling agricultural credits can increase productivity by 4-5% using cross-country data. Wongnaa et al. (2023) reported a 30% productivity improvement among small-scale rice farmers in Ghana's Northeast region who participated in these programs. Therefore, financial integration, primarily used to support farm production, is another crucial factor in enhancing food security. Batool et al. (2023) pointed out that increasing financial development, farm mechanization, and environmental sustainability are all critical to increasing food production to feed China's growing population. These studies show that complementarities between financial development and credit programs and technology improve agricultural productivity and hence food security in developing countries. Farooq et al., (2023), Shahbaz et al. (2013) and Zakaria et al. (2019) also supported the part of financial development in improving food security. As a result, improvement in the levels of the financial systems results in an improvement in agricultural productivity. In addition, Chandio et al. (2022) highlighted factors such as stability of financial advancement and efficient governance of climate change finance to help farmers from the adverse effects of climate change in the agricultural sector in Southeast Asia. All these studies prove the fact that agricultural finance is a vital factor in food security.

Increased credit opportunities can be used to finance the investments of producers operating in the agricultural sector to increase their capacity and renew and modernize their businesses (construction and renovation of agricultural buildings, other investments with projects, irrigation investments, land purchases, etc.). In addition, favorable financing conditions can change the risk perception of agribusiness. Access to innovative techniques such as precision farming technologies also becomes affordable for small-scale businesses. This kind of financial promotion lead to higher agricultural productivity and lower risks. (Anh et al., 2020; Hu et al., 2021). Besides banking or financial credits, various institutional mechanisms support agriculture-related activities such as public development banks (PDBs), government grants, warrants, leasing, rural cooperatives, and microfinance programs (Xu et al., 2021).

Agricultural credit plays an important role in this process because policies associated with the expansion of the money supply generally aim to support economic activities in these regions by improving credit conditions. Efforts to enhance agricultural credit usage should especially prioritize small farmers, ensuring that they have easier access to credit facilities (Jiang et al., 2023). Various studies have been conducted on this subject in different countries. For instance, Zakaria et al. (2019) conducted an assessment of the connection between financial expansion and agricultural output in South Asian economies during the period spanning from 1973–2015. The results show that there is a U-shaped connection between financial expansion and agricultural production. That is, agricultural productivity initially increases with financial expansion, but beyond a certain point, further financial expansion leads to a decrease in agricultural output. Similar findings are also reported by (Farooq et al., 2023; Hu et al., 2021). However, limited research has explored the long-term effects of broad money and financial and banking credit on food production within the context of the nexus between agricultural production and agricultural finance. These aspects include agricultural total factor productivity growth (Hu et al., 2021), technical efficiency, agricultural output (Agbodji and Johnson, 2021; Rehman et al., 2017), agricultural GDP (Anh et al., 2020; Farooq et al., 2023; Narayanan, 2016). Our goal is to use econometric analysis to uncover the causal relationships between the food production index and related financial and control variables. This study's novel contribution lies in examining the impact of three distinct financial variables—broad money, financial credit, and banking credit—on the food production index. This will provide insights for

policy decisions, sustainable food production, and economic development in East Asia. Accordingly, Figure 2 shows the conceptual framework of the study.

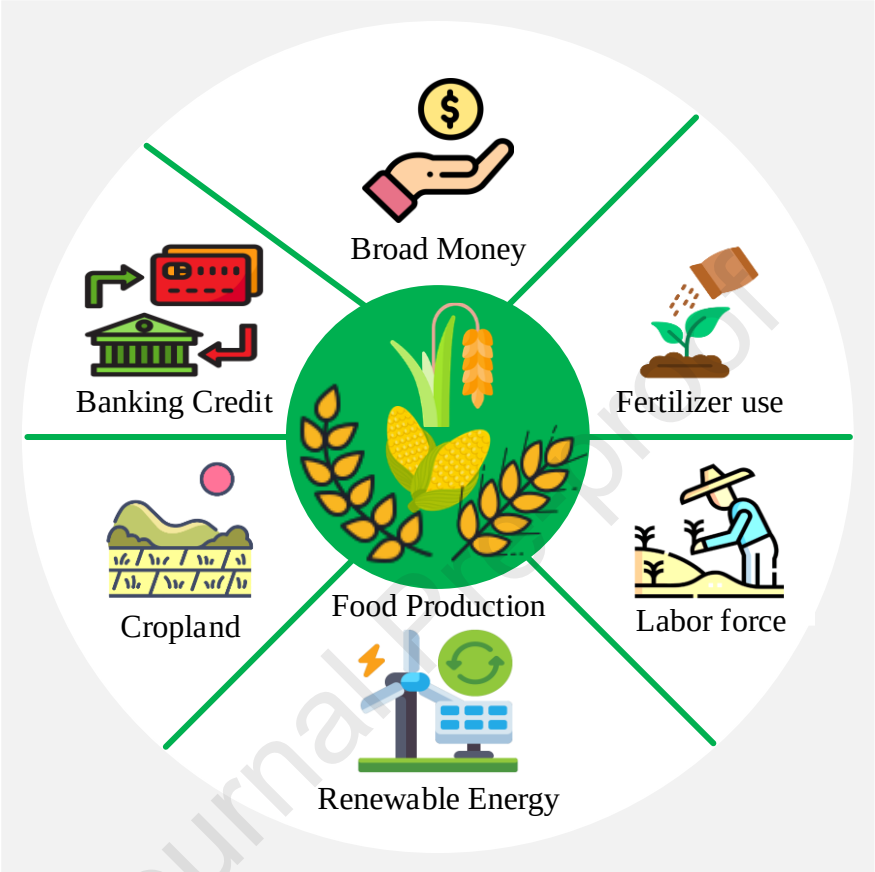


***Figure 2:*** *Broad financing, banking credit and other determinants influencing food crops production.*

## 4. Data and Methodology

### 4.1. Data description

This paper investigates the long-term impact of broad money and credit supply on food security in selected East Asian countries (China, Indonesia, Korea, Rep., Myanmar, Mongolia, Malaysia, Philippines, Thailand, and Vietnam) by using a panel dataset from 1995 to 2019. Figure 3 shows the geographical location of the selected nations. Table 1 reports the description of the studied variables.


***Figure 3:*** *Geographical location of the selected East Asian nations.*

**Table 1:** Description of the variables.

| Variables | Description | Source |
|---|---|---|
| Food security | Food production index (2014-2016 = 100) | WDI |
| Broad money | % of GDP | WDI |
| Domestic credit provided by financial sector | % of GDP | WDI |
| Domestic credit to private sector by banks | % of GDP | WDI |
| Fertilizer consumption | kilograms per hectare of arable land | WDI |
| Agricultural land | % of land area | WDI |
| Renewable energy use | % of total final energy consumption | WDI |
| Rural population | % of the total population | WDI |

Following the works of Shahbaz et al. (2013), Zakaria et al. (2019), Anh et al. (2020), and Farooq et al. (2023), to examine the nexus amid broad money, financial credit, domestic credit, fertilizer use, arable land, renewable energy use, labour force, and food security, Eq. (1) is formed:

$$FS_{it} = f(BF_{it}, FCR_{it}, BCR_{it}, AL_{it}, FER_{it}, RE_{it}, LF_{it}) \quad (1)$$

where broad money (BF), financial credit (FCR), and banking credit (BCR) are used as main input factors while food security (FS) stands as the output variable. Whereas, arable land (AL), fertilizer use (FER), renewable energy use (RE), and labour force (LF) are taken as control parameters to reduce bias in the omitted parameters results. Besides, Eq. (1) can be rewritten into panel data form as:

$$FS_{it} = \theta_{it} + \Upsilon_1 BF_{it} + \Upsilon_2 FCR_{it} + \Upsilon_3 BCR_{it} + \Upsilon_4 AL_{it} + \Upsilon_5 FER_{it} + \Upsilon_6 RE_{it} + \Upsilon_7 LF_{it} + \mu_{it} \quad (2)$$

where $\Upsilon_1, \Upsilon_2, \Upsilon_3, \Upsilon_4, \Upsilon_5, \Upsilon_6$ and $\Upsilon_7$ represent parameters of BF, FCR, BCR, arable land, fertilizer use, renewable energy use, and labor force, respectively. Whereas θ denotes the constant term, $i$ and $t$ represent the subscript for cross-sections (East Asian Countries: including China, Indonesia, Korea, Rep., Myanmar, Mongolia, Malaysia, Philippines, Thailand, and Vietnam) and time period (1995-2019). The Equation (2) is further transformed into the natural logarithm form as:

$$FS_{it} = \theta_{it} + \Upsilon_1 LnBF_{it} + \Upsilon_2 LnFCR_{it} + \Upsilon_3 LnBCR_{it} + \Upsilon_4 LnAL_{it} + \Upsilon_5 LnFER_{it} + \Upsilon_6 LnRE_{it} + \Upsilon_7 LnLF_{it} + \mu_{it} \quad (3)$$

### 4.2. Econometric modelling

In the present study, five significant econometric steps were used to investigate the robust relationship between the study variables: examining the cross-sectional dependency (CSD) issue, confirming the stationarity of variables, examining the long-term cointegration relation, examining the long-run associations, and identifying the causal associations between the selected time series. Figure 4 shows the flowchart of research methodology.

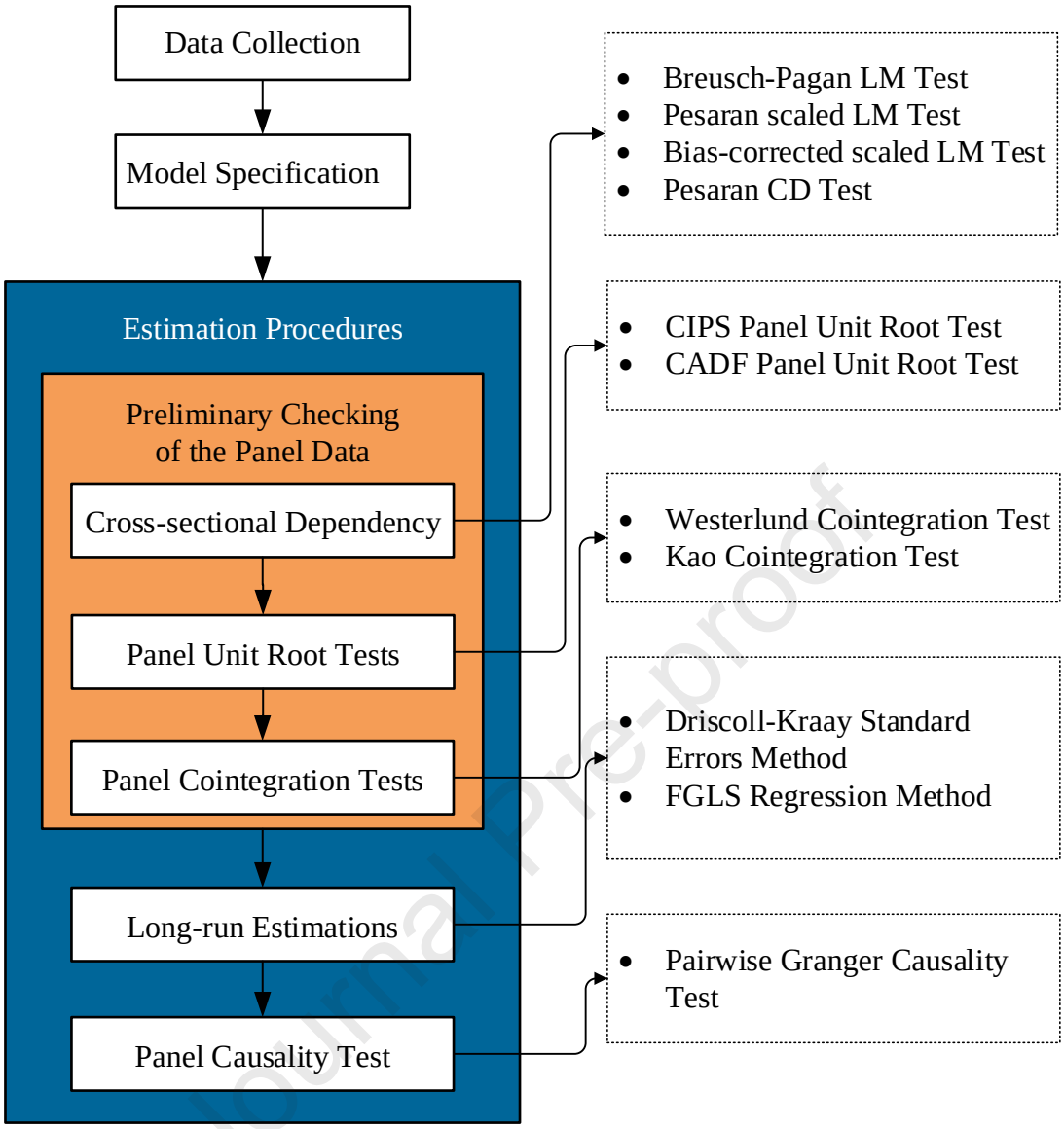


Figure 4: Flowchart of research methodology.

### 4.2.1. Cross-sectional dependence tests

The study initially examines the problem of CSD across selected countries by applying the Breusch and Pagan (1980) and Pesaran (2006) CSD tests. Domestic activities related to production, infrastructure, transportation, and inter-trade promote domestic and global interconnectedness in all three spheres of influence: social, economic, and political (Fakher and Ahmed, 2023). This interlinkage significantly causes the phenomena of possible CSD in the estimation of panel data. The traditional econometric results may be biased and unreliable if this observable fact occurs. Accordingly, it is significant to appraise the CSD issue in the econometric procedure that is commonly avoided in the earlier literature. In sequence with the research work of Pesaran (2006),

and Breusch & Pagan (1980), this study guesstimates the CSD, and LM test statistics utilizing the equations presented below:

$$CD = \sqrt{\frac{2(T)}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\delta}_{ij}\right) \sim N(0,1) \;\; \text{i, j} \tag{4}$$

*CD= (1, 2, 3…….55……N)*

$$M = \sqrt{\frac{2(T)}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\delta}_{ij}\right)\left[\frac{(T-K)\hat{\delta}_{ij}^{2} - (T-K)\hat{\delta}_{ij}^{2}}{Var(T-K)\hat{\delta}_{ij}^{2}}\right] \tag{5}$$

The term $\hat{\delta}_{ij}^{2}$ represents the bivariate pairwise cross-correlation of sample estimates, estimated through the OLS regression technique.

### 4.2.2. Panel unit root tests

After tackling the problem of slope heterogeneity and possible cross-sectional dependency, this study continues to the next step, checking the variable's stationarity characteristic. Consequently, it is crucial to determine whether the selected series in the current research are stationary. This study applied the second-generation panel stationary approach like CADF and CIPS unit root tests, at this phase. Above and beyond, Pesaran (2007) established these approaches to avoid the cross-section dependence issue across panels. The CADF test statistic is measured by using the Equation below as:

$$Z_{it} = \pi_i + \Psi_i z_{i,t-1} + \xi_i \bar{z}_{t-1} + \eta_i \Delta \bar{z}_t + \varepsilon_{it} \tag{6}$$

Here, Δ shows the operator of the first difference operative, $\varepsilon_{it}$ and $Z_{it}$ represent the error term and selected variables used in the current paper. By incorporating the one lag (previous values) into the above equation, the outcomes can be derived as shown in the following equation:

$$\Delta Z_{it} = \pi_i + \Psi_i z_{i,t-1} + \xi_i \bar{z}_{t-1} + \sum_{j=0}^{p}\eta_{ij}\Delta\,\bar{z}_{t-j} + \sum_{j=1}^{p}\lambda_{ij}\Delta\, z_{i,t-j} + \varepsilon_{it} \tag{7}$$

Where $\pi_i$ explores the benchmark point (constant), $\bar{z}_{t-j}$ and $\Delta z_{i,t-j}$ signify the mean operators and first difference of the selected variables at the lagged level of each province. Considering this, the CIPS test statistic can be presented in the equation below:

$$CIPS = N^{-1} \sum_{i=1}^{N} \Psi_i (N, T) \tag{8}$$

Where, the term $\Psi_i(N, T)$ explores the parameter of earlier estimated (CADF) test statistics, which can be replaced with the present term, and this can be expressed in bellow equation as:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \tag{9}$$

### 4.2.3. Westerlund cointegration tests

Before testing the long-term influence of regressors on the dependent variable of the long term, the long-run cointegration link must be verified. For this motive, the present research applied the Westerlund panel cointegration technique developed by (Westerlund, 2007). While, the first-generation cointegration (e.g., Pedroni, Kano, and Johansen) tests overlook cross-section dependence and slope heterogeneity, the approach developed by (Westerlund, 2007) can overcome this issue. The general form of the Westerlund test is explored as follows:

$$G_\tau = \frac{1}{N} \sum_{i=1}^{N} \frac{\delta_i}{SE(\hat{\delta}_i)} \tag{10}$$

$$G_a = \frac{1}{N} \sum_{i=1}^{N} \frac{T\delta_i}{\delta'_i(1)} \tag{11}$$

$$P_\tau = \frac{\hat{\delta}_i}{SE(\hat{\delta}_i)} \tag{12}$$

$$P_a = T\hat{\delta} \tag{13}$$

### 4.2.4. Panel estimation techniques

This statistical method is robust and provides continuous and reliable outcomes that account for the CD problem in the panel dataset. Furthermore, this technique is superior due to its adaptability and significant time-based component, as stated by Baloch and Meng (2019). The D-KSE technique has several advantages, including: (i) it can be used in both unbalanced as well as balanced panel dataset and counters missing values in the data estimation, and (ii) it further resolves the issue of heteroscedasticity, autocorrelation, and spatial problems in panel data analysis (Baloch & Meng, 2019; Baloch et al., 2019; Sarkodie & Strezov, 2019). Thus, this study applies the D-KSE technique to investigate the impact of broad money and credit supply on food security in selected East Asian countries for the period 1995 to 2019. The Driscoll-Kraay standard errors model is presented as follows:

$$y_{i,t} = x'_{i,t}\,\Upsilon + \varepsilon_{i,t} \tag{14}$$

Following the long-run analysis using the Driscoll-Kraay standard error approach, the Feasible Generalized Least Squares (FGLS) estimator was used to validate the long-run link between the variables under consideration. The FGLS gives stable long-run coefficients, so eliminating the problem of cross-sectional dependence.

## 5. Findings and discussion

Table 2 shows the results of descriptive statistics. The mean values of LnFS, LnBF, LnFCR, LnBCR, LnAL, LnFER, LnRE, and LnLF are 4.384, 4.258, 3.936, 3.928, 3.499, 4.984, 2.665, and 3.841, respectively. Likewise, the maximum values of the LnFS, LnBF, LnFSCR, LnBCR, LnAL, LnFER, LnRE, and LnLF are 4.878, 5.336, 5.115, 5.115, 4.435, 7.740, 4.452, and 4.355, respectively. Furthermore, the Jarque-Bera (J-B) test reveals that the panel dataset of this study is not normal and comprises some outliers.

**Table 2: Descriptive statistics.**

| Variables | Obs | Mean | Std. Dev. | Min | Max | J-B | Prob. |
|---|---|---|---|---|---|---|---|
| LnFS | 225 | 4.384 | 0.240 | 3.649 | 4.878 | 24.696 | 0.000 |
| LnBF | 225 | 4.258 | 0.631 | 2.751 | 5.336 | 12.313 | 0.002 |
| LnFCR | 225 | 3.936 | 0.946 | 1.245 | 5.115 | 29.409 | 0.000 |
| LnBCR | 225 | 3.928 | 0.950 | 1.245 | 5.115 | 29.274 | 0.000 |
| LnAL | 225 | 3.499 | 0.468 | 2.772 | 4.435 | 11.890 | 0.002 |
| LnFER | 225 | 4.984 | 1.666 | 0.415 | 7.740 | 24.000 | 0.000 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LnRE | 225 | 2.665 | 1.343 | -0.821 | 4.452 | 21.091 | 0.000 |
| LnLF | 225 | 3.841 | 0.422 | 2.894 | 4.355 | 32.649 | 0.000 |

Moreover, Table 3 shows the results of correlation analysis, which reveals that broad money, financial credit, domestic credit, fertilizer use, and arable land are positively correlated with food security, while renewable energy use and labour force are negatively correlated.

**Table 3: Matrix of correlations.**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| (1) LnFS | 1.000 | | | | | | | |
| (2) LnBF | 0.334 | 1.000 | | | | | | |
| (3) LnFCR | 0.309 | 0.921 | 1.000 | | | | | |
| (4) LnBRC | 0.308 | 0.923 | 1.000 | 1.000 | | | | |
| (5) LnAL | 0.017 | 0.035 | 0.090 | 0.087 | 1.000 | | | |
| (6) LnFER | 0.276 | 0.715 | 0.740 | 0.739 | -0.315 | 1.000 | | |
| (7) LnRE | -0.214 | -0.311 | -0.458 | -0.451 | -0.024 | -0.250 | 1.000 | |
| (8) LnLF | -0.337 | -0.285 | -0.399 | -0.395 | 0.144 | -0.278 | 0.922 | 1.000 |

The results of cross-sectional dependence tests (CSD) are shown in Table 4. The estimated p-values for the entire model are less than 0.05, confirming the presence of CSD between the cross-sections.

**Table 4: Cross-section dependence tests.**

| Tests | LnFS | LnBF | LnFCR | LnBCR | LnAL | LnFER | LnRE | LnLF |
|---|---|---|---|---|---|---|---|---|
| Breusch-Pagan LM | 614.471 | 396.132 | 317.108 | 317.730 | 624.326 | 342.745 | 335.0191 | 641.475 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Pesaran scaled LM | 68.173 | 42.442 | 33.128 | 33.202 | 69.334 | 36.150 | 35.23974 | 71.355 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Bias-corrected scaled LM | 67.985 | 42.254 | 32.941 | 33.014 | 69.1474 | 35.962 | 35.05224 | 71.168 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Pesaran CD | 24.269 | 10.188 | 5.044 | 5.208 | 6.062 | 9.489 | 1.086 | 22.529 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.277) | (0.000) |

Table 5 shows the outcomes of panel unit root and cointegration tests. The upper portion of Table 5 (Panel A) demonstrates the outcomes of the CIPS and CADF unit root tests. The results of CIPS test show that all variables are stationary at first difference, while CADF test indicates that LnMSCR, and LnBCR are stationary at level while LnFS, LnBF, LnAL, LnFER, LnRE, and LnLF are stationary at first difference. The findings of both tests allow us to examine the long-run cointegration among the variables by using the panel cointegration tests. Furthermore, the lower portion of Table 5 (Panels B and C) demonstrates the outcomes of Westerlund panel cointegration test and Kao panel cointegration test. The Westerlund panel cointegration test indicates that two out of four statistics are statistically significant, confirming the cointegration among the Similarly, the outcomes of the Kao panel cointegration test show that the t-Statistic value of ADF is highly significant and rejects the null hypothesis of no long-run cointegration relationships among the variables.

**Table 5: Outcomes of Panel unit root and cointegration tests.**

| **Panel A** | CIPS test | | CADF test | |
|---|---|---|---|---|
| | I[0] | I[1] | I[0] | I[1] |
| LnFS | -1.347 | -3.711*** | -0.748 | -2.493*** |
| LnBF | -2.016 | -3.929*** | -1.576 | -3.117*** |
| LnFCR | -1.397 | -3.923*** | -2.688*** | -3.199*** |
| LnBCR | -1.339 | -3.573*** | -2.627*** | -3.213*** |
| LnAL | -1.455 | -3.515*** | -1.406 | -2.708*** |
| LnFER | -1.878 | -5.471*** | -1.097 | -3.772*** |
| LnRE | -0.950 | -3.774*** | -0.950 | -2.975*** |
| LnLF | -0.237 | -2.518** | -0.899 | -4.255*** |
| **Panel B** | Westerlund panel cointegration test | | | |
| Statistics | Value | Z-value | Robust P-value | |
| $G_t$ | -2.322 | 0.307 | 0.188 | |
| $G_a$ | -9.097** | 1.712 | 0.010 | |
| $P_t$ | -3.661 | 2.276 | 0.758 | |
| $P_a$ | -9.542* | 0.160 | 0.065 | |
| **Panel C** | Kao panel cointegration test | | | |
| | t-Statistic | Prob. | | |
| ADF | -2.367*** | 0.009 | | |

*** *p<.01,* ** *p<.05,* * *p<.1.*

After checking the long-run co-integration among the variables, this study applies the D–K method to explore the long run impact of financial development on food security. Table 6 demonstrates the outcomes of the D–K estimator, which reveals that broad money has a significantly positive effect on food security. Similarly, it is worth noting that domestic credit provided by financial sector (FCR) also has a significantly positive effect on food security. More precisely, a 1 percent increase in broad money and financial sector funds improves food security by 0.216% and 0.846% in the long-run. Zakaria et al. (2019) found similar results for South Asian countries, and Farooq et al. (2023) observed the same trend in Pakistan. On the other hand, financial efficiency in agri-food firms is closely linked to effective resource management and strategic partnerships. Zhao et al. (2021) stated that internal integration as well as supplier collaboration enhances the quality of agri-food products resulting in more financial performance among the Chinese firms.

Our empirical findings reveal an inverse relationship between domestic credit to private sector by banks and food security. A 1% increase in domestic credit supply to the private sector leads to a 0.972% decrease in long-term food security. The expansion of these credits may harm food production for several reasons, including the nature of financial markets and the specific needs of agriculture. A large share of the available credit might be allocated to other sectors, resulting in insufficient funding for agriculture and potentially lowering food production. Moreover, high interest rates may limit access to financing for agricultural enterprises. Additionally, when credits are applied to operating expenses instead of to the efficiency-boosting equipment and facilities, there can be no enhancements of production capabilities or productivity yields in the long run. This analogy of spending credits in operating expenses means that investment efficiencies may not cause long-term production capacity and efficiency improvements. Large debts are also known to hamper the ability of business entities to produce and expand due to existing debt constraints. Economic conditions and political uncertainties can also impact financing for the agricultural sector.

In addition to broad money, financial sector funds, and domestic credit variables, the results from the D-K method indicate that farm inputs like arable land, fertilizer use, and renewable energy use significantly and positively impact food security in the long run, except domestic credit to private sector by banks. Specifically, a 1% increase in these variables enhances food security by 0.219%, 0.049%, and 0.146%, respectively.

**Table 6: Outcomes of Driscoll-Kraay standard errors**

| Variables | Coef. | St.Err. | t-value | p-value | [95% Conf | Interval] |
|---|---|---|---|---|---|---|
| LnBF | 0.216*** | 0.034 | 6.410 | 0.000 | 0.146 | 0.286 |
| LnFCR | 0.846* | 0.428 | 1.980 | 0.060 | -0.037 | 1.729 |
| LnBCR | -0.972** | 0.428 | -2.270 | 0.032 | -1.856 | -0.088 |
| LnAL | 0.219*** | 0.063 | 3.500 | 0.002 | 0.090 | 0.349 |
| LnFER | 0.049*** | 0.011 | 4.280 | 0.000 | 0.025 | 0.072 |
| LnRE | 0.146*** | 0.047 | 3.110 | 0.005 | 0.049 | 0.243 |
| LnLF | -0.665*** | 0.037 | -18.110 | 0.000 | -0.741 | -0.590 |
| Constant | 5.108*** | 0.222 | 22.990 | 0.000 | 4.650 | 5.567 |
| R-squared | | 0.2823 | Prob > chi2 | | 0.000 | |
| Number of obs | | 225 | Wald chi2(7) | | 5065.73 | |

*** *p<.01,* ** *p<.05,* * *p<.1.*

This study also employs the FGLS method as a robustness check to inspect the consistency of the regression findings. The robustness test results have shown that all variables are statistically significant and have the same signs (see Table 7). The overall analysis demonstrates that broad money, financial sector funds, arable land, fertilizer use, and renewable energy use are positively associated with food security, implying that these factors are valuable components that improve food security in selected Asian countries, implying that investments in these areas can significantly bolster food production.

**Table 7: Outcomes of FGLS regression (Robustness check).**

| Variables | Coef. | St.Err. | t-value | p-value | [95% Conf | Interval] |
|---|---|---|---|---|---|---|
| LnBF | 0.112*** | 0.018 | 6.15 | 0.000 | 0.077 | 0.148 |
| LnFCR | 0.548*** | 0.212 | 2.58 | 0.001 | 0.133 | 0.964 |
| LnBCR | -0.571*** | 0.213 | -2.68 | 0.007 | -0.989 | -0.153 |
| LnAL | 0.118*** | 0.012 | 9.98 | 0.000 | 0.095 | 0.142 |
| LnFER | 0.015*** | 0.005 | 3.23 | 0.001 | 0.006 | 0.024 |
| LnRE | 0.172*** | 0.008 | 22.15 | 0.000 | 0.157 | 0.187 |
| LnLF | -0.655*** | 0.026 | -33.34 | 0.000 | -0.693 | -0.616 |
| Constant | 5.562*** | 0.074 | 75.64 | 0.000 | 5.418 | 5.707 |
| Mean dependent var | | 4.384 | SD dependent var | | 0.240 | |
| Number of obs | | 225 | Chi-square | | 2821.626 | |

*** *p<.01.*

Finally, this research assessed causal links among food security, broad money, financial credit, domestic credit, arable land, fertilizer use, renewable energy use, and labour force. Once the long-run co–integration link is established, there should be bidirectional or unidirectional causality connections that exist between the considered variables. This investigation examines this causality connection using the Granger causality test. As shown in Table 8, bidirectional causality from *LnBF, LnMSCR, LnBCR, LnFER, and*

*LnLF* with LnFS is observed. The findings validate that financial development along with inputs play a fundamental role in improving food security in selected Asian countries. In addition, there is unidirectional causality from *LnAL* and *LnRE* to *LnFS*, which suggests that arable land and renewable energy use also enhance food security.

**Table 8: Findings of Granger causality test.**

| Null Hypothesis: | F-Statistic | Prob. | Remarks |
|---|---|---|---|
| *LnBF ≠ LnFS* | 3.12440*** | 0.0064 | *LnBF ⇔ LnFS* |
| *LnFS ≠ LnBF* | 2.72067** | 0.0153 | |
| *LnFCR ≠ LnFS* | 2.22326** | 0.0436 | *LnFCR ⇔ LnFS* |
| *LnFS ≠ LnFCR* | 3.00856*** | 0.0082 | |
| *LnBCR ≠ LnFS* | 2.13573** | 0.0522 | *LnBCR ⇔ LnFS* |
| *LnFS ≠ LnBCR* | 2.84853** | 0.0116 | |
| *LnAL ≠ LnFS* | 1.38205 | 0.2250 | *LnFS ⟹ LnAL* |
| *LnFS ≠ LnAL* | 3.01725*** | 0.0081 | |
| *LnFER ≠ LnFS* | 2.54382** | 0.0223 | *LnFER ⇔ LnFS* |
| *LnFS ≠ LnFER* | 3.54819*** | 0.0025 | |
| *LnRE ≠ LnFS* | 4.83266*** | 0.0001 | *LnRE ⟹ LnFS* |
| *LnFS ≠ LnRE* | 1.48192 | 0.1876 | |
| *LnLF ≠ LnFS* | 3.79038*** | 0.0015 | *LnLF ⇔ LnFS* |
| *LnFS ≠ LnLF* | 3.29724*** | 0.0044 | |

**** p<.01 and ** p<.05.*

**Conclusion and policy implications**

This research extensively examined the nexus between financial variables and critical agricultural components in certain East Asian countries, aiming to gain deeper insights into the issue of food security, utilizing data spanning from 1995 to 2019. Our investigation confirms the long-held hypothesis that broad money, inclusive of banking credit, wields a potent influence over food security outcomes. Employing the D-K method, we observe that a 1 percent increase in broad money leads to a substantial 0.216% improvement in long-term food security. Similarly, domestic credit provided by financial sector demonstrates a notably positive impact, with a 1% rise resulting in a significant 0.846% enhancement in food security. These findings not only validate existing research but also underscore the critical role of financial resources in ensuring a stable and resilient food supply chain. This study also investigates the crucial role of fundamental agricultural inputs—such as land, fertilizers, and renewable energy sources—in enhancing food security, alongside financial factors. Consequently, a 1% increase in agricultural land leads to a 0.219% increase in food security. Similarly, fertilizer usage and renewable energy sources lead to an increase in food security by

0.049% and 0.146%, respectively. These results show that investing in agricultural inputs is essential to improving food security and are consistent with previous research. Nevertheless, there's a puzzling finding regarding domestic credits by banks. When domestic credits to the private sector by banks increase by 1 percent, it unexpectedly leads to a long-term decrease in food security by 0.972%. In some cases, domestic credit may be diverted to speculative investments or non-productive purposes, such as real estate or stock markets, instead of being invested in productive agricultural activities. This misallocation can result in the underfunding of essential agricultural needs. Poor governance and corruption within financial systems can lead to loans being granted based on political connections rather than economic merit. Furthermore, low financial literacy can result in poor credit utilization, leading to weak investment decisions that fail to enhance agricultural productivity or food security (Karlan et al., 2014). Finally, the robustness tests using the cross-sectional time-series FGLS method confirm the statistical significance of the relationships among the variables. Furthermore, Granger causality tests indicate a two-way causal relationship between broad money, financial sector credit, agricultural inputs, and food security. Additionally, there is a one-way causal link between agricultural land and renewable energy to food security, highlighting the importance of the nexus among them in boosting food security. These findings provide a compelling rationale for evidence-based policymaking aimed at bolstering food security and propelling long-term economic development in the region. Accessing innovative financial tools for agriculture can be difficult, especially for small-scale farmers, due to the perceived investment risks associated with small-scale agriculture. Providing financial services to small-scale farmers can improve their lives but making these services available and affordable in rural areas is a major challenge. For instance, agent and mobile banking show promise despite weak mobile signals and limited transaction options in remote areas. Besides, to offer affordable and accessible financial solutions for smallholders and SMEs, financial service providers need to understand the relationships and risks within value chains, as stated in a 2015 report by the Global Partnership for Financial Inclusion (GPFI, 2015). To support small-scale farmers, governments should simplify contracts, establish reliable banking services, and implement collateral rules. Additionally, targeted financial aid can encourage farmers to use technology.

The number of regions where climate change threatens food security is steadily increasing. To make our policy recommendations for East Asia more relevant, it's important to look at how similar strategies have worked in other countries. To improve access to credit, a program called 'the Alliance for a Green Revolution in Africa' (AGRA) was implemented in Sub-Saharan Africa (AGRA, 2019). Through this program, small-scale farmers partner with local financial institutions, and mobile banking is utilized to reach rural areas more efficiently. This program emphasizes the significance of creating financial products that address the unique needs of farmers. Such programs could also be beneficial in East Asia. Similarly, Brazil's 'Bolsa Família' program has aimed to reduce food insecurity by linking financial aid to education and health outcomes (Soares et al., 2010). In essence, while different regions face climate challenges like East Asia, the impact of financial development differs due to varying economic and institutional capacities (FAO et al., 2018). In conclusion, governments are the primary actors in the sustainable management of resources, the preservation of biodiversity, and the fair distribution of benefits. To achieve these objectives, policymakers need to arrange agricultural credit distribution effectively that is in harmony with the strategic goals of the agriculture sector.

Our results provide evidence that domestic credit plays a significant role in food security, contributing to the framework of sustainable development goals. This is particularly relevant to Target 2.3 on enhancing the productivity and incomes of small-scale food producers by providing them with domestic credit aimed at increasing agricultural productivity and food availability in the country. In addition, our findings reflect on Target 2.a. of investing in infrastructure and research in rural development and agriculture. Thus, domestic credit plays a crucial role in developing these sectors and promoting sustainable agricultural practices. To enhance agricultural production and foster food security in East Asia, the following measures should be implemented: expanding agricultural land, integrating pest management, reducing resource degradation, and encouraging the adoption of renewable energy sources in agricultural production. Future research should include structural break analyses to consider potential time-varying relationships and structural changes. Additionally, incorporating machine learning and artificial intelligence algorithms for predictive modelling and data-driven policy recommendations could enhance the prediction of food security projections. Employing spatial econometrics to investigate the spatial dependencies and spillover effects in food security among neighbouring countries in East Asia would

contribute to a more comprehensive understanding. Finally, big data analytics on real-time and high-frequency data on weather patterns, and geopolitical events could offer more timely insights for proactive policy responses.

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**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: