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ARTICLE

Determinant of Food Security Index in Central Sulawesi Province Indonesia

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ABSTRACT

The Food Security Index (IKP) is a comprehensive indicator for evaluating the multidimensional aspects of food availability, accessibility, and quality adoption. From 2019 to 2024, IKP in Central Sulawesi showed considerable variation among districts and cities. Although there is significant growth at the provincial level, certain districts remained stagnant and slightly vulnerable. These inequalities underscore the importance of identifying key drivers of IKP to guide more effective and localized interventions that cover all aspects. This study aimed to employ an Instrumental Variable (IV) approach, leveraging climate data, to identify the determinants of IKP in the region. The selected instrument was validated for its relevance to rice production, which served as the primary endogenous variable. Using the IV Two-Stage Least Squares (2SLS) approach, the analysis outlined the significant influence of local government expenditure on goods and services, village funds, population density, and rice production on the IKP. The results showed that only expenditures on goods and services, as well as rice production, had a positive and substantial impact on food security, increasing it by 0,0807 and 0,0513 points, respectively, for every 1% increase in realization. Conversely, population density, village funds, real economic output, and other local government expenditures were associated with IKP reduction, suggesting demographic pressure, imbalanced income distribution, and inefficiencies in fund allocation. These findings emphasized the need for more strategic, productivity-oriented,

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and better-targeted fiscal allocation. Additionally, the study outlined the importance of correlating policy actions with evidence-based determinants of IKP to support inclusive and resilient development in Central Sulawesi.
Keywords: Climate Change; Food Security; Government Expenditure; Instrumental Variable; 2SLS Regression

1. Introduction

Food security is a crucial aspect of Indonesian socio-economic stability and development. The need for food sufficiency and sustainability has intensified alongside the nation's growing population and expanding economic aspirations. Furthermore, the significance has drawn attention from policymakers, academics, and the public, particularly following its prioritization as one of the eight National Priority Programs for 2025–2029, as outlined in Law Number 59 of 2024. This presidential priority program has been further elaborated upon by regional governments, including those in Central Sulawesi. Central Sulawesi's Regional Medium-Term Development Plan (RPJMD) incorporates food security and diversification policies as part of its regional acceleration program.

Food security has been defined and measured from various scientific perspectives [1]. Previous studies outlined that food security comprised multiple dimensions, including food supply adequacy to meet public needs [2], farmers' empowerment [3], the attainability of social, economic, and environmental justice [4], as well as the usefulness in promoting the general welfare such as supporting poverty alleviation programs [5].

In the local context, the Indonesian government, through the National Food Agency (Bapanas), publishes the Food Security Index (Indeks Ketahanan Pangan/IKP) as an indicator of food security. The IKP is adapted from the Global Food Security Index (GFSI) with considerations for local characteristics [6]. It is also evaluated based on three primary components, namely Food Availability, Affordability, and Adoption. Food Availability assesses the correlation between the supply and public consumption needs. The affordability aspect reflects the population's purchasing power to acquire food. Finally, Food Adoption measures the extent to which food contributes to community welfare. A detailed breakdown of the IKP components is presented in **Table 1**.

Table 1. Indonesian food security index indicators.

No	Indicators	Weight
Food Availability Aspect		
1	The ratio of normative consumption to net production of rice, corn, sweet potatoes, cassava, and sago, as well as regional government rice stocks	0.30
Food Affordability Aspect		
2	Percentage of the population below the poverty line	0.15
3	Percentage of households with a proportion of expenditure on food of more than 65% of total expenditure	0.075
4	Percentage of households without access to electricity	0.075
Food Adoption Aspect		
5	The average length of schooling for girls aged over 15 years	0.05
6	Percentage of households without access to clean water	0.15
7	The ratio of the number of residents per health worker to the population density level	0.05
8	Stunting Prevalence	0.05
9	Life expectancy at birth	0.10

Source. Bapanas, 2024.

The current condition in Central Sulawesi reflects growing food security with continued improvements over time. However, in 2024, a sub-regional analysis revealed that three districts were categorized as moderately food secure, and one district was classified as slightly vulnerable, as indicated in **Figure 1**. This con-

dition suggests that food security development policies remain less integrated across territories. Furthermore, as outlined in Central Sulawesi's RPJMD for 2021–2026, the region's geographical conditions and vast expanse pose significant challenges, particularly in food production and distribution.

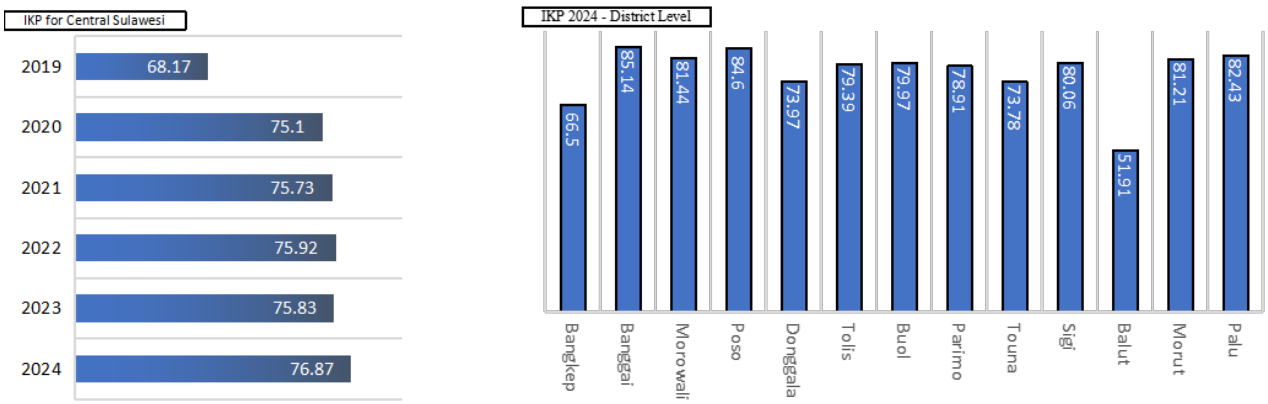

Figure 1. Central Sulawesi IKP 2019–2024 (Bapanas, edited).

Efforts to improve food security have faced numerous challenges that hinder progress. Suryana[7] asserted that Indonesian sustainable food production was affected by climate change and competition among farmers. Climate variability and change pose increasing threats to food productivity and the quality of food output[8, 9]. Additionally, rising input costs for food production worsen household economic conditions[10] and may lead to farmers leaving the profession due to declining profitability. High food prices have also become a significant concern[11], specifically for underprivileged populations[12], potentially limiting access to adequate food consumption.

In the context of food affordability and adoption, government expenditure has been widely studied due to its significant role in improving community welfare by supporting overall economic conditions and household consumption. Arestis et al.[13] argued that government expenditure has a positive impact on economic output, with fiscal instruments delivering a multiplier effect on economic growth and reducing the poverty level[14]. However, some studies have shown that fiscal tools can be ineffective in addressing existing socioeconomic challenges. For example, Tran et al.[15] outlined that higher government consumption would increase the budget deficit and expand the shadow (informal) economy rather than strengthening the formal sector. From an environmental perspective, government expenditure has been found to impact environmental sustainability negatively[16]. Considering these diverse implications, government budget refocusing evolves as a critical tool for achieving public objectives through more targeted strategies, particularly when food security is designated as a national priority.

Adequate and collaborative strategies are crucial for addressing the growing challenges of food security. Elzubair et al.[17] proposed cooperation-based agricultural activities, which were empirically successful in South Kordofan State, Sudan. Governments are motivated to adopt environmental and green economic policies, as suggested by Fajri et al.[18], such as creating sustainable agricultural production systems[19] to address these issues effectively. Additionally, the demand for financial inclusion is rapidly increasing in rural areas. This was underscored by Hu et al.[20], who outlined the positive impact of financial inclusion on agricultural growth.

Recognizing the multiple factors that determine food security, there is a need for empirical modeling to identify which variables contribute most significantly to achieving food security. This is especially relevant given the decline in rice harvest area observed in Central Sulawesi in 2024[21]. A recent study by Meliala et al.[22] found that government expenditure had a positive effect on Indonesian food security, although the model had low explanatory power (R-squared < 3%). Another

study by Farooq et al.[23] also highlighted how climate change threatens food security quality worldwide. From a different perspective, Molotoks et al.[24] identified population growth as a dominant factor influencing food adoption. It is argued that population increases could strain progress in food security when there is a mismatch between food supply and demand, unless population growth is accompanied by strong human capital development.

This study aimed to develop an empirical model to assess the determinants of IKP in Central Sulawesi. The model integrates both endogenous and exogenous variables to minimize bias and enhance accuracy by using instrumental variable regression, which will be detailed in the methodology section. Key variables include population density, government expenditure and accountability, economic output, and climate-related indicators such as temperature variability, precipitation, and soil moisture. As explained previously, the use of climate data as an instrument variable for rice production is based on its impact on determining the success of the rice harvest. Anshari et al.[25] found that changing rainfall patterns, rising temperatures, and intensifying solar radiation could potentially reduce rice farming productivity in Keduang Watershed, Central Java. Similarly, Setiadi et al.[26] explained that rice plants required relatively more water than other plants, making the monitoring of soil moisture conditions crucial for maintaining the quality of the rice produced. In a broader context, changes in temperature, precipitation, and soil moisture are often interrelated. For example, rising temperatures can reduce precipitation and soil moisture, thereby increasing the risk of rice production failure. By incorporating these diverse factors, the model aims to provide a comprehensive framework for understanding the dynamics of food security in the region while fostering a more targeted and thematic study of the critical issue.

This study serves as a valuable reference for evidence-based policymaking in Central Sulawesi. By identifying the key drivers of food security, the results can support the development of regional strategies to address vulnerabilities, optimize resource allocation, and design targeted interventions that promote food sufficiency, affordability, and sustainability. Ultimately, integrating scientific research into policy formulation is essential for developing resilient and adaptable food security systems in response of the current economic, demographic, and environmental challenges.

2. Materials and Methods

2.1. Data

This study utilized secondary data collected from government official sources and open-source datasets, covering the period from 2019 to 2024, for each district and city in Central Sulawesi. Therefore, a minimum of 78 data points were observed in the analysis. To enhance the clarity of the variables, the detailed definitions of each variable were presented in **Table 2**.

This study incorporated multi-domain variables to enhance the explanatory quality of the determinants (independent variables) influencing IKP, serving as the dependent variable. Among these determinants, government intervention was represented by various components of government expenditure, such as *GEem*, *GEgs*, GEcap, *GEot*, and *DD*, as well as *Acc* which represents the local government accountability. Additionally, the study examined the influence of current economic conditions, such as population density and GDRP, on IKP variability.

Although the majority of independent variables were considered exogenous, *Rice* was treated as an endogenous variable due to its dependence on climate-related factors. These factors were modeled using instrumental variables, including temperature, precipitation, and soil moisture quality, to address endogeneity concerns and ensure robust results. The simplified variable connections were visually represented in **Figure 2**.

The justification for the effect of independent variables on food security relies on both conceptual reasoning and empirical evidence. First, the government fiscal instruments—such as *GEe*, *GEgs*, GEcap, *GEot*, *DD*, and *Acc*—play a crucial role in promoting food security, particularly by enhancing the aspects of Food Affordability and Food Adoption. This concept is rooted in the 1945 Constitution of the Republic of Indonesia, which mandates the use of public funds for the greatest prosperity of the people. Moreover, such government spending has been empirically shown to support

poverty reduction programs (Food Affordability)[27], increase years of schooling (Food Adoption)[28], promote better health quality as proxied by the Human Development Index (HDI) (Food Adoption)[29], and reduce stunting prevalence within the village level (Food Adoption)[30, 31]. Second, the economic indicator is to influence Food Affordability and Food Adoption. A higher economic level generally leads to better community welfare[32] under fair income distribution. Furthermore, increasing population density intensifies food demand, which can threaten the Food Availability aspect if not adequately addressed. Last, as stated in the Introduction, rice—being the staple food in Indonesia—plays a key role in determining food availability. The treatment of rice production as an endogenous variable stems from its susceptibility to climate factors, which can affect both the quantity and quality of agricultural outputs.

Table 2. Operational variable definition.

Variable	Definition	Domain	Source
IKP	Composite indicator of Indonesian food security denoted in the index point	Food Security [Y]	National Food Agency (Bapanas)
GEem	Local government expenditure for government officials (wage) noted in billion Indonesia Rupiah (IDR)	Government Expenditure (GE) [X]	Ministry of Finance (MOF) of The Republic of Indonesia
GEgs	Local government budget for goods and services, represented in billion IDR	GE [X]	MOF
GEcap	Capital expenditure realization in billion IDR	GE [X]	MOF
GEot	Other expenditures budgeted from APBD (Local Revenue and Expenditure Budget) in billion IDR	GE [X]	MOF
Acc	Audit opinion from BPK that represent accountability quality of local budget management, ranged from Disclaimer (TMP) to Reasonable Without Exception (WTP)	GE [X]	The Audit Board of The Republic of Indonesia (BPK)
DD	Realization of Village Funds, aggregated into district-level, which delivered from the State Revenue and Expenditure budget in billion IDR	GE [X]	MOF
E	Constant valued Gross Domestic Regional Product (GDRB) in billion IDR which reflects the current economic level of certain regions.	Economy [X]	Central Bureau of Statistics (BPS)
Popden	Regional population density that occupied a certain area, denoted in headcount/km3	Economy [X]	BPS
Rice	Rice production in Ton	Economy [X]	BPS
Temp	Yearly-averaged temperature 2 meters from the ground in Celsius	Climate [Z]	Open-meteo
P	Total precipitation for a yearly period in mm	Climate [Z]	Open-meteo
Soil	Soil moisture indicator measurement, measured in m3/m3 units	Climate [Z]	Open-meteo
Ln_	Natural logarithm function		
i	District/city		
t	Year		

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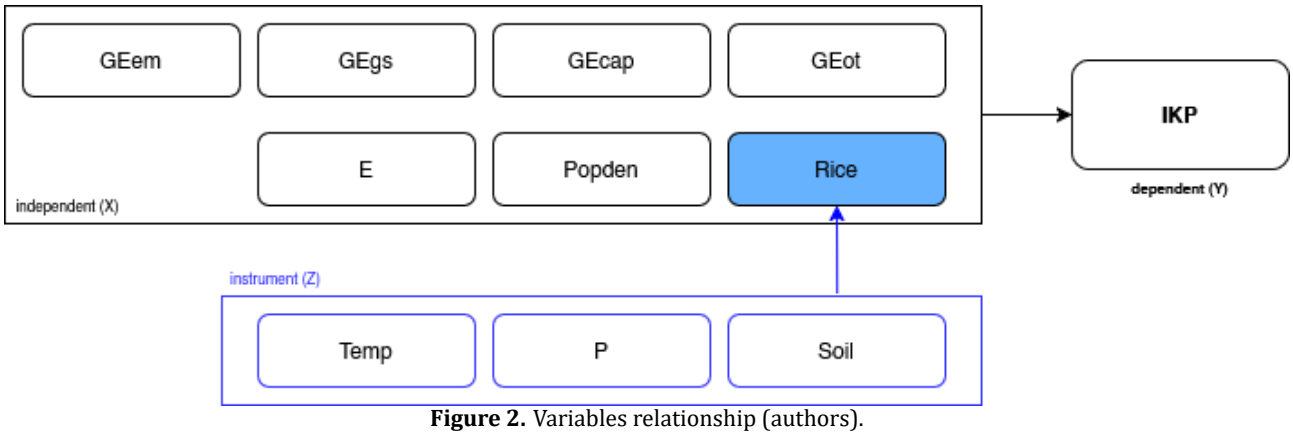

Figure 2. Variables relationship (authors).

2.2. Study Model

This study employed a quantitative approach using Instrumental Variable (IV) regression. The authors aimed to develop a more robust and precise model to address endogeneity issues[33] in identifying the determinants of food security in Central Sulawesi. Specifically, the analysis employed the Two-Stages Least Square (IV-2SLS) model, a method commonly used to ensure robustness and minimize bias[34, 35] in estimating the relationship between variables. IV-2SLS model was implemented using the linear model library in Python within Jupyter Lab. The empirical model was formulated as Equations (1) and (2):

$$\begin{aligned} ln\_IKP_{it} &= \beta_0 + \beta_1 ln\_GEem_{it} \\ &+\beta_2 ln\_GEgs_{it} + \beta_3 ln\_GEcap_{it-1} \\ &+\beta_4 ln\_GEot_{it} + \beta_5 Acc_{it-1} + \beta_6 ln\_DD_{it} \\ &+\beta_7 ln\_E_{it-1} + \beta_8 ln\_Popden_{it} \\ &+\beta_9 ln\_\widehat{Rice}_{it} \end{aligned} \quad (1)$$

$$\begin{aligned} ln\_\widehat{Rice}_{it} &= \beta_{10} ln\_Temp_{it} + \beta_{11} ln\_P_{it} \\ &+\beta_{12} Soil_{it} \end{aligned} \quad (2)$$

Where *IKP* represented Food Security Index, *GEem...GEot* denoted local government expenditure for each respective account, *Acc* referred to audit results from BPK, *DD* represented the village fund, *E* suggested constant GDRP, *Rice* indicated rice production while $\widehat{Rice}$ was the estimated rice production obtained using instrumental variables as defined in Equation (2). *Temp* corresponded to the yearly-averaged temperature, *P* represented precipitation, and *Soil* measures average soil moisture quality. β_0 denoted the constant variable, while $\beta_1 ... \beta_{12}$ were the coefficients or weights of the respective variables. A detailed definition of each variable is provided in **Table 2** of the Data subsection for further elaboration.

The validity of instruments served as a critical assumption for conducting IV regression[36, 37]. Ullah et al.[36] explained that the Instrument validity test was based on endogeneity and causal identification, ensuring the instruments affect the endogen variable (Z→X→Y). In this study, endogeneity testing for *Rice* was conducted using Wooldridge Regression to confirm whether IV regression was necessary. When no endogeneity (omitted variable) problem was detected, an Ordinary Least Square (OLS) would suffice to provide an unbiased estimator[36]. Additionally, the overidentification test was used to ensure the instrument's validity through the Sargan test[38]. To further strengthen the analysis, this study also incorporated classical assumption tests, such as the Multicollinearity Test and a robust Heteroscedasticity covariance estimator embedded in the IV-2SLS model.

Furthermore, descriptive or explanatory analysis of the data was used in the later section to enrich the context and provide deeper insights into the phenomena reflected in these results. Sarker[39] outlined that descriptive analysis was an essential approach in emphasizing "what has occurred," thereby effectively showcasing underlying patterns. By connecting the results with explanatory analysis, a more comprehensive and nuanced insight can be observed more clearly.

3. Results

3.1. Empirical Model Findings

Using the IV-2SLS estimator, this study examined the determinants of IKP in Central Sulawesi, providing a robust analysis that addressed potential endogeneity concerns. The study model incorporated a comprehensive set of variables across multiple domains, including government fiscal intervention, economic factors, and climate variability indicators.

Table 3. IV-2SLS regression result.

Dep. Variable	IKP	R-squared	0.8251
Estimator	IV-2SLS	Adj. R-squared	0.8020
Cov. Estimator	Robust	F-statistic	1069.4
No. Observations	78	P-value (F-Stat)	0.0000

Parameter Estimates

	Parameter	Std. Err.	T-Stat	P-Value	Lower CI	Upper CI
Constant	4.5350	0.3386	13.392	0.0000	3.8713	5.1987
GEem_t	−0.0579	0.0627	−0.9236	0.3557	−0.1807	0.0650
GEgs_t**	0.0807	0.0332	2.4328	0.0150	0.0157	0.1456
GEcap_t-1	−0.0109	0.0221	−0.4913	0.6232	−0.0541	0.0323
GEot_t	−0.0120	0.0131	−0.9132	0.3611	−0.0377	0.0137
Acc_t-1	0.0211	0.0134	1.5737	0.1156	−0.0052	0.0474
DD***	−0.0825	0.0094	−8.8228	0.0000	−0.1008	−0.0642
E_t-1	−0.0158	0.0149	−1.0592	0.2895	−0.0450	0.0134
Popden***	−0.0550	0.0110	−4.9836	0.0000	−0.0767	−0.0334
Rice***	0.0513	0.0064	8.0348	0.0000	0.0388	0.0638

Endogenous: *Rice*
Instruments: *Temp, P, Soil*
Robust Covariance (Heteroskedastic)
Debiased: False

Source. Data Analysis with Jupyter Lab. ***p-value < 0,01; ** p-value < 0,05; *p-value < 0,10.

As shown in **Table 3**, IV-2SLS regression was conducted using 78 observable data points. The model achieved an R-squared value of 82.51%, which was considered highly acceptable in the absence of multicollinearity among the independent variables[40]. Furthermore, the significance level of less than 5% outlined the reliability and validity of the estimated values. The following mathematical equation could represent the key determinants of IKP in Central Sulawesi based on IV-2SLS estimation:

$$\begin{aligned} ln\_IKP_t &= 4.5350 - 0.0579\, ln\_GEem_t \\ &+0.0807\, ln\_GEgs_t - 0.0109\, ln\_GEcap_{t-1} \\ &-0.0120\, ln\_GEot_t + 0.0211\, Acc_{t-1} \\ &-0.0825\, ln\_DD_t - 0.0158\, ln\_E_{t-1} \\ &-0.0550\, ln\_Popden_t + 0.0513\, \widehat{ln\_Rice_t} \end{aligned} \quad (3)$$

The empirical model found that not all aspects or determinants exert a significant and positive influence on food security in Central Sulawesi. Based on the regression equation, the results were summarized as follows:

a. Default condition: In the absence of all other variables, the default IKP level was approximately 4.5350, as reflected by the constant value.
b. Government Expenditure on Employee wages (GEem) had a counterproductive effect, reducing IKP by approximately 0.0579 points for each additional unit of expenditure. This suggested inefficiency in employment-related government expenditures in improving community food security.
c. Government Expenditure on goods and services (GEgs) showed a positive coefficient of 0.0807. This implied that higher expenditure on goods and services contributed positively to food security.
d. The negative coefficient of -0.0109 for one-year-lagged capital expenditures (GEcap) suggested that these expenditures had a slight negative impact on IKP. This could indicate delayed or ineffective impacts of the local government infrastruc-

ture projects.

e. Other forms of government expenditure (GEot) exhibited a minimal negative impact with a coefficient of -0.0120, suggesting limited contributions to food security.
f. The one-year-lagged audit results (Acc) showed a positive impact on IKP with a coefficient of 0.0211. This suggested that improved accountability and effective local budget execution enhanced government performance in delivering successful programs.
g. *DD* indicated a negative impact on IKP of approximately -0.0825 points for each village fund realization, suggesting potential inefficiencies in this fund.
h. The past constant GDRP (E) had a minor negative impact on IKP with a coefficient of -0.0158, suggesting its limited influence on food security progress in Central Sulawesi.
i. The population density was identified as a counter-productive determinant for IKP progress. The negative coefficient of -0.0550 indicated that higher population density was associated with a decline in food security.
j. As an endogenous or instrumented variable, rice production became another primary contributor to food security in Central Sulawesi. The high positive coefficient emphasized its crucial role in maintaining IKP, resulting in an additional output of around 0.0513 points.

The coefficients mentioned were further discussed in the Discussion Sub-section, along with respective explanatory analyses of the data.

3.2. Model Validity Testing

The overall estimation confirmed the model's significant level in explaining the determinants of food security in Central Sulawesi. As stated earlier, the R-square value of 0.8251 indicates that approximately 82.51% of IKP variability is explained by the independent variables, while the remaining 17.49% is attributed to unobserved factors outside the model. Additionally, the p-value of the F-stats indicated model significance (p-val < 0.05) and confirmed its usability in this study [41].

Although the model showed overall significance, not all determinants were statistically significant in explaining IKP. This conclusion was supported by t-test results, which assessed the individual importance of each determinant on the dependent variable [42]. As shown in **Table 4**, four out of nine independent variables had a strong individual impact on the food security index in Central Sulawesi. This included government expenditure on goods and services, village funds, population density, and rice production. The variables were considered individually significant as the p-values fell below the 5% threshold.

Table 4. T-test or variable partial test result.

Variable	Coefficient	T-Statistic	P-Value
GEem_t	−0.0579	−0.9236	0.3557
GEgs_t**	0.0807	2.4328	0.0150
GEcap_t-1	−0.0109	−0.4913	0.6232
GEot_t	−0.0120	−0.9132	0.3611
Acc_t-1	0.0211	1.5737	0.1156
DD***	−0.0825	−8.8228	0.0000
E_t-1	−0.0158	−1.0592	0.2895
Popden***	−0.0550	−4.9836	0.0000
Rice***	0.0513	8.0348	0.0000

Source. Data Analysis with Jupyter Lab. ***p-value < 0,01; ** p-value < 0,05; *p-value < 0,10.

As emphasized by Azizah et al. [43] and Mahardini et al. [44], ensuring the absence of multicollinearity was crucial to maintaining estimation quality. Technically, variables highly affected by multicollinearity could introduce errors in the IV-2SLS regression process when using the linear model Python library. Priambodo et al. [45] used the Variance Inflation Factor (VIF) to conduct multicollinearity tests in the publication, applying a threshold value below

10 points. Following the approach, this study confirmed that all determinants of IKP in Central Sulawesi were free from multicollinearity problems, including the instrumental variables as observed in **Table 5**.

Table 5. VIF test result for multicollinearity detection.

Variable	VIF Value	Threshold	Status
GEem_t	5.807687	< 10	No Multicollinearity Detected
GEgs_t	8.801562	< 10	No Multicollinearity Detected
GEcap_t-1	1.801177	< 10	No Multicollinearity Detected
GEot_t	2.631355	< 10	No Multicollinearity Detected
Acc_t-1	1.254326	< 10	No Multicollinearity Detected
DD	7.211131	< 10	No Multicollinearity Detected
E_t-1	6.409191	< 10	No Multicollinearity Detected
Popden	4.738942	< 10	No Multicollinearity Detected
Rice	9.799574	< 10	No Multicollinearity Detected
Temp	2.642734	< 10	No Multicollinearity Detected
P	1.974303	< 10	No Multicollinearity Detected
Soil	5.546904	< 10	No Multicollinearity Detected

Source. Data analysis with Jupyter Lab.

In the IV regression context, the validity of the instrumental variables was tested using Wooldridge's Regression for endogeneity and the Sargan test for overidentification. Initially, the significant p-value of Wooldridge's Regression indicated that the null hypothesis (H0) was rejected, confirming the endogenous variables were not exogenous (**Table 6**). Consequently, the *Rice* variable was identified as an endogenous variable, justifying the need for instrumental variables. The overidentification test also showed the inability to reject H0, indicating that the model was not overidentified. The high p-value (0.9477) correlated with the recommendations of Kiviet et al.[38], showing that the current instruments were strongly valid, which further enhanced the robustness of IV-2SLS regression results.

Table 6. Instrumental variables validity results.

Endogeneity Test	Overidentification Test
Wooldridge's regression test of exogeneity	**Sargan's test of overidentification**
H0: Endogenous variables are exogenous	H0: The model is not overidentified
Statistic: 5.4407	Statistic: 0.1074
P-value: 0.0197	P-value: 0.9477
Distributed: chi2(1)	Distributed: chi2(2)

Source. Data analysis with Jupyter Lab.

4. Discussion

Before delving further into the discussion, it is essential to revisit the multidimensional aspects of food security, as outlined earlier in **Table 1**. Indonesian food security is represented by IKP, which comprises three primary dimensions, namely food availability, affordability, and adoption. Understanding these dimensions provides essential context for interpreting the current conditions and the results of this study.

4.1. Government Expenditure Effect on IKP

The results showed that only Government Expenditure on Goods and Services (GEgs) and the Village Fund possessed a significant effect on food security development in Central Sulawesi. Moreover, only GEgs have a positive impact on IKP. The role of government fiscal intervention remains a topic of debate within the scope of the respective study. Governments are expected to deliver adequate services to improve community welfare,

strengthen economic conditions, and address income inequality. For instance, Poku et al.[46] argued that public expenditure could benefit Ghana's economic growth in the short run. Similarly, Kusuma et al.[47] observed that local government expenditure on health programs had a positive impact in leveraging the community welfare in Pati Residency, Jawa Tengah. However, the publication also asserted that educational and social assistance expenditure possessed no meaningful effect on improving human development quality. In another study conducted at the district/city level in Indonesia, Khairunnisa et al.[48] reached two primary conclusions, namely (a) local government expenditure had no significant effect on poverty alleviation, and (2) only the local education budget has a significant impact, but positively increasing the income inequality. Additionally, government accountability is identified as an impactful indicator[49, 50] in determining the effectiveness of government services.

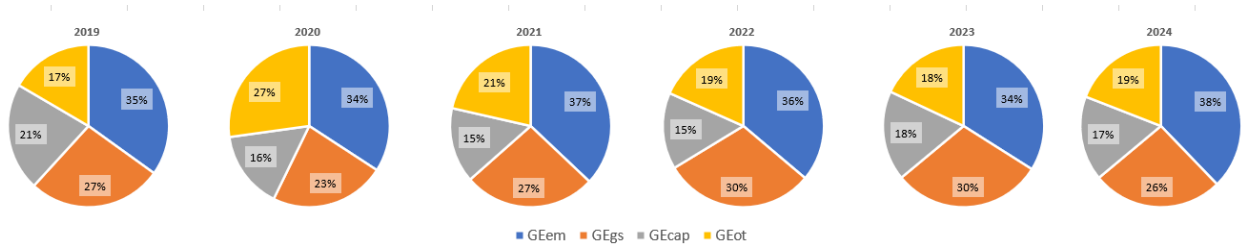

Figure 3. Local government expenditure distributions by accounts (MOF, compiled by authors).

In Central Sulawesi, the results can be related to the distribution of local government expenditure, as shown in **Figure 3**. The local government budget is primarily allocated to the wages of government officials, consistently absorbing more than 30% of the total budget. This allocation has increased over the years, reaching 38% in 2024. The focus on employee expenses further limits the resources available for food security programs.

Food affordability, which is a dimension influenced by poverty levels and household food expenditure, is unlikely to improve significantly under this expenditure pattern. Furthermore, spending classified under "Other Government Expenditure" (yellow segment) ranged from 17% to 27%, outlining additional fiscal burdens that further constrain impactful interventions. Although expenditure on goods and services (orange segment) has maintained a steady share of 26% to 30% in recent years, its capacity to enhance food security depends on the specific programs funded under this category. The allocation of goods provided to the community also has a direct impact on improving community welfare.

The relatively low allocation for local infrastructure expenditure, ranging from Rp 2.37 trillion to Rp 3.44 trillion, contributes to the lack of significance in addressing food security challenges. In the food security context, inadequate infrastructure expenditure can worsen the current situation when capital projects primarily support large economic sectors (e.g. downstream industry and mining) while having minimal impact on underprivileged communities and food-supporting sectors (e.g., agriculture).

Table 7. Village funds yearly realization (in Billion IDR).

	2019	2020	2021	2022	2023	2024
Dana Desa	1564,36	1589,46	1592,47	1476,94	1561,06	1568,81
Villages Count	2020	2020	2020	2020	2020	2020
Average Village Fund	0,77	0,79	0,79	0,73	0,77	0,78

Source: MOF.

The significant negative impact of the village fund contradicted Raharjo[51], who stated that the village fund was intended for village development and empowerment. Similarly, it does not correlate with the results

of Hardianto [52], which outlines improvements in local community welfare and poverty reduction due to the village fund.

In food affordability and adoption dimensions, the results of the village fund in Central Sulawesi can be attributed to two main factors. First, the relatively low allocation of the village fund as observed in **Table 7**, amounting to only Rp0.78 billion per village in 2024, is insufficient to address the complex food security challenges. These challenges include poverty alleviation, improving household access to electricity and water, enhancing the effectiveness of schooling programs, and tackling issues such as stunting prevention. Second, the current policy does not adequately design the village fund to address these complex problems. As Hardianto [52] explained, the authority of village governments was limited, restricting the usage of the village fund despite the promoted priority programs by the Ministry of Villages, Development of Disadvantaged Regions, and Transmigration. Furthermore, the earmarked design for the village fund is only recently enacted through the Regulation of the Ministry of Finance Number 145/2023 for the 2024 fiscal year. This regulation aims to enhance the fund's effectiveness in supporting national priority programs, but the impact on addressing food security challenges remains to be seen.

Limited local budgets, combined with this allocation pattern, restrict the implementation of effective strategies to address food affordability and strengthen other dimensions of food security, such as food availability and adoption. Both local and central governments need to advocate rational budget allocation and increase local revenue [53] to finance upcoming strategic programs.

4.2. Demographic and Economic Challenges on Food Security and Rice Productivity

Food security progress in Central Sulawesi faces significant challenges posed by demographic and economic conditions, as evidenced by the negative impact of population density and GDRP. A study by Cahyono et al. [54] outlined the higher vulnerability of larger populations, particularly at the household level. On the other dimension, the primary concern of GDRP or economic growth lies in the limited trickle-down effect on income distribution. As asserted by Tasyim et al. [55] and Arfa et al. [56], economic growth did not immediately lead to improvements in public welfare, such as poverty reduction or increased employment opportunities.

Economic growth in Central Sulawesi has not significantly improved the quality of life, particularly in terms of increasing yearly per capita expenditure. Over the past decade, GDRP has consistently grown, ranging from 4.86% (year-on-year/yoy) to as high as 20.6% (yoy) even during the challenging COVID-19 period. However, adjusted per capita expenditure has only grown by approximately 1-3 percentage points annually in comparison, reaching Rp10.5 billion in 2024.

Additionally, data from BPS indicates that economic growth has been concentrated mainly in the nickel downstream industrial zones, specifically in Morowali and North Morowali Districts. These results underscore the limited trickle-down effect of economic development to other regions and sectors. The dimensions of food affordability and adoption are unlikely to perceive significant improvement with minimal trickle-down effect on household purchasing power, validating the insignificant economic impact on IKP.

The rising population may also threaten food availability and drive up food costs due to increased scarcity. A comprehensive study by Giller et al. [57] found that densely populated areas faced similar levels of food insecurity and poverty. It is argued that without a sufficient income, households are more inclined to experience food insufficiency. Moreover, the growing population density poses a risk to environmental conditions [58], which may threaten agricultural productivity.

As projected by BPS in **Figure 4**, this situation has the potential to increase food insecurity among households. Considering the average rice consumption per capita, the forecasted population growth is expected to significantly increase food demand, particularly for rice, as it is the primary food commodity. By holding the average rice consumption constant from 2019 to 2024 for the upcoming years, it is estimated that total rice demand will reach a minimum of 290,465 tons by 2030, as shown in **Figure 5**.

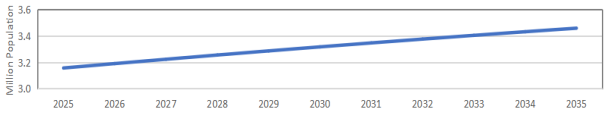

Figure 4. Population growth forcast (BPS).

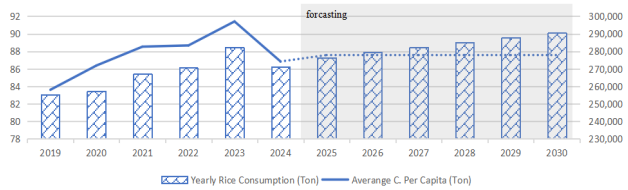

Figure 5. Yearly rice consumption in Central Sulawesi and upcoming rice need (BPS, further analyzed by authors).

The challenges posed by the rising populations can be addressed through sufficient local production. The results indicate that, rice as an instrumental variable, has played a significant role in advancing food security. This claim is supported by the current rice production data for Central Sulawesi, as shown in **Figure 6**. Between 2019 and 2024, local rice production consistently exceeded 400,000 tons, ensuring food availability to meet the population's demands. However, the variability of Central Sulawesi's rice productivity needs to be recognized in future governmental programs to address potential gaps in productivity, maintain long-term food security, and anticipate climate change dynamics.

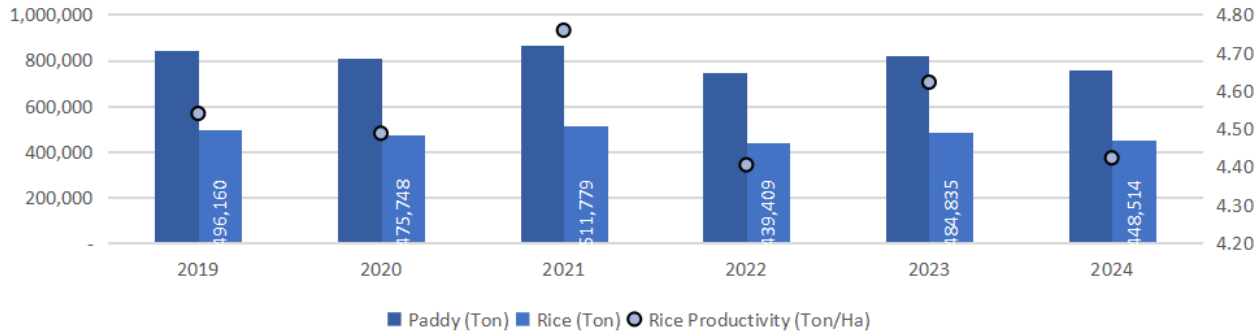

Figure 6. Recent rice production in Central Sulawesi (BPS, Compiled by authors).

Addressing the results requires collaborative strategies that engage multiple stakeholders. These strategies should encompass not only local and central government efforts but also active participation from community groups, the private sector, and international organizations. A unified approach is essential to tackle the interconnected challenges of food security, such as improving agricultural productivity, enhancing household income, and ensuring the quality of food adoption. By fostering partnerships and connecting resources toward targeted interventions, Central Sulawesi can build a resilient food security framework that proposes long-term solutions benefiting all levels of society.

4.3. Additional Discussion on Climate-Affected Rice Production

Many recent studies have outlined current climate variability and the future challenges to food security. Extreme temperatures are widely recognized as a threat to the agricultural sector[59]. Furthermore, declining soil quality, increased weed growth, and volatile rainfall patterns pose significant problems for plantation quality[60]. During the climate challenges, Azadi et al.[61] proposed Vulnerable-Smart Agriculture practices to address the food security approach. In this study, rice production is instrumented using climate data, including average temperature, precipitation, and soil moisture. As previously discussed, this approach addresses the existing endogeneity problem and captures the regional climate conditions that influence the primary food commodity. Through the IV-2SLS model, the *Rice* variable shows a significant positive impact on food security development in Central Sulawesi. Although the underlying factors contributing to the effect have been discussed earlier, it is also essential to examine how the instrumental variables influence the endogenous variable.

Table 8. First-stage result of IV-2SLS.

Endogenous	**Rice**
R-squared	0.8980
Partial R-squared	0.4847
Partial F-statistic	0.4847
P-value (Partial F-statistic)	0.0000
Temp [Temperature]	−2.5202 (−1.3267)
P [Precipitation]	−1.0785 (−1.3481)
Soil [Soil Moisture]	14.268 (7.9406)
T-stats reported in parentheses (t-stat)	
T-stats use the same covariance type as the original model	

Source. Data analysis with Jupyter Lab.

Using the first-stage regression results from the IV-2SLS model, this study shows that current rice production is highly correlated with the climate instruments. R-squared, Partial R-squared, Shea's R-squared, and F-statistics probability values confirm that the instruments are not weak[62]. The results suggest that soil moisture plays a primary role in increasing rice production, while temperature and precipitation pose potential threats to rice output. For clarity, the first-stage regression results are presented in **Table 8**.

As previously analyzed by Famiono et al.[63] in the Regional Fiscal Study (KFR) of Central Sulawesi Province for the Second Quarter of 2024, the region has experienced an ongoing temperature increase of approximately 1.2°C over the past decade. Moreover, the analysis of open-meteo data, as outlined in KFR, identifies a decline in rainfall events in the Central Sulawesi region, with the ratio decreasing from 46.39% (4,074.7 hours) in 2020 to 34.8% (3,046.5 hours) in 2023. This study supports the challenges posed by the instrumental variables.

5. Conclusion

In conclusion, food security in Central Sulawesi, as measured by IKP, comprises multidimensional aspects that ideally should benefit from economic growth and government expenditure. However, by analyzing district-level data from 2019 to 2024, the IV-2SLS model identified four out of nine variables as statistically significant determinants of food security in Central Sulawesi. The variables included government expenditure on goods and services, village funds, population density, and rice production. Among these, only local government expenditure on goods and services, as well as rice production, showed a positive impact on food security, contributing approximately 0.0807 and 0.0513 points, respectively, for each additional realization. Furthermore, the rising population density hindered progress in food security, reducing the IKP by -0.055 points. The village fund exhibited a contradictory impact on Central Sulawesi's IKP, despite being a fiscal tool.

Moreover, the ineffective government expenditures, non-inclusive economic growth, and a rising population posed challenges to the future food security of Central Sulawesi. Although rice production satisfies the demand, mitigation strategies should be implemented to address potential risks from future climate volatility affecting agricultural output. Based on the results, the following policy recommendations were proposed to enhance food security in Central Sulawesi.

a. In budget constraints, the government should ensure efficient expenditure and effective program implementation. For example, investing in connectivity infrastructure to support agricultural areas could enhance productivity and lower distribution costs.
b. Strengthen social protection mechanisms by effectively expanding direct cash assistance, food subsidies, and employment-based social programs to ensure vulnerable households possess access to adequate nutrition.
c. Promoting labor-intensive job opportunities aimed to increase local household incomes, thereby improving access to adequate food consumption.

d. Establishing clear and rational authority for each level of government concerning national priority programs was necessary. Food security responsibilities should also be appropriately distributed based on each government level's fiscal capacity, administrative authority, and program execution capabilities.
e. At the local government level, reallocating the government budget toward expenditures on goods and services, including agricultural inputs, extension services, irrigation maintenance, food distribution systems, and community nutrition programs, significantly enhanced food security outcomes. This shift in expenditure priorities directly supported farmers' productivity, improved access to essential food items, and strengthened the capacity of local institutions to address food security challenges.

6. Limitations

In conducting this study, the authors intentionally limited the scope of local government expenditure data to maintain propriety. It was widely recognized that the respective regional governments had incorporated inputs from academics, the central government, and other stakeholders into their policy-making processes. However, recognizing the inherent limitations in the execution of governmental interventions was equally important. For example, while reducing the number of government officials could alleviate the budget burden, such actions would be impractical and lead to broader social and administrative challenges. These constraints outlined the complexity of balancing fiscal efficiency with effective governance and emphasized the need for innovative solutions to optimize resource allocation without compromising essential services or social stability.

Several avenues remained open for future investigation. A broader analysis across multiple regions, along with more detailed accounts of government budgets, could reveal patterns in government spending that most effectively support food security outcomes. Additionally, incorporating household-level welfare data could provide a more granular understanding of how government programs affect food affordability and adoption. The use of geospatial and remote sensing data could also strengthen the analysis of how infrastructure development, such as roads and irrigation systems, contributes to long-term food security resilience.

Author Contributions

Conceptualization, A.P.P. and M.A.D.; methodology, A.P.P.; software, A.P.P.; validation, A.P.P. and M.A.D.; formal analysis, A.P.P. and M.A.D.; investigation, A.P.P.; resources, A.P.P.; data curation, A.P.P.; writing-original draft preparation, A.P.P.; writing-review and editing, A.P.P. and M.A.D.; visualization, A.P.P.; supervision, A.P.P.; project administration, A.P.P. and M.A.D.; funding acquisition, A.P.P. and M.A.D. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

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Conflicts of Interest

The authors declare that they have no conflict of interest.

References

[1] Sumsion, R.M., June, H.M., Cope, M.R., 2023. Measuring food insecurity: the problem with semantics. Foods 12(9), 1816. DOI: https://doi.org/10.3390/foods12091816

[2] Yudha, A.T.R.C., Setiani, S.Y., Huda, N., Maksum, Sugiyanto, 2023. The existence of the younger generation in maintaining food security for sustainable development: A study in Kadungrembug Village, Sidoarjo Regency [in Indonesian]. Journal of Economics Development Issues 6(2), 106–116. DOI: https://doi.org/10.33005/jedi.v6i2.157

[3] Nugraha, A.T., Fikriyah, F., Hidayana, I.I., Najid, S.A., Prayitno, G., 2023. The relationship between social capital, human capital, and the level of welfare of farmers in Ponorogo, Indonesia. Khazanah Sosial 5(3), 453–467. DOI: https://doi.org/10.15575/ks.v5i3.28736

[4] Rhofita, E.I.R., 2022. Optimizing Indonesia's agricultural resources to support national food and energy security programs [in Indonesian]. Jurnal Ketahanan Nasional 28(1), 82. DOI: https://doi.org/10.22146/jkn.71642

[5] Ainistikmalia, N., Kharisma, B., Budiono, B., 2022. Analysis of multidimensional poverty and food security in North Kalimantan Province [in Indonesian]. Jurnal Ekonomi dan Pembangunan Indonesia 22(1), 72–97. DOI: https://doi.org/10.21002/jepi.2022.05

[6] Badan Pangan Nasional, 2024. Food security index 2023 [in Indonesian]. Badan Pangan Nasional: Jakarta Selatan, DKI Jakarta. Available from: https://satudata.badanpangan.go.id/statisticpublications/pm

[7] Suryana, A., 2014. Towards sustainable Indonesian food security 2025: Challenges and their solutions [in Indonesian]. Forum Penelitian Agro Ekonomi 32(2), 123–135.

[8] Godde, C.M., Mason-D'Croz, D., Mayberry, D.E., et al., 2021. Impacts of climate change on the livestock food supply chain: A review of the evidence. Global Food Security 28, 100488. DOI: https://doi.org/10.1016/j.gfs.2020.100488

[9] Toromade, A.S., Soyombo, D.A., Kupa, E., Ijomah, T.I., 2024. Reviewing the impact of climate change on global food security: Challenges and solutions. International Journal of Applied Research in Social Sciences 6(7), 1403–1416. DOI: https://doi.org/10.51594/ijarss.v6i7.1300

[10] Maria, B., Roy, N.D., Siska, E., et al., 2023. Exploring the dynamics of food prices and farmer's terms of trade: Reflecting on the welfare of Indonesian farmers. Eurasia: Economics and Business 12(78), 81–90. DOI: https://doi.org/10.18551/econeurasia.2023-12

[11] Megavitry, R., Harsono, I., Widodo, I., et al., 2024. Measuring the effectiveness of food information systems and the affordability of healthy food towards food security in Indonesia [in Indonesian]. Jurnal Multidisiplin West Science 3(03), 334–343. DOI: https://doi.org/10.58812/jmws.v3i03.1058

[12] Pujiati, S., Pertiwi, A., Silfia, C.C., et al., 2020. Analysis of availability, affordability and utilization of food in supporting the achievement of community food security in Central Java Province [in Indonesian]. Jurnal Sosial Ekonomi Pertanian 16(2), 123. DOI: https://doi.org/10.20956/jsep.v16i2.10493

[13] Arestis, P., Şen, H., Kaya, A., 2021. On the linkage between government expenditure and output: Empirics of the Keynesian view versus Wagner's law. Economic Change and Restructuring 54(2), 265–303. DOI: https://doi.org/10.1007/s10644-020-09284-7

[14] Akhmad, A., Amir, A., Saleh, S., et al., 2022. Effectiveness of regional government expenditure in reducing unemployment and poverty rate. European Journal of Development Studies 2(4), 90–99. DOI: https://doi.org/10.24018/ejdevelop.2022.2.4.129

[15] Tran, T.P.K., Tran, N.P., Van Nguyen, P., et al., 2024. Government expenditure–shadow economy nexus: The role of fiscal deficit. International Journal of Emerging Markets 19(2), 322–338. DOI: https://doi.org/10.1108/IJOEM-12-2021-1934

[16] Khan, I., Tan, D., Hassan, S.T., et al., 2022. Role of alternative and nuclear energy in stimulating environmental sustainability: Impact of government expenditures. Environmental Science and Pollution Research. 29(25), 37894–37905. DOI: https://doi.org/10.1007/s11356-021-18306-4

[17] Elzubair, A., Murad, A.A., 2024. The role of infor-

mal cooperation to improve the agricultural practices: Case of El-Nafir in South Kordofan State, Sudan. The Journal of Indonesia Sustainable Development Planning. 5(2), 101–116. DOI: https://doi.org/10.46456/jisdep.v5i2.557

[18] Fajri, M.N., Munawaroh, S., 2023. Exploring sustainable economic growth: Promoting green development productivity through decentralized environmental policy and regional competitiveness. The Journal of Indonesia Sustainable Development Planning. 4(3), 246–262. DOI: https://doi.org/10.46456/jisdep.v4i3.422

[19] Wang, X., 2022. Managing land carrying capacity: Key to achieving sustainable production systems for food security. Land. 11(4), 484. DOI: https://doi.org/10.3390/land11040484

[20] Hu, Y., Liu, C., Peng, J., 2021. Financial inclusion and agricultural total factor productivity growth in China. Economic Modelling. 96, 68–82. DOI: https://doi.org/10.1016/j.econmod.2020.12.021

[21] BPS of Central Sulawesi, 2025. Berita Resmi Statistik No. 18/03/72/Th. XXVIII. Badan Pusat Statistik Kota Palu: Sulawesi, Indonesia.

[22] Meliala, E.S., Djamaluddin, S., 2024. The effect of special allocation fund for agriculture on food security in Indonesia. Jurnal Bina Praja. 16(2), 251–260. DOI: https://doi.org/10.21787/jbp.16.2024.251-260

[23] Farooq, M.S., Uzair, M., Raza, A., et al., 2022. Uncovering the research gaps to alleviate the negative impacts of climate change on food security: A review. Frontiers in Plant Science. 13, 927535. DOI: https://doi.org/10.3389/fpls.2022.927535

[24] Molotoks, A., Smith, P., Dawson, T.P., 2021. Impacts of land use, population, and climate change on global food security. Food and Energy Security. 10(1), e261. DOI: https://doi.org/10.1002/fes3.261

[25] Ansari, A., Lin, Y.P., Lur, H.S., 2021. Evaluating and adapting climate change impacts on rice production in Indonesia: A case study of the Keduang Subwatershed, Central Java. Environments. 8(11), 117. DOI: https://doi.org/10.3390/environments8110117

[26] Setiadi, Y.K.A., Nugroho, B.D.A., Maftukhah, R., 2022. Soil moisture monitoring to determine irrigation water supply. Proceedings of the 2nd International Conference on Smart and Innovative Agriculture (ICoSIA 2021); November 3–4, 2021; Yogyakarta, Indonesia. DOI: https://doi.org/10.2991/absr.k.220305.052

[27] Choir, Z., Hapsari, M.T., 2023. The influence of unemployment rate, education level and government spending on poverty in Gerbangkertasusila 2015–2022 [in Indonesian]. Jurnal Mirai Management. 8(2), 94–105.

[28] Miranda-Lescano, R., Muinelo-Gallo, L., Roca-Sagales, O., 2024. Human development and inequalities: The importance of social public spending. Structural Change and Economic Dynamics. 69, 363–377. DOI: https://doi.org/10.1016/j.strueco.2023.12.008

[29] Nurvita, D., Rohima, S., Bashir, A., et al., 2022. The role of public spending on education, health, and economic growth toward human development index in the local economy. Sriwijaya International Journal of Dynamic Economics and Business. 6(2), 197–210. DOI: https://doi.org/10.29259/sijdeb.v6i2.197-210

[30] Anggreani, R.D., Margawati, A., Nurjazuli, N., 2021. Evaluation of stunting handling through village funds during the Covid-19 pandemic using the systematic review method [in Indonesian]. Jurnal Ilmiah Kesehatan. 14(2), 139–151. DOI: https://doi.org/10.48144/jiks.v14i2.571

[31] Ardella, S., Ariyanto, E., 2025. The effectiveness of the use of village funds through village programs on the prevalence of stunting in Pesisir Selatan Regency [in Indonesian]. Jurnal Ilmiah Manajemen, Ekonomi, & Akuntansi. 9(1), 1514–1521. DOI: https://doi.org/10.31955/mea.v9i1.5227

[32] Neumann, T., 2021. The impact of entrepreneurship on economic, social and environmental welfare and its determinants: A systematic review. Management Review Quarterly. 71, 553–584. DOI: https://doi.org/10.1007/s11301-020-00193-7

[33] Ajayi, T.A., 2024. Natural gas rents and institutions as co-growth drivers: evidence from Gas Exporting Countries Forum with a panel 2SLS approach. International Journal of Energy Sector Management. 18(3), 474–499. DOI: https://doi.org/10.1108/IJESM-01-2023-0015

[34] Paul, S.C., Rosid, M.D., Xuefeng, Z., et al., 2021. The macroeconomic determinants of cross-country FDI flows: A comparative analysis through the Driscoll–Kraay, 2SLS and GMM models. Asian Economic and Financial Review. 11(2), 129–140. DOI: https://doi.org/10.18488/journal.aefr.2021.112.129.140

[35] ul Ain, Q., Awan, A., Bashir, F., 2024. Analyzing the intricate nexus of ecological footprint, urbanization & economic growth in South Asia: A panel 2SLS analysis. iRASD Journal of Economics. 6(2), 598–619. DOI: https://doi.org/10.52131/joe.2024.0602.0226

[36] Ullah, S., Zaefarian, G., Ullah, F., 2021. How to use instrumental variables in addressing endogeneity? A step-by-step procedure for non-specialists. Industrial Marketing Management. 96, A1–A6. DOI: https://doi.org/10.1016/j.indmarman.2020.03.006

[37] Lousdal, M.L., 2018. An introduction to instrumental variable assumptions, validation and estimation. Emerging Themes in Epidemiology. 15(1), 1. DOI: https://doi.org/10.1186/s12982-018-0069-7

[38] Kiviet, J.F., Kripfganz, S., 2021. Instrument approval by the Sargan test and its consequences for coefficient estimation. Economics Letters. 205, 109935. DOI: https://doi.org/10.1016/j.econlet.2021.109935

[39] Sarker, I.H., 2021. Data science and analytics: an overview from data-driven smart computing, decision-making and applications perspective. SN Computer Science. 2(5), 377. DOI: https://doi.org/10.1007/s42979-021-00765-8

[40] Ozili, P.K., 2023. The acceptable R-square in empirical modelling for social science research. In: Saliya, C.A. (ed.). Social Research Methodology and Publishing Results: A Guide to Non-native English Speakers. IGI Global: Hershey, PA, USA. pp. 134–143. DOI: 10.4018/978-1-6684-6859-3.ch009

[41] Faridatussalam, S.R., Wahyuningrum, D., 2021. Analysis of determinants of regional expenditure in districts/cities in East Java in the era of fiscal decentralization [in Indonesian]. Proceedings of the 13th University Research Colloquium 2021: Sosial, Ekonomi, dan Psikologi; May 27, 2021; East Java, Indonesia. pp. 40–48

[42] Priambodo, A.P., 2024. Quantifying government support for MSMEs: Case studies at the provincial level in Indonesia 2019–2023 [in Indonesian]. Proceedings of The Management Business Innovation Conference (MBIC) 2024; December 7, 2024; Kalimantan Barat, Indonesia. pp. 580–592

[43] Azizah, I.N., Arum, P.R., Wasono, R., 2021. The best model of multicollinearity test for analysis of factors influencing rice production in Blora Regency in 2020 [in Indonesian]. Proceedings of The Seminar Nasional UNIMUS; October 20, 2020; Semarang, Indonesia.

[44] Mahardini, S., Singal, V.G., Hidayat, M., 2023. The influence of content marketing and influencer marketing on purchasing decisions of Tik-Tok application users in the DKI Jakarta area [in Indonesian]. Ikraith-Ekonomika. 6(1), 180–187

[45] Priambodo, A.P., Hidayat, N.W., 2024. The influence of PAD, DAU, DBH, and capital expenditure on GRDP and poverty in Sidoarjo Regency [in Indonesian]. Jurnal Manajemen Keuangan Publik. 8(1), 1–14. DOI: https://doi.org/10.31092/jmkp.v8i1.2279

[46] Poku, K., Opoku, E., Ennin, P.A., 2022. The influence of government expenditure on economic growth in Ghana: An ARDL approach. Cogent Economics & Finance. 10(1), 2160036. DOI: https://doi.org/10.1080/23322039.2022.2160036

[47] Kusuma, A.P., Arif, M., 2022. An analysis of the effectiveness of local government expenditure allocations in education, health, social assistance, and per capita income on the Human Development Index in the Pati Residency. Proceeding of The International Conference on Economics and Business Studies (ICOEBS 2022); January 15, 2022; Surakarta, Indonesia. DOI: https://doi.org/10.2991/aebmr.k.220602.021

[48] Khairunnisa, R., Imansyah, M.H., Rahayu, D., 2021. The impact of government spending on education, health and infrastructure sectors [in Indonesian]. Syntax Idea. 3(12), 2748–2757. DOI: https://doi.org/10.46799/syntax-idea.v3i12.1678

[49] Maharani, D.A., Arofah, A.A., 2021. Determination of regional government characteristics towards BPK opinion [in Indonesian]. Jurnal Akuntansi Keuangan dan Bisnis. 14(1), 113–122. DOI: https://doi.org/10.35143/jakb.v14i1.4562

[50] Iskandar, A., 2021. Decentralization and efficiency of educational function spending and its implications for community welfare in South Sulawesi Province [in Indonesian]. Info Artha. 5(1), 11–24. DOI: https://doi.org/10.31092/jia.v5i2.1139

[51] Raharjo, M.M., 2020. Village fund management [in Indonesian]. PT Bumi Aksara: Jakarta Timur, Indonesia.

[52] Hardianto, H., 2022. Determination of community empowerment and eradication of village poverty: Analysis of village funds and allocation of village funds (literature review of financial management) [in Indonesian]. Jurnal Manajemen Pendidikan dan Ilmu Sosial. 3(1), 266–275. DOI: https://doi.org/10.38035/jmpis.v3i1.872

[53] Sari, R.K., Woestho, C., Handayani, M., 2021. Analisis kemampuan keuangan daerah pada daerah tertinggal di Provinsi Sulawesi Tengah. Jurnal Kajian Ilmiah. 21(1), 45–54. DOI: https://doi.org/10.31599/jki.v21i1.324

[54] Cahyono, T.W., Tokuda, H., 2024. Sociodemographic factors and policy implications for improved food security. The Journal of Indonesia Sustainable Development Planning. 5(1), 1–14. DOI: https://doi.org/10.46456/jisdep.v5i1.495

[55] Tasyim, D.A.R.S., Kawung, G.M.V., Dj. Siwu, H.F., 2021. The influence of the number of MSME business units and GRDP on labor absorption in North Sulawesi [in Indonesian]. Jurnal EMBA: Jurnal Riset Ekonomi, Manajemen, Bisnis dan Akuntansi. 9(3), 391–400. DOI: https://doi.org/10.35794/emba.v9i3.34740

[56] Arfa, V.K., Bhinadi, A., Syari'udin, A., 2022. The influence of GRDP, life expectancy, and average length of schooling on poverty in districts/cities

in Central Java Province 2013–2021 [in Indonesian]. SIBATIK JOURNAL: Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya, Teknologi, dan Pendidikan. 1(12), 2959–2968. DOI: https://doi.org/10.54443/sibatik.v1i12.482

[57] Giller, K.E., Delaune, T., Silva, J.V., et al., 2021. Small farms and development in Sub-Saharan Africa: Farming for food, for income or for lack of better options? Food Security. 13(6), 1431–1454. DOI: https://doi.org/10.1007/s12571-021-01209-0

[58] Wafiq, A.N., Suryanto, S., 2021. The impact of population density and economic growth on environmental quality: Study in Indonesia. Jurnal Ekonomi & Studi Pembangunan. 22(2), 301–312. DOI: https://doi.org/10.18196/jesp.v22i2.10533

[59] Parolini, G., 2022. Weather, climate, and agriculture: Historical contributions and perspectives from agricultural meteorology. WIREs Climate Change. 13(3), e766. DOI: https://doi.org/10.1002/wcc.766

[60] Shahzad, A., Ullah, S., Dar, A.A., et al., 2021. Nexus on climate change: Agriculture and possible solution to cope future climate change stresses. Environmental Science and Pollution Research. 28(12), 14211–14232. DOI: https://doi.org/10.1007/s11356-021-12649-8

[61] Azadi, H., Moghaddam, S.M., Burkart, S., et al., 2021. Rethinking resilient agriculture: From climate-smart agriculture to vulnerable-smart agriculture. Journal of Cleaner Production. 319, 128602. DOI: https://doi.org/10.1016/j.jclepro.2021.128602

[62] Drichoutis, A.C., Lazaridis, P., Nayga, R., 2009. Body weight outcomes and food expenditures among older Europeans: A simultaneous equation approach. Proceedings of the 113th EAAE Seminar "A resilient European food industry and food chain in a challenging world"; September 3–6, 2009; Crete, Greece. pp. 1–18. DOI: https://doi.org/10.22004/ag.econ.58010

[63] Famiono, H., Meygautama, H., Priambodo, A.P., et al., 2024. Regional fiscal study of Central Sulawesi Province, second quarter of 2024 [in Indonesian]. Palu: Kantor Wilayah Direktorat Jenderal Perbendaharaan Provinsi Sulawesi Tengah. Available from: https://djpb.kemenkeu.go.id/kanwil/sulteng/id/data-publikasi/publikasi-djpb-sulteng/kfr/2906-kajian-fiskal-regional-triwulan-ii-tahun-2024.html (cited 29 January 2025)