Simpson index and food security: The case study of Kalimantan

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Abstract

Dietary diversity is a reliable indicator of food security. This study examines diversity in consumption through the Simpson Index using the food expenditure approach at the regency and city levels in Indonesia, with a particular focus on Kalimantan, the location of the new capital city, Nusantara. Further analysis explores the relationship between dietary diversity and food inflation, a key aspect of food security. The data used to develop the index is drawn from the National Socio-Economic Survey (SUSENAS) conducted by Statistics Indonesia from 2020 to 2023. Food inflation modeling was performed using the Threshold Panel Regression method on data from 90 cities. The findings suggest that concerted efforts are required to enhance food diversity in the supporting regions around IKN, particularly in South Kalimantan, which exhibits a relatively lower Simpson Index compared to other areas in Kalimantan. Moreover, the Simpson Index achievement has a significant impact on reducing food inflation rates, indicating its potential as a tool for monitoring and evaluating food price fluctuations, which are critical for maintaining economic access to national food security.

Keywords: food security; consumption; Simpson index; Nusantara; food inflation

JEL Classification: C24; D12; E31

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1. Introduction

Discussions on food security issues continue to evolve in response to the emergence of various problems related to hunger and nutritional fulfillment (Xie et al., 2021). This has become one of the agendas in the Sustainable Development Goals (SDGs), specifically Goal 2: Zero Hunger. Fundamentally, food security encompasses more than mere food availability, as it also highlights the population's access to food (García-Díez et al., 2021). According to the Food and Agriculture Organization of the United Nations (FAO), there are four dimensions that must be fulfilled in building food security: (1) physical availability of food; (2) physical and economic access to food; (3) food utilization; and (4) stability of the three aforementioned dimensions (FAO, 2008).

Various events in recent years have, in fact, made food security increasingly vulnerable. Climate change and ecological stability issues, such as soil quality degradation that can affect the productive capacity of the agricultural sector, are considered major shocks that hinder the achievement of food security (Pozza & Field, 2020; Xie et al., 2021; Singh et al., 2023). In addition, geopolitical situations that affect the distribution and trade of food commodities can also threaten food security. During the conflict between Russia and Ukraine, which are both major wheat producers, key wheat-importing countries such as Indonesia and other developing nations were forced to face shortages and rising food prices, which in turn affected public consumption (Mottaleb, Kruseman, & Snapp, 2022; Ubiora et al., 2023). This price surge or inflation also poses a threat to food security. Food price inflation disrupts people's access to food, thereby creating more cases of malnutrition (Headey & Ruel, 2023).

National Food Agency (NFA) developed the Food Security Index using ten indicators that reflect the aspects of food availability, affordability, and utilization (NFA, 2023). In 2022, at least 14.39 percent of regencies and municipalities had low food security. In terms of progress, as many as 270 regencies and municipalities, representing more than half of the regions, experienced a decline in index scores compared to the achievements in 2021. Specifically, regions on the island of Kalimantan dominated this decline. This indicates that food security conditions remain unstable and are not yet under control. The ecological conditions of Kalimantan, characterized by a tropical rainforest climate and peatland landscapes, actually hold great potential for strengthening food security through optimized agricultural production with proper management, including water and soil management, fertilizer application, and the selection of adaptive crop varieties (Sulaeman et al., 2024). Moreover, with the designation of Nusantara in East Kalimantan as the new capital city, food security conditions on the island of Kalimantan require more serious attention.

Although Indonesia is an agrarian country with a substantial contribution from the agricultural sector, achieving food security is by no means an easy task. The Indonesian government's excessive focus on rice commodities is also an important issue in building food security (Rozaki, 2021). The availability of and public purchasing power for rice have a significant influence on national inflation (Setiartiti, 2021). In the context of food diversification, communities that rely too heavily on certain food groups or have low dietary diversity will face increasing dependency. From the demand side, excessive public consumption of certain commodity groups can significantly raise the rate of food price inflation (Kurniawan, 2022).

Specifically, the price of healthy food increased by more than 5 percent between 2020 and 2021 in nearly all parts of the world (FAO et al., 2023). Food price inflation is one of the factors that significantly influence the food security system (Aliyu et al., 2021). Rising prices weaken people's economic access to healthy food. In fact, food security should be realized through a diverse dietary pattern rich in nutrients (Wudil et al., 2022).

All food groups should be adequately consumed by the population. A balanced food group diversification program should play a major role in efforts to strengthen food security, particularly on the island of Kalimantan as the location of the new capital city, Nusantara (IKN). All regions of Kalimantan, as a supporting zone, should be able to contribute to achieving dietary diversity among the population.

From an economic perspective, household food consumption patterns can be observed through expenditure indicators for food groups such as cereals, meat, fish, eggs and milk, as well as other food groups. Unfortunately, studies on food security from an economic perspective, particularly in relation to inflation using the expenditure diversification approach, remain limited, especially in Indonesia. Balanced expenditure across food groups should support the achievement of an ideal and nutrient-dense dietary diversification. Therefore, this study aims to analyze the diversity of household food consumption at the regency and municipal levels in Kalimantan using the Simpson Ecological Index (hereafter called as the Simpson Index), which is constructed from the structure of household food expenditure in Indonesia, weighted by the inflation rate for each expenditure group. The Simpson Index can reveal the degree of diversity in food groups consumed by the population, particularly in Kalimantan, as a basis for mapping food security development in Nusantara as the new capital city. Furthermore, this study conducts an in-depth analysis of the effect of consumption diversity on the level of food price inflation, which is one of the key aspects of national food security in relation to the population's economic access.

In developing countries, the risk to food security is closely related to food price inflation, which reflects the population's access to adequate food (Erokhin & Gao, 2020; Ben Abdallah, Fekete-Farkas, & Lakner, 2021). The continued rise in global food prices has caused low-income households to experience food shortages, making well-targeted food assistance programs necessary (Rajesh et al., 2022). Controlling inflation itself is crucial, as several studies have revealed that expectations of inflation can determine future inflation levels. Cochrane (2022) explained in his study that past inflation plays a significant role in shaping current inflation as a result of expectations. Teena Lakshmi (2022), in her research, specifically identified that short-run food price inflation in India is influenced by overall inflation and past food price inflation. In the context of Indonesia, a study conducted by Ismaya and Anugrah (2018) using the GMM method found that food price inflation in Indonesia is significantly influenced by inflation expectations, both backward-looking and forward-looking, as well as agricultural food production indicators and phenomena that create price shocks. Similarly, Aziza et al. (2023) identified consistent findings using Singular Spectrum Analysis to predict the Consumer Price Index for food.

Several events, such as national policies and global phenomena, can create shocks to food prices. In this period, one of the significant phenomena affecting many aspects of international relations is the Russia–Ukraine war. Russia's invasion of Ukraine in February 2022 has driven increases in food prices across various parts of the world, including the European Union, which shares a direct geographical border (Balogh & Sárvári, 2024), the Middle East and North Africa (Mezouri & Benharrat, 2024), and North America through disruptions in grain and vegetable oil exports (Malakhail, Debnath, & Westhoff, 2023). Considering the massive impact of this war on global food prices, as well as the nature of Indonesia's international relations with Russia and Ukraine, it is important to account for the war's existence when analyzing food price inflation in Indonesia. In addition, Gholizade, Norouzi, and Feizabadi (2024) found a negative effect of the unemployment rate on the agricultural commodity price index. This is inseparable from the impact of the COVID-19 pandemic, which demonstrated the strong linkage between rising unemployment, market disruptions, and soaring food prices that threaten public access to food (Endris Mekonnen & Kassegn Amede, 2022).

Food security does not end with the mere presence of food but also encompasses the quality of the food itself. In the second goal of the SDGs, nutrition is addressed specifically. Access to nutritious food remains a serious issue, with 3.2 billion people worldwide unable to afford a healthy diet in 2020 (FAO et al., 2023). This problem has implications for public health, including underweight, stunting, and obesity. In their study, Headey and Ecker (2013) found that dietary diversity is the most reliable indicator of food security because it serves as a robust determinant in depicting poverty and malnutrition, as well as being sensitive to shocks. A higher level of dietary diversity is associated with better food security (Endris Mekonnen & Kassegn Amede, 2022; Diansari, Nanseki, & Chomei, 2023; Saydullaeva et al., 2023). Unfortunately, the measure of dietary diversity has not been discussed intensively in the context of food security in Indonesia. In fact, there is no indicator representing the dietary diversity of the Indonesian population included in the Food Security Index developed by NFA. The current measure of diversity is the Food Consumption Pattern Score, which is based on meeting the Dietary Energy Adequacy (DEA) target, thereby obscuring inequality or the actual proportional distribution across different food groups (NFA, 2023).

To date, studies employing various methodologies have been conducted to measure the level of dietary diversity. Verger et al. (2021) conducted a systematic review of dietary diversity in articles published up to 2018 and classified the various indicators into four categories: (1) food item–based indicators, (2) food group–based indicators, (3) consumption guideline–based indicators, and (4) other indicators. The first and second categories use a simple scoring method by assigning a score of 1 to a food item/commodity or food group that has been consumed and a score of 0 to those not consumed. This method is used by the FAO in developing the Household and Individual Dietary Diversity Score (DDS), which scores the food groups consumed within the past 24 hours (Ganpule-Rao et al., 2021). The food groups covered in the questionnaire include cereals, roots and tubers, vegetables, fruits, meat, eggs, fish and seafood, legumes and nuts, milk and dairy products, oils and fats, sugar, as well as spices, condiments, and beverages. The third indicator category involves calculating dietary diversity by considering the recommended consumption limits set by experts or established standards. Such health-conscious indicators are used as measures of dietary diversity in several countries (Gómez et al., 2020; Verger et al., 2021).

In the category of other indicators, the most commonly used methods are the construction of the Simpson Index or the Berry Index, which examine the distribution of consumed food groups. Measurement using the Simpson Index, which accounts for the distribution of food consumption, addresses the limitations of conventional measurement methods that fail to capture the nutritional diversity derived from dietary diversity, the inequality among food groups, and their relative distribution in overall consumption (Hanley-Cook et al., 2023).

Based on the literature review, it is evident that food diversification reduces dependence on certain commodities, thereby potentially mitigating food price volatility. High food inflation decreases households' ability to access nutritious food and undermines food security. More diverse consumption patterns tend to be negatively correlated with food inflationary pressures. Considering this relationship, this study hypothesizes that the Simpson Index has a negative effect on food inflation, whereby an increase in dietary diversity will reduce the level of food inflation.

2. Methodology

The data used in this study are derived from the National Socioeconomic Survey (SUSENAS) of Indonesia, covering 514 regencies and municipalities, the 2022 Cost of Living Survey as the basis for weighting, and inflation data from 90 cities. The data coverage for modeling spans the period 2020–2023. All data were obtained from Statistics Indonesia.

This study introduces a novel approach to measuring household dietary diversity by utilizing expenditure data for each food group obtained from SUSENAS conducted by Statistics Indonesia, represented through the Simpson Index. Furthermore, compared to previous studies, the Simpson Index used in this research is not only more representative in depicting consumption patterns but also accounts for the dynamics of food prices, which are related to market fluctuations and government policies. By incorporating expenditure into the analysis of dietary diversity, this study is expected to capture the relationship between household dietary diversity and food price inflation as an indicator of food security more effectively. In this context, an expenditure-based approach offers a new contribution to understanding how consumption preferences based on spending can influence changes in food prices, which is essential for ensuring household economic well-being in Indonesia.

The Simpson Index, first introduced by Edward Hugh Simpson in 1949, is an index that describes diversity across several observation groups. In his study, Simpson (1949) applied the calculation of this index in an ecological context, which later became known as the Simpson Ecological Index. The Simpson Index can be expressed as follows.

$$D = 1 - \sum_1^k p_i{}^2 \quad (1)$$

where:
D = Simpson Index, which represents the diversity within the observation groups; proportion of observation group i relative to the total number of groups k.
p_i = proportion of observation group i relative to the total number of groups k.
In calculating p_i, the formulation is as follows.

$$p_i = \frac{n_i}{N} \quad (2)$$

where:
n_i = a given observation value n in the i-th group;
N = the total value of n across all groups.

The value of the Simpson Index ranges from 0 to 1, where 0 represents perfect uniformity and 1 represents perfect diversity. The classification of diversity in the Simpson Index is as follows: low diversity if the value of the Simpson Index is less than 0.3; moderate diversity if it ranges between 0.3 and 0.7; and high diversity if it is greater than 0.7 (Khandelwal, n.d.).

Over time, the Simpson Index has provided information not only in the context of ecological diversity but also, among others, in consumption diversity. When linked to consumption diversity, the value of the Simpson Index reflects household consumption behavior, particularly regarding the demand for a certain group of goods, which in turn will affect the Consumer Price Index (CPI) for that group of goods. An increase or decrease in the demand for a group of goods or services will influence the rate of inflation or deflation in a given region (Mankiw, 2012).

In relation to price levels, particularly for the food, beverages, and tobacco group (hereafter referred to as food), household consumption patterns can be described using the Simpson Index, which is composed of several food groups with data provided by Statistics Indonesia, covering the following 14 categories: cereals; roots and tubers; fish; meat; eggs and milk; vegetables; legumes; fruits; oils and coconut; beverage ingredients; other food ingredients; spices and seasonings; prepared food and beverages; and cigarettes and tobacco.

The advantage of the Simpson Index in this study lies in its ability to capture the effect of consumption pattern diversity on the demand for food. To accommodate the influence of these consumption patterns, this study applies inflation weights for each commodity corresponding to the grouping of food, beverages, and tobacco in the calculation of the Simpson Index. The inflation weights are the average weights of all inflation cities in Indonesia, as specified in the weighting diagram from the 2022 Cost of Living Survey published by Statistics Indonesia (2024). Accordingly, Equations (1) and (2) can be rewritten into a new formula for the Simpson Index through the following steps.

Determine the consumption of 14 food commodity groups based on SUSENAS data. The SUSENAS data used in this study cover the period 2020–2023 and include 90 inflation-monitoring cities in Indonesia.

$$\sum_1^{14} n_i = N \tag{3}$$

Multiply the consumption of each food group by its corresponding weight so that

$$\sum_1^{14} w_i n_i = \sum_1^{14} n_{wi} = N_w \tag{4}$$

where:
w_i= the weight assigned to food group i;
n_{wi}= a given observation value n in the i-th group that has been weighted by w_i;
Nw= the total value of across all food groups.

Substitute into the Simpson Index formula in Equation (1) to obtain

$$D = 1 - \sum_1^{14} {p_i}^2 = 1 - \sum_1^{14} \left[\frac{n_{wi}}{N_w}\right]^2 \tag{5}$$

The calculation of the modified Simpson Index in the context of dietary diversity will be conducted for the period 2020–2023, covering 514 regencies and municipalities in Indonesia, and subsequently analyzed for 56 regencies and municipalities in Kalimantan.

The food price inflation modeling was carried out to examine the significance of the Simpson Index and other factors on food inflation. This study employs the Threshold Panel Regression approach, covering 90 inflation-monitoring cities in Indonesia for the period 2020–2023 (the period was selected based on the completeness of the panel data). The variables used in the food price inflation model are presented in Table 1 below.

Table 1. Description of Variables

Variable	Operational Definition
Annual Food Inflation Rate (Dependent Variable)	The current year's inflation rate for the food group is expressed as a percentage.
Simpson Index (Independent Variable)	An index of consumption diversity for 14 food commodity groups, expressed as an index value.
Unemployment Rate (Control Variable)	The number of unemployed individuals compared to the total labor force, expressed as a percentage.
Russia–Ukraine Conflict Dummy (Control Variable)	A variable assigned a value of 1 for the period during which the Russia–Ukraine conflict occurred (2022) and 0 for all other periods. The dummy variable has no units (unit-free).
Outlier Dummy (Control Variable)	A variable assigned a value of 1 for observations with extreme values (beyond three standard deviations from the mean) and 0 for regular observations. The dummy variable has no units (unit-free).
Previous Year's Inflation Rate (Control Variable)	The annual inflation rate of the previous year, expressed as a percentage.
Threshold Inflation Dummy (Control Variable)	A variable assigned a value of 1 if the previous year's annual inflation rate is greater than a certain threshold (k), and 0 if it is less than or equal to k. The dummy variable has no units (unit-free).

Source: Processed by Author

In addition, the panel regression used in this study is a modification of the Threshold Regression model (Hansen, 2000), whose variations can also be found in the studies of Mubarik (2005), Frimpong and Oteng-Abayie (2010), and Murjani (2019). This model can also provide insights into the ideal inflation rate in terms of controlling food inflation. The food inflation model is formulated as follows.

$$INFM_{it} = \beta_0 + \beta_1 SIM_{it} + \beta_2 TPT_{it} + \beta_3 D2022_{it} + \beta_4 DOUT_{it} + \beta_5 INF_{it-1} + \beta_6(D)(INF_{it-1} - k) + \varepsilon_{it} \quad (6)$$

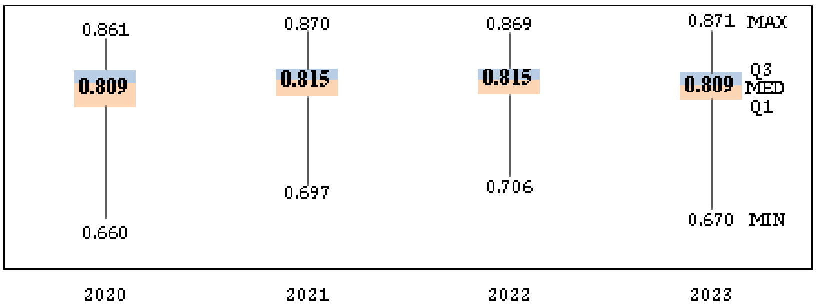
Where:
$INFM_{it}$ = the inflation rate of food, beverages, and tobacco in the inflation-monitoring city *i* at time *t* (in percent);
INF_{it-1}= the inflation rate in inflation-monitoring city *i* in year *t–1* (in percent);
D = dummy variable with a value of 1 if INF_{it-1} > inflation threshold (*k*), and 0 otherwise. The value of *k* is considered optimal when the adjusted R^2 reaches its highest value and the coefficient of INF_{it-1} is statistically significant;
SIM_{it} = the Simpson Index in inflation-monitoring city *i* at time *t*;
TPT_{it} = the unemployment rate in inflation-monitoring city *i* in year *t* (in percent);
$D2022_{it}$ = dummy variable for inflation-monitoring city *i* in year *t*, indicating the occurrence of the Russia–Ukraine conflict in 2022;
$DOUT_{it}$ = dummy variable for inflation-monitoring city *i* in year *t* that has an extreme value (Hawkins, 1980).

3. Results and Discussion

The level of dietary diversity in Indonesia is measured at the regency and municipal levels using the Simpson Index. In general, changes in regional Simpson Index scores across periods are relatively small, although some developments are observed. In 2023, the average Simpson Index for dietary diversity across regencies and municipalities reached 0.804, with the highest score at 0.871 and the lowest at 0.670. Compared to the 2020 level, there was a slight upward trend in the Simpson Index, indicating that food security conditions have improved in the context of food consumption expenditure. However, this figure represents a decline compared to the previous year's average of 0.810.

The range between the maximum and minimum scores also widened compared to 2022. This indicates that food security, as reflected in dietary diversity in Indonesia, has not been sufficiently stable in recent years. The development of the distribution of Simpson Index scores for regencies and municipalities in Indonesia during the period 2020–2023 is presented in full in Figure 1.

Figure 1. Trends in Simpson Index Scores for Regencies and Municipalities in Indonesia, 2020–2023



Source: Processed by Author

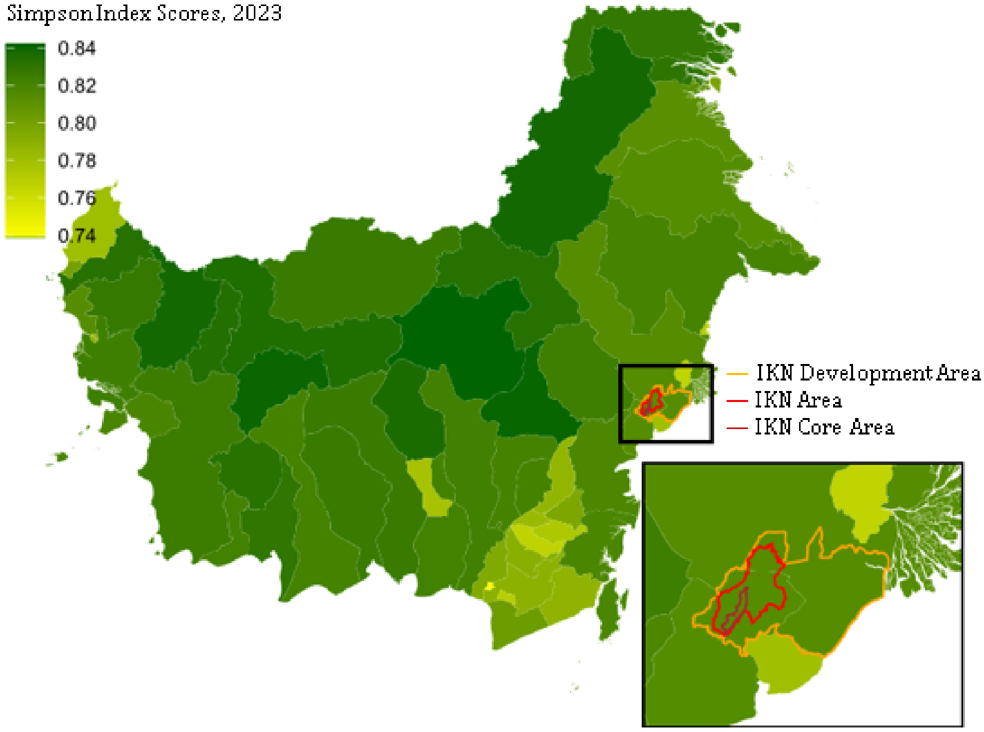
In general, there is an upward trend in the Simpson Index scores over the study period. However, the year-to-year development has not shown a consistent movement toward increasing dietary diversity in the context of food expenditure. One important indicator in assessing the distribution of Simpson Index scores is the lowest score achieved, which reflects the minimum condition of dietary diversity.

When examined more specifically for Kalimantan Island, the 2023 Simpson Index results for dietary diversity are presented through the thematic map in Figure 2. Overall, Simpson Index scores in Kalimantan ranged from a low of 0.739 to a high of 0.842, corresponding to Banjarmasin City and North Barito Regency, respectively. On the thematic map illustrating the geographic areas of Kalimantan, darker green shades dominate the central and northern parts, which are the island's primary rainforest areas. Communities living closer to forested areas tend to have expenditure patterns for consumption that are more evenly distributed across food groups. The biological richness and ecological functions of forest ecosystems directly and indirectly support the continuous provision of food for surrounding communities, making dietary diversity more attainable. This finding is consistent with the study by Baudron et al. (2019), conducted on sample landscapes in seven developing countries, including Indonesia, which found that forest cover positively influences agricultural and livestock production in five landscapes and dietary diversity in three landscapes. The contribution of forests extends beyond their role as ecosystems that directly provide food; they also enhance environmental quality for agricultural activities that support food production. The existence and preservation of forest ecosystems are important components in formulating policies to improve food security, given their capacity to produce nutrient-rich food and their role in supporting the quality and diversity of household food consumption (Rasmussen et al., 2020).

In contrast, lighter-colored areas with lower dietary diversity are more prominently concentrated in South Kalimantan Province compared to other regions. Although they are still classified within the high diversity category, the Simpson Index scores of areas in South Kalimantan remain below both the national and Kalimantan averages. As part of the supporting region for IKN on Kalimantan Island, this should be a concern, as the relatively suboptimal and geographically clustered diversity indicates a potential vulnerability of communities' dependence on certain food groups. Such dependence should be avoided to anticipate potential price fluctuations in specific food groups. To support the IKN, regencies and municipalities in South Kalimantan still need to pay attention to food diversification programs to enhance household dietary diversity.

In East Kalimantan Province, particularly in regencies and municipalities directly bordering the IKN Development Area, the level of dietary diversity varies considerably. In urban areas such as Balikpapan City and Samarinda City, Simpson Index scores tend to be lower. This indicates that household expenditure in these urban areas is not yet evenly distributed across all food groups. The presence of the new capital city, Nusantara (IKN), is significant because Balikpapan City and Samarinda City are urban areas directly adjacent to the IKN Development Area, meaning that local consumption patterns will influence conditions in the IKN. The study by Yahya et al. (2023) found evidence of spatial interdependence between neighboring regions in meeting food consumption needs in Indonesia. Meanwhile, the Simpson Index scores for North Penajam Paser Regency and Kutai Kartanegara Regency, whose territories are part of the IKN construction site, are relatively better in terms of dietary diversity.

Figure 2. Thematic Map of Simpson Index Scores in Kalimantan Island, 2023



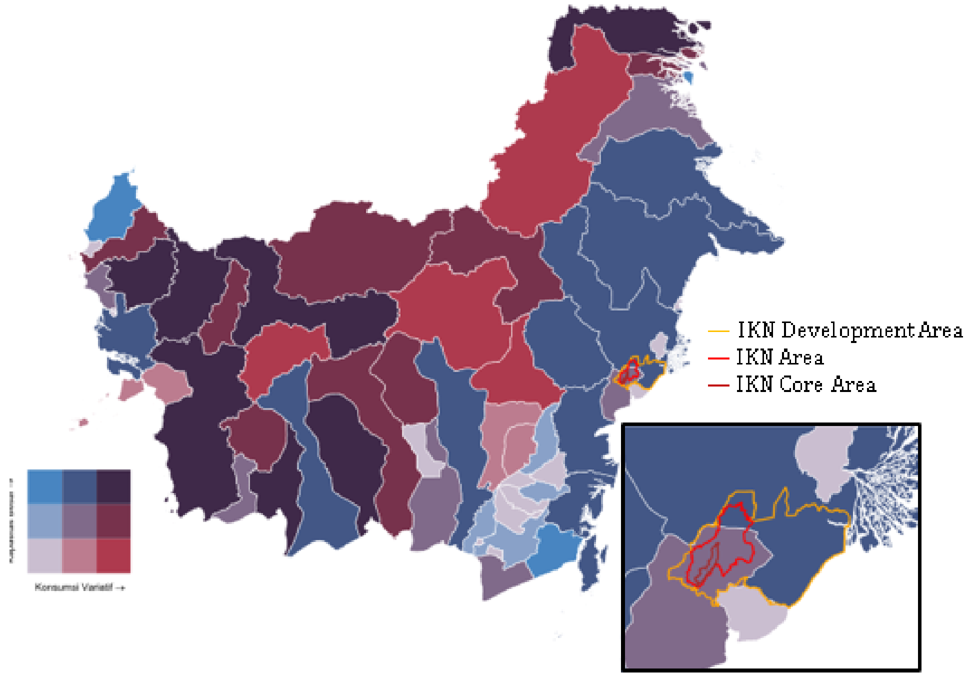
Source: Processed by Author

To build food security in the IKN area, the surrounding regions should first be able to maintain food stability through dietary diversification within their territories before functioning as food security buffers for the IKN. Jiuhardi et al. (2023) in their study showed that food consumption expenditure simultaneously affects food security in the four supporting regions of the IKN: Balikpapan City, Samarinda City, North Penajam Paser Regency, and Kutai Kartanegara Regency. In addition, from the supply side, the production capacity of the agriculture, fisheries, and forestry sectors in food also influences food security in these four regions.

Figure 3 presents a visualization of the correlation between Simpson Index scores and the Gross Regional Domestic Product (GRDP) for Category A (Agriculture, Fisheries, and Forestry) as an indicator of food production capacity in Kalimantan Island, using a Bivariate Choropleth. Dark purple areas represent the ideal condition, where agricultural production capacity is relatively high and consumption is sufficiently diverse. Based on Figure 3, these areas are primarily located in the central–western part of Kalimantan. A high food production capacity combined with sufficiently varied household consumption can create optimal food security conditions.

In East Kalimantan, particularly in the IKN buffer zones, some areas have relatively high agricultural production capacity, such as Kutai Kartanegara Regency, yet the dietary diversity of their populations remains at a moderate level. In contrast, urban areas such as Samarinda City and Balikpapan City tend to have lower production capacity and less diverse household consumption. As part of the supporting regions for the IKN, the nearby regencies and municipalities should possess sufficient food production capacity to supply food to the national capital area.

Figure 3. Bivariate Choropleth of Simpson Index for Dietary Diversity and GRDP Category A in Kalimantan Island, 2023



Source: Processed by Author

On a broader scale, South Kalimantan Province, as a neighboring region to East Kalimantan, is also dominated by regencies and municipalities with relatively low dietary diversity, with high production capacity found only in a few areas. This means that the IKN buffer zones, both those directly bordering the IKN area and those in East Kalimantan Province and its surroundings, still need to optimize food security development in the context of dietary diversity. The areas with ideal conditions in Kalimantan Island are, in fact, located quite far from the IKN area in East Kalimantan. The more difficult the access to available food, the more constrained the efforts will be to promote dietary diversity among the population. This raises concern that food prices in the IKN area will become increasingly vulnerable to shocks, thus posing a risk of food inflation.

In analyzing the relationship between dietary diversity in the context of expenditure and food prices, this study models food inflation data for inflation-monitoring cities in Indonesia. The previous year's annual inflation threshold value (k) used in this model ranges from 1.0 to 5.0 percent. The results of the food inflation model from Equation (6) are presented in Table 2 below.

Table 2. Estimation Results of Threshold Panel Regression for Food Inflation in 90 Inflation-Monitoring Cities, 2020–2023

k	Variable	Coefficient	Standard Error	t-statistic	Probability	Adjusted-R^2
1,0	C	11.536	3.455	3.339	0.001	0.259
	SIM	-7.784	4.077	-1.909	0.057	
	TPT	-0.115	0.052	-2.223	0.027	
	D2022	2.316	0.304	7.613	0.000	
	DOUT	-9.505	1.490	-6.378	0.000	
	INF(-1)	-1.063	0.793	-1.340	0.181	
	D(INF-1.0)	1.372	0.816	1.681	0.094	
1,5	C	10.907	3.404	3.204	0.002	0.256
	SIM	-7.599	4.081	-1.862	0.064	
	TPT	-0.109	0.052	-2.101	0.037	
	D2022	2.311	0.309	7.487	0.000	
	DOUT	-9.587	1.494	-6.417	0.000	
	INF(-1)	-0.280	0.411	-0.683	0.495	
	D(INF-1.5)	0.579	0.430	1.348	0.179	
2,0	C	11.296	3.342	3.380	0.001	0.269
	SIM	-7.515	4.039	-1.861	0.064	
	TPT	-0.108	0.052	-2.085	0.038	
	D2022	2.457	0.312	7.881	0.000	
	DOUT	-9.678	1.482	-6.530	0.000	
	INF(-1)	-0.556	0.335	-1.660	0.098	
	D(INF-2.0)	0.960	0.383	2.504	0.013	
2,5	C	11.060	3.301	3.350	0.001	0.276
	SIM	-7.241	4.016	-1.803	0.073	
	TPT	-0.109	0.051	-2.116	0.035	
	D2022	2.505	0.310	8.093	0.000	
	DOUT	-9.663	1.474	-6.557	0.000	
	INF(-1)	-0.483	0.256	-1.883	0.061	
	D(INF-2.5)	0.985	0.326	3.023	0.003	
3,0*	C	10.644	3.283	3.242	0.001	0.278
	SIM	-6.871	4.012	-1.712	0.088	
	TPT	-0.109	0.051	-2.128	0.034	
	D2022	2.459	0.304	8.102	0.000	
	DOUT	-9.526	1.471	-6.476	0.000	
	INF(-1)	-0.369	0.213	-1.733	0.084	
	D(INF-3.0)	0.963	0.307	3.136	0.002	
3,5	C	10.361	3.285	3.155	0.002	0.276
	SIM	-6.732	4.021	-1.674	0.095	
	TPT	-0.112	0.051	-2.180	0.030	
	D2022	2.388	0.299	7.982	0.000	
	DOUT	-9.384	1.474	-6.364	0.000	

k	Variable	Coefficient	Standard Error	t-statistic	Probability	Adjusted-R^2
	INF(-1)	-0.226	0.178	-1.270	0.205	
	D(INF-3.5)	0.881	0.296	2.976	0.003	
4,0	C	10.227	3.296	3.103	0.002	0.270
	SIM	-6.797	4.037	-1.684	0.093	
	TPT	-0.115	0.052	-2.231	0.027	
	D2022	2.322	0.297	7.812	0.000	
	DOUT	-9.452	1.480	-6.387	0.000	
	INF(-1)	-0.088	0.152	-0.578	0.564	
	D(INF-4.0)	0.769	0.297	2.593	0.010	
4,5	C	10.125	3.313	3.056	0.003	0.262
	SIM	-6.922	4.058	-1.706	0.089	
	TPT	-0.117	0.052	-2.247	0.026	
	D2022	2.259	0.297	7.617	0.000	
	DOUT	-9.493	1.488	-6.382	0.000	
	INF(-1)	0.045	0.131	0.342	0.733	
	D(INF-4.5)	0.608	0.310	1.965	0.051	
5,0	C	10.057	3.327	3.022	0.003	0.256
	SIM	-7.072	4.074	-1.736	0.084	
	TPT	-0.116	0.052	-2.221	0.027	
	D2022	2.214	0.296	7.471	0.000	
	DOUT	-9.510	1.494	-6.367	0.000	
	INF(-1)	0.151	0.113	1.337	0.182	
	D(INF-5.0)	0.425	0.333	1.276	0.203	

Source: Processed by Author

Note: * *Represents the inflation threshold for the best-fitting model*

The modeling results in Table 2 have met all panel regression assumptions, as shown in Table 3. All estimation results in Table 3 have passed the basic assumption tests. This indicates that the model specification is appropriate and free from bias due to violations of classical assumptions. Therefore, the estimated model can be considered reliable for drawing conclusions and interpreting results statistically.

Table 3. Model Selection and Panel Regression Assumption Tests

Test	Probability	Note
Random Effects vs. OLS (Breusch and Pagan Lagrangian Multiplier Test)*	1.000	Utilization of OLS
Multicollinearity	-	*Mean* VIF 5.12, no multicollinearity
Autocorrelation (*Wooldridge test for autocorrelation*)	0.863	No autocorrelation
Heteroskedasticity (*Breusch-Pagan / Cook-Weisberg test for heteroskedasticity*)	0.704	Constant residual variance
Residual normality (*Skewness/Kurtosis tests for Normality*)	0.207	Residuals are normally distributed

Source: Processed by Author. Note: * *The Fixed Effects model was not tested because it was not significant.*

The estimation results indicate that the previous year's inflation rate, along with the threshold effect, is significant within the inflation range of 2 to 3 percent (Table 2). Referring to Equation (6), the best model is the one with the highest adjusted R^2 value, which occurs at $k = 3$ percent with an adjusted R^2 of 0.278. Here, it can be seen that each variable is significant at the $\alpha = 1$ percent, 5 percent, and 10 percent levels.

The SIM variable has a coefficient of -6.871, meaning that an increase or decrease of 1 unit in the Simpson Index will reduce or increase food inflation by 6.871 percentage points (with other factors held constant). Considering the relatively small differences in the Simpson Index across regions and time, this can also be interpreted as a 0.01 unit increase or decrease in the Simpson Index, reducing or increasing food inflation by 0.06871 percentage points. This finding aligns with the theory that as consumption diversity increases, dependence on any single group of goods decreases, thus demand for those goods becomes more controlled (resulting in controlled inflation from the demand side). Furthermore, the Simpson Index shows a significant effect on food inflation across all tested inflation threshold values. This indicates that the Simpson Index consistently and significantly impacts food inflation across all threshold scenarios. Although the Simpson Index coefficient is smaller compared to other variables in the model, from a long-term perspective, a consistent increase in the Simpson Index across regions could cumulatively have a large and significant effect on reducing the rate of food inflation.

Additionally, the unemployment rate (TPT) has a negative and significant effect on food inflation. Each 1 percent increase or decrease in the unemployment rate results in a 0.109 percentage point decrease or increase in food inflation. This is consistent with the Phillips Curve theory, which posits an inverse relationship between unemployment and inflation in the short term, where rising unemployment reduces overall demand, leading to lower price levels (Murjani, 2022).

The variable D2022 has a significant coefficient value of 2.459, indicating that the year 2022 (when D2022 equals 1, marking the Russia–Ukraine conflict) had an average food inflation rate 2.459 percentage points higher than other years. The dummy variable DOUT also has a significant coefficient of -9.526, meaning that observations identified as outliers have, on average, a food inflation rate 9.526 percentage points lower than other observations.

For the variable related to the previous year's inflation, INF(–1) has a coefficient of –0.369. This means that when the last year's annual inflation rate is less than or equal to 3 percent, a one percentage point increase in the previous year's inflation causes a 0.369 percentage point decrease in the current year's food inflation rate. Conversely, when the last year's inflation rate exceeds 3 percent, a one percentage point increase in the previous year's inflation results in a 0.594 percentage point increase in current food inflation (calculated from the sum of the coefficients INF(–1) + D(INF–3.0) or –0.369 + 0.963). This is closely related to inflation expectations, where an increase in general inflation in the prior year leads the government to respond with price control efforts that impact prices (especially food prices) in the current year. Here, it is evident that when the annual inflation rate is at or below the low threshold (3 percent or less), price control efforts significantly reduce food inflation in the subsequent period. Conversely, when annual inflation is above the threshold, inflation control becomes relatively ineffective (food inflation continues to rise). Therefore, managing yearly inflation at the specified threshold plays a crucial role in reducing food inflation rates in the following period.

The modeling results show that the Simpson Index has a negative and significant effect on food inflation, meaning that the more diverse the dietary consumption pattern in a region, the lower the inflationary pressure experienced. This finding has important policy implications, namely the need to promote household food consumption diversification to reduce dependence on certain commodities that are vulnerable to price fluctuations. Furthermore, the inflation threshold of 3 percent indicates that price control at relatively low inflation levels is more effective in maintaining food price stability. Thus, inflation control strategies should not only focus on supply-side aspects but also on strengthening more balanced consumption patterns to support food security.

4. Conclusion

The increasing importance of food security, particularly in terms of food price control, has become a pressing need for this study to introduce a modified traditional index in the context of dietary diversity. Dependence on or reduced diversity in consumption makes a region more vulnerable to price fluctuations. This study aims to introduce the Simpson Index while modeling the factors influencing food inflation rates in 90 inflation-monitoring cities in Indonesia during the period 2020–2023. Additionally, an in-depth analysis of food security in Kalimantan is conducted concerning the presence of the Nusantara Capital City and the food security of its surrounding areas supporting the IKN.

This study draws several conclusions as follows. First, the development of consumption diversity at the regency and municipal levels in Indonesia remains unstable in its improvement during the period 2020–2023. Specifically, concerning the development of the new capital city in Kalimantan, consumption diversity in areas surrounding the IKN, predominantly urban areas, remains insufficiently high. The Simpson Index scores in South Kalimantan, one of the buffer zones of the IKN on Kalimantan Island, are also not yet optimal. Most regencies and municipalities in South Kalimantan have consumption diversity below the national and Kalimantan averages. Therefore, to anticipate potential price fluctuations in specific food groups in the IKN area, efforts to increase consumption diversity in buffer zones need to be prioritized. Second, the Simpson Index, which reflects consumption diversity, is proven to influence the rate of food inflation, where each 0.01 increase in the Simpson Index can reduce food inflation by 0.06871 percentage points and consistently has a significant effect across all tested inflation thresholds. Third, other control variables were also found to have significant effects, including the unemployment rate, the occurrence of the Russia–Ukraine conflict, the presence of outliers, and previous year inflation, along with its threshold effects. Furthermore, the inflation threshold effect was significant at a 3 percent annual inflation rate in the last year. Specifically, each one percentage point increase in the previous year's inflation rate (when the inflation threshold is less than or equal to 3 percent) reduces current food inflation by 0.369 percentage points. Conversely, a one percentage point increase in previous year inflation (when above the 3 percent threshold) raises current food inflation by 0.594 percentage points. This indicates that under relatively low and controlled annual inflation, increases in the previous year's inflation rate still exert a lowering effect on current food inflation, which relates to the effectiveness of price control interventions.

Several policy recommendations related to food security and food inflation control stemming from this study are as follows. First, the continuous implementation of the Simpson Index is recommended as a tool for monitoring and evaluating dietary diversity among the population to anticipate food price fluctuations that could further impact overall price levels. The use of the Simpson Index also complements the Food Consumption Pattern Score and the Food Security Index currently employed as indicators for regional food security monitoring. Second, there is a need to intensify the promotion of programs encouraging more diverse food consumption or food diversification, which can reduce dependence on specific food commodities and thereby enhance resilience against food inflation. This is important for controlling food prices as a measure of economic access to food in efforts to build food security. Third, diversification programs should be further strengthened within agricultural production activities so that a more diverse supply can optimize efforts to diversify food consumption. Furthermore, general inflation control is essential to create an economic climate that supports various government interventions aimed at more effective price control. Regarding the IKN, special attention should be given to food diversification efforts as a means of inflation control in the main buffer zones in East Kalimantan and the broader South Kalimantan region, which still face challenges in optimizing consumption diversity and agricultural production. Identification and development of primary agricultural production areas for each food group around the IKN are necessary, enabling the government to develop distribution roadmaps to the IKN. This will ensure optimal food supply, supporting dietary diversity and better control of food prices.

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