Mixed linear model for investigating food security during the covid-19 pandemic: Panel data for rice consumption in indonesia

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Article Info	Abstract
	The Covid-19 pandemic has affected human life behavior, starting from health, the economy to living habits, one of them is the rice consumption. This study aims to find out whether the Covid-19 pandemic can affect people's rice consumption, and what are the factors that can affect people's rice consumption before and during the pandemic. The independent factors studied in this study were harvested area, productivity, rice production, crime rate, and the ratio of household gas use, with rice consumption as the dependent variable. The data used is panel data for 2019 and 2020, from 34 provinces in Indonesia, which is one of the five countries with the highest rice consumption in the world. By using mixed linear models, the research results show that in general Covid-19 pandemic has not had a significant effect on rice consumption in Indonesia. Other facts also show that social factors, namely the crime rate during a pandemic, did not have a significant effect on rice consumption. However, this is different from economic factors such as productivity and harvested area which have a significant positive effect on rice consumption in Indonesia.

INTRODUCTION

Community needs are very diverse, one of the basic needs of society is food. Food is the main basic need for humans that must be met at any time. For Indonesia food is closely related to rice, because the main feature of food in Indonesia is rice. History in Indonesia proves that during the 1997/1998 economic crisis it could develop into a multidimensional crisis triggering social insecurity which was very dangerous for economic stability and national stability, one of the effects of which was the emergence of food insecurity. The main topic of discussion in this article is the focus on food analysis, namely rice consumption before and during the Covid - 19 pandemic.

Covid-19, also known as the corona virus, is an infectious disease caused by severe acute respiratory syndrome corona virus 2. Corona viruses cause respiratory tract infections, such as flu, MERS (Middle East Respiratory Syndrome), and SARS (Severe Acute Respiratory Syndrome). This coronavirus was first discovered in Wuhan, Hubei, China in 2019 (Hui et al., 2020). The SARS-CoV-2 virus has infected more than 220 million individuals worldwide in early 2020 and the disease related to COVID-19 has been reported to have caused >4.5 million deaths. Several risk factors associated

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with SARS-CoV-2 infection and COVID-19 disease severity that have been identified are older age, gender, ethnicity, blood type, cardiovascular, respiratory and kidney disease (D'Antonio et al., 2021). Disease and death of COVID – 19 is one of the main research targets to achieve clinical and public health decision-making such as triaging inpatients or adjusting vaccination strategies (Andrejko et al., 2022). Covid-19 is data in the form of a time series, so many studies and research on Covid-19 use a time series analysis approach. Covid - 19 is a virus that can always mutate, allowing its direction of movement to change from time to time resulting in nonlinearity (Sunjaya et al., 2023).

At the beginning of 2020, Indonesia was one of the countries that experienced Covid - 19 pandemic. Almost every day there were additional cases of Covid-19, this condition required the Indonesian people to adapt to new conditions (Isnawati et al., 2022). To reduce the additional cases of Covid - 19, the government has implemented policies in the form of social distancing, physical distancing, and washing hands with soap. Apart from that, the government has also made other policies in the form of large-scale social restrictions (PSBB) which are enforced in all regions in Indonesia which are handed over to the local government.

On the one hand, this policy provides benefits for reducing the transmission of Covid-19, but this policy also has a downward impact on the people's economy. BPS reported that economic growth in Indonesia in 2020 experienced a contraction of -2.07% (Sitorus, 2022). Contraction can occur if there is a decline in aggregate economic activity, with this event it can experience a recession. The Covid - 19 pandemic that hit countries in the world showed that the structure of "neocolonialism" and neoliberal "structural adjustment" policies had an adverse effect on the public health system and exacerbated the critical condition of food security. This process exacerbates malnutrition due to the threat of global climate disaster. In overcoming the food crisis, several Global South countries mobilized small farmers to secure global food supplies and chains through large-scale food garden mega-project schemes (Simanjuntak & Erwinsyah, 2020).

One of the economic sectors affected by Covid - 19 is food or rice consumption. Rice is one of the staple foods of Indonesian society. Furthermore, around 95% of Indonesian people depend on rice. This is because Indonesia is an agricultural country with 40% of the livelihood of the majority of the population is farming. Indonesia is an agricultural country due to Indonesia's location in a tropical climate which makes the weathering process perfect so that the soil is fertile for agriculture. With the existence of fertile land for agriculture, it is used by the Indonesian population to grow staple crops. The basic need that is often grown by farmers is rice (Ayun et al., 2020).

The main food commodities consumed by Indonesian people are rice, corn, tubers, and sago. However, the majority of Indonesian people choose bers as a source of daily food fulfillment. Based on statistical data as reported by the Central Bureau of Statistics, people's preference for consuming rice is higher compared to other food commodities with an average consumption of 2047 kilograms per capita per week. Other types of food such as tubers, corn and sago cannot replace rice as the main staple food in the household. So that it is known that rice is a commodity with inelastic demand, where changes in price hardly cause changes in the amount of consumer demand. The social restrictions implemented to stop the spread of Covid-19 will indirectly affect the smooth supply chain of several rice-producing centers. The government through the Food Security Agency has a strategy for developing a national food logistics system in ensuring the stability of food supply and prices in Indonesia. This strategy includes simplifying the supply chain and intervening in the distribution of food products, coordinating and synergizing between logistics actors (Asrin et al., 2022).

However, the conditions of the Covid-19 pandemic have changed people's consumption patterns. A decrease in economic activity will have an impact on reducing people's consumption patterns or even due to large-scale social restrictions (PSBB), this can result in reduced income from the community. Based on data taken by BPS in 2019 and 2020, the results showed that in 2019 rice consumption was recorded at 3237.35 tons per week and in 2020 rice consumption was recorded at 3212.93 tons per week. Based on this, it can be seen that with the Covid - 19 pandemic there were no significant changes seen before and after the pandemic. This shows that the Indonesian people are still trying to meet their food needs in various ways. To analyze this problem, the authors used five independent variables, namely harvested area, productivity, production, crime rate, and gas usage ratio with one dependent variable, namely the level of Indonesian rice consumption.

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METHODS

Data Sets

The data that the author uses in writing this article is longitudinal data. Naturally, all objects will change over time. This kind of information cannot be obtained from cross-sectional data which only observes data at one point (Hidayat et al., 2022). In general, the longitudinal data set is written as follows:

$$(y_{ij}, t_{ij}, x_{ij}), i = 1,2,\dots,m \; dan \; j = 1,2,\dots,n$$

by m stating the number of subjects and n stating the number of observations. $t_i:_j$ states the observation time for the t-th subject i at the t-th time j, y_{ij} states the response variables observed at the time t_{ij} and x_{ij} states the observations at the time t_{ij}.

The data used is data from 34 provinces in Indonesia in the 2019 and 2020 timeframes. The timeframe was taken because the author wanted to know about the effect of rice consumption before and during the Covid-19 outbreak. The data the author used were harvested area, productivity, production, crime rate, gas usage ratio, and rice consumption level of Indonesian people. The data was obtained from the Central Bureau of Statistics in 2019 and 2020.

Method

The Linear Mixed Model, also known as the variance component, is an extension of the linear model by adding a random effect. This method uses 2 effects, namely random effects and fixed effects (Simbolon et al., 2022). The Linear Mixed Model is a model consisting of fixed effects and random effects. An effect is said to be fixed if in a study, the influence is considered to have represented all possible levels of influence that exist and have been determined previously. Meanwhile, an effect is said to be random if the factor is taken randomly on a problem that presumably represents that characteristic.

According to Gumedze, the research model uses a mixed linear method models are as follows

$$Y = X\beta + Zu + e$$

with:
 Y : The observed vector
 X : Matrix of explanatory variables for fixed effects
 β : Vector fixed effects
 Z : Matrix of explanatory variables for random effects
 u : Vector random effect
 e : residual error vector

In addition, the u and e vectors follow the multivariate Gaussian distribution as follows

$$\begin{bmatrix} u \\ \hline e \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ \hline 0 \end{bmatrix}, \sigma^2 \begin{bmatrix} G(\gamma) & 0 \\ 0 & R(\rho) \end{bmatrix} \right)$$

In the linear mixed model, two independent variable effects are used, namely X and Z. The independent variable X consists of p independent variables, $X^{(1)}, X^{(2)}, \dots, X^{(p)}$ which have a relationship with a fixed effect $\beta_1, \beta_2, \dots, \beta_p$. The independent variable Z consists of q independent variables $Z^{(1)}, Z^{(2)}, \dots, Z^{(p)}$, which have a relationship with the random effect coefficient which $b_{1i}, b_{2i}, \dots, b_{qi}. \varepsilon_{ij}$ is the residual for the jth observation for the Ith subject (Meysani et al., 2020).

RESULTS AND DISCUSSION

In this study, we use a number of important random factors that are island (I), and province (prov), and fixed effects are Harvested Area (HA), Production (pro), Productivity (pr), Crime Rate (CR) and Ratio The use of Gas (RPG). Several models are constructed, compared and analyzed to find factors that significantly affect rice consumption in Indonesia. Table 1 presents the summary from the eight linear (mixed) models.

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Table 1. Models Summary

Model	I	prov	HA	pro	pr	CR	RPG	time	interactions
1								✓	
2	✓							✓	
3		✓						✓	
4			✓					✓	HA:time
5				✓				✓	pro:time
6					✓			✓	pr:time
7						✓		✓	CR:time
8							✓	✓	RPG:time

The first initial model is the simplest, because the pure model uses a linear model without random effects. In this model, includes the intercept (β_0) and the influence of the time (β_1) before and during the pandemic on rice consumption in Indonesia. The model is declared by,

$$Y_{ijk} = \beta_0 + \beta_1 t_k + \varepsilon_{ijk}$$

$$\varepsilon_{ijk} \sim N(0, \sigma^2_{residu}).$$

The second model is a mixed linear model by adding island random effects and time fixed effects. We know that Indonesia consists of 5 major islands, so that each existing province is grouped into these islands. The third model is also a mixed linear model that includes provincial random effects and time fixed effects. In this model, each province is used as a unique random effect, so there are 34 random effects in this model. Table 2 shows a summary of the results from models 1 to 3. Models 1 to 3 state that there was no significant difference in rice consumption in Indonesia before and during the pandemic. In case of models 2 and 3, random effects island (I) and province (prov) cannot explain rice consumption in Indonesia better than the simple linear model. From the results of models 3 and 4 it can be seen that the provincial random effect has a better influence in explaining the variation in the value of rice consumption in Indonesia. This is indicated by the proportion of residual variance for provinces that is greater than the proportion of residual variance for islands. The proportion of variation in rice consumption that can be explained by the random effect of islands is around 93.77%, while the proportion of variation in rice consumption that can be explained by the random effect of province is around 96.75%.

Table 2 Summary of Model Significance Value

Model		Value	Std Error	p-values
1	(Intercepts)	32.9631	9.2233	0.00070***
	Time	1.72	10.6086	0.8717
		Value	Std Error	p-values
	(Intercepts)	35.3729	7.6741	0.00058***
2	Time	1.72	10.6729	0.8729
			Variances	
	(Intercepts)		127.9276	
	residual		1913.2231	
		Value	Std Error	p-values
	(Intercepts)	35.3729	7.6741	0.00012***
3	Time	1.72	10.8539	0.8745
			Variances	
	(Intercepts)		65.8924	
	residual		1936.4778	

Notes: *** significant at $\alpha = 1\%$, ** significant at $\alpha = 5\%$, * significant at $\alpha = 10\%$

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Table 3 presents the statistical result of the Model 4 to model 8. Model 4 to model 8 is an extension of the mixed linear model involving time interactions with various independent variables. In these models, the random effect used is the provincial random effect. The results of model 4 state that the harvested area (HA) has a significant positive effect on rice consumption in Indonesia. The results of model 6 state that the productivity (pr) of harvest has a significant positive effect on rice consumption in Indonesia. In these models, the interaction of time with various independent variables does not show a significant effect. However, even though these interactions do not show a significant effect on rice consumption, these models generally state that changes in harvested area, productivity and crime rates during 1 year of the pandemic can have an impact on reducing rice consumption.

Table 3 Summary of Model Significance Value

Model		Value	Std Error	p-values
4	(Intercepts)	21.9327	1.0708	0.0490***
	HA	3.5217	0.000016	0.0384**
	time	8.3984	12,437	0.5045
	time:HA	-0.000021	0.000022	0.3451
			Variances	
	(Intercepts)		0.000035	
	residual		1808.6164	
		Value	Std Error	p-values
5	(Intercepts)	40.3429	10.9903	0.0000***
	Production (pro)	-0.4535	0.3646	0.2231
	time	-6.4848	14.3276	0.6539
	time:pro	0.4915	0.4966	0.3298
			Variances	
	(Intercepts)		0.000042	
	residual		1925.9373	
		Value	Std Error	p-values
6	(Intercepts)	22.4101	10.4758	0.0404***
	Productivity (pr)	0.0066	0.0029	0.0284**
	time	8.5408	12,437	0.4834
	pr:time	-0.0042	0.0038	0.2841
			Variances	
	(Intercepts)		0.0000316	
	residual		1794.1476	
		Value	Std Error	p-values
7	(Intercepts)	31.7570	12.2505	0.0144**
	CR	0.00013	0.00104	0.8097
	time	6.0836	15.5667	0.6986
	CR:time	-0.00058	0.0014	0.6953
			Variances	
	(Intercepts)		0.000199	
	residual		1963.4578	
		Value	Std Error	p-values
8	(Intercepts)	27.9297	9.2979	0.00713*
	RPG	0.2941	0.2225	0.1959
	Time	3.6068	12.5937	0.7764
	Time:RPG	-0.1299	0.3026	0.6707
			Variances	
	(Intercepts)		6.78331	
	residual		1925.6772	

Notes: *** significant at $\alpha = 1\%$, ** significant at $\alpha = 5\%$, * significant at $\alpha = 10\%$

The data used in this study is panel data, namely by involving annual rice consumption before and during pandemic, in 34 provinces throughout Indonesia. Panel data analysis is very interesting to study because we can detect data trends from time to time from many research objects, and can observe interactions between one variable and another. In this study, 5 independent variables were

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used with rice consumption as the dependent variable. In this study, we have modeled using mixed linear models. The mixed linear model is an extension of the simple linear model by including random effects. Random effects can be selected, so that the model can better explain the diversity of dependent variables. By using random effects in each province, the results of various mixed linear modeling results suggest that the pandemic has no significant effect on changes in rice consumption in Indonesia.

In other words, rice consumption before the pandemic, namely in 2019, was the same as rice consumption during the 2020 pandemic. The results of the modeling also state that only 2 of 5 independent variables have a significant effect on rice consumption, namely harvested area and productivity. This shows that factors other than rice have not been able to play a significant role in influencing rice consumption in the community within one year of pandemic. The mixed linear model in this study also involves interactions between time and various independent variables. However, the interaction results also did not show a significant effect. But the results of the model, in general, the coefficient value of the interaction estimator has a negative coefficient. This shows that changes in independent variables during one year pandemic can lead to a decrease in people's rice consumption.

Even though the pandemic is almost over worldwide, food security must be maintained. Not only a pandemic that can affect food stability, but world economic stability, unrelenting wars can also have a negative impact on world food needs and consumption. For this reason, it is hoped that the results of this study can provide a view that changes in phenomena over time (ie the interaction of independent variables over time) need to be anticipated. Even though the results for one year of the pandemic have not been able to have a significant effect, this effect can be meaningful if the time and object/observation unit are carried out more broadly.

CONCLUSION

During the pandemic, there was a very significant decrease in public consumption throughout the world, and Indonesia was no exception. Rice is the main food commodity in Indonesia. However, there was no visible decrease in rice consumption during the pandemic, because rice is the staple food for the majority of the Indonesian population. Based on this, whether the one-year COVID-19 pandemic can affect rice consumption in Indonesia. The result of this research shows that the coefficient value of the interaction estimator has a negative coefficient. This shows that changes in independent variables during one year pandemic can lead to a decrease in people's rice consumption.

For further research, it is necessary to investigate rice availability and rice consumption after the COVID-19 pandemic. This is because this research only focuses on the pandemic situation before COVID-19.

AUTHOR CONTRIBUTIONS

The publication of our paper cannot be separated from the contributors who have helped in completing this research. Thanks to the first author to the third author who has assisted in collecting and processing data in statistical software R. And to the corresponding author in assisting in writing and interpreting research results.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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