Strategies for achieving targeted Indonesian rice self-sufficiency: A comprehensive policy analysis

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Abstract. Attaining self-sufficiency in rice production is paramount to Indonesia's food security and economic independence. This study attempts to formulate a national alternative policy to achieve a Self-Sufficiency Ratio (SSR) of 97.8% for Indonesia. Drawing on data sourced from reputable institutions spanning the years 1998 to 2018, we propose econometric models, which are subsequently analysed using Two-Stage Least Square (2 SLS) methodology. The study's findings highlight three critical strategies for achieving a 97.8% SSR in rice production: (a) focus on maximising productivity gains, (b) emphasise a balanced approach through expanding irrigated areas and enhancing productivity, and (c) advocate for a comprehensive approach involving increased irrigated areas, heightened productivity, and stricter import tariffs.

1 Introduction

Rice is a staple food for most Indonesians [1−3]. Unfortunately, although Indonesia is the 5th largest rice producer in the world [4,5], imports are still needed to fulfil the needs. Importing rice has been done since 1960 [6], stopped when Indonesia got self-sufficiency in 1984; however, in another year, Indonesia imported rice in large enough quantities [7,8]. According to Erwidodo [9], in 2005–2014, the ratio of import to total demand of rice in Indonesia was 2.2%, which meant that self-sufficiency was 97.8%, but Paipan and Abrar [10] said that the Self-Sufficiency Ratio (SSR) in 1997–2017 decreased by 96.6% and increased by 96.99% in 1998–2018 [11]. The Self-Sufficiency Ratio (SSR) gauges food resilience by assessing a country's capacity for meeting its needs through domestic production, calculated as the ratio of total domestic production minus exports to the sum of imports and domestic production [12].

Domestic rice production is one of the factors affecting Indonesia's rice imports [13]. Therefore, increasing domestic rice production is a strategic plan to improve SSR and food resilience. Production is the result of the multiplication between production area and productivity. The production area decreased by 1.6% during the 2010–2019 period [14] due to land conversion in Indonesia [15] and the decline of irrigation facility function [16], even

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damage [17]. Consequently, an appropriate strategy is to increase productivity. Based on China's experience [18,19] and Vietnam's and Thailand's, increasing productivity can be done through the use of hybrid seeds, improvement of irrigation facilities, and the use of balanced fertilisers [20]. Irrigation could increase production by extending irrigated areas for paddy cultivation and keeping enough water for plants to grow and reach high productivity.

Imports are a crucial aspect of international trade. Governments impose import tariffs to shield domestic producers from potentially cheaper foreign products, though this also raises the prices of imported goods [21]. This ripple effect on the domestic market leads to reduced consumption, heightened domestic prices, and increased local production [22]. In the context of rice, the Indonesian government, as per the Regulation of the Ministry of Finance number 180/PMK.011/2007, has set the rice import tariff at IDR 450 per kg, which remains unchanged. Raising the import tariff on rice can positively impact the Self-Sufficiency Ratio (SSR); as noted by Sayaka et al. [23], it tends to reduce rice imports. In pursuit of achieving an SSR of 97.8%, akin to the 2004–2015 period, this study seeks to propose various national alternative policies, focusing on augmenting productivity, expanding irrigated areas, and adjusting the import tariff for rice.

2 Methodology

2.1 Data Sources, concept and measurement

The study used secondary data from various national and international institutions related to rice between 1998 and 2018, such as the World Bank, Food and Agriculture Organization (FAO), United States Department of Agriculture (USDA), BPS-Statistics Indonesia, Ministry of Agriculture, and Ministry of Finance.

Self-sufficiency is the ability to fulfil the needs of domestic production. When domestic production cannot do so, imports are the answer, but the consequence is decreased self-sufficiency. Imports are a part of international trade; therefore, the domestic market of importing countries is affected by the global market. The proportion of total domestic production to the sum of imports and domestic production in which exports have reduced is known as the SSR.

2.2 The model and procedures for analysis

The study used a simultaneous equation model with a Two-Stage Least Square (2 SLS) method using eight simultaneous regression equations and four identity equations involving 45 variables have been arranged as follows:

$$PMIna = d_0 + d_1\, PW + d_2\, TMIna + d_3\, LPMIna \quad (1)$$
$$MIna = e_0 + e_1\, PW + e_2\, SMIna \quad (2)$$
$$DIna = f_0 + f_1\, PopIna + f_2\, PJIna + f_3 LDIna \quad (3)$$
$$PBIna = g_0 + g_1 DIna + g_2 LPBIna + g_3\, PMIna + g_4 PGIna \quad (4)$$
$$PGIna = h_0 + h_1 HPP + h_2 PBIna + h_3 MIna \quad (5)$$
$$APIna = i_0 + i_1 LPrIna + i_2 LPGIna + i_3 PUr + i_4 SAIIna \quad (6)$$
$$PrIna = j_0 + j_1 PGIna + j_2 PTSP + j_3 SAIIna \quad (7)$$
$$Xina = k_1 ERIna + k_2 LPW + k_3 DIna \quad (8)$$
$$YIna = APIna*PrIna/10 \quad (9)$$
$$QIna = 0.6302*Yina \quad (10)$$
$$SIna = QIna+MIna+StockIna-Xina \quad (11)$$

SSR = Production/(Production+Import-Export) …………………………… *(12)*

Description

Yina : Indonesian yield
QIna : Indonesian rice production
SIna : Indonesian supply
StockIna : Indonesian stock

Data were analysed using Statistical Analysis System/Econometric Time Series (SAS/ETS) software version 9.0, with the SAS SYSLIN procedure for estimation and SAS SIMNLIN for model simulation. The steps of the SAS analysis are described in Figure 1.

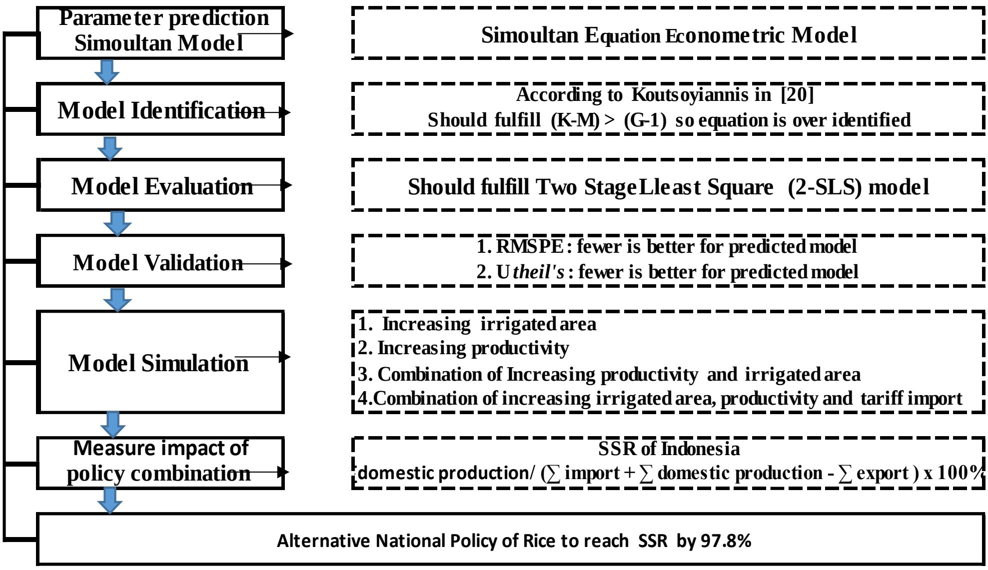

Fig. 1. Step by step of SAS analysis.

3 Results and Discussion

3.1 Simultaneous equation model evaluation

Model identification confirmed that all equations in the simultaneous model were clearly defined and eligible for further analysis. The model evaluation results (refer to Table 1) demonstrate that the developed simultaneous equation model accurately represents the estimation of policies to attain the targeted SSR for rice in Indonesia. The F-test values indicate that all the independent variables in each equation collectively exert a significant influence on the dependent variable. The coefficient of determination (R^2) falls within the range of 0.65 to 0.92, except for Indonesian imports and exports, signifying the independent variables' capacity to elucidate the dependent variable. Notably, the coefficient of determination for Indonesian imports and exports is less than 40%, attributable to extensive government intervention. Furthermore, based on the Durbin-Watson value, none of the equations exhibit signs of autocorrelation.

Table 1. Evaluation of the simultaneous equation model.

Simultaneous equation	Parameter				
	Model fitness test		R^2	Autocorrelation series test	
	F counted	Pr> F		DW	d_L – d_H
World price of rice	10.08	0.0004	0.72878	1.00692**)	0.92719 – 1.81157
Ind. price of imported rice	36.99	0.0001	0.87399	2.08101*)	1.02624 – 1.66942
Ind. domestic price of rice	26.94	<0.0001	0.87781	2.07077*)	0.92719 – 1.81157
Indonesian price of paddy	17.56	<0.0001	0.76702	1.04762**)	1.02624 – 1.66942
Indonesian demand	13.64	0/0001	0.71888	1.83545*)	1.02624 – 1.66942
Indonesian harvested area	30.99	<0.0001	0.89205	0.98714**)	0.92719 – 1.81157
Indonesian productivity	21.21	<0.0001	0.79908	0.87835**)	1.02624 – 1.66942
Indonesian import	4.67	0.0241	0.35474	0.83659**)	1.12461 – 1.53849
Indonesian export	3.90	0.0275	0.30284	2.28392*)	1.12461 – 1.53849

Note: *) no positive autocorrelation; **) no negative autocorrelation

3.2 Relationship among determinant variables in the domestic rice market

The relationship among the determinant variables in this study delineates how these factors interrelate to shape the performance of the domestic rice market (refer to Figure 2). The response of the dependent variable in the domestic market equation model is elaborated in Table 2.

1. The price of imported rice is positively and significantly influenced by the world price and the previous year's price of imported rice. Import tariffs, however, have a positive but not significant effect.
2. The price of rice is primarily affected positively and significantly by the previous year's price of rice. Demand, the price of imported rice, and the price of paddy have a positive but not significant effect.
3. The price of paddy is positively and significantly affected by the price of rice. Additionally, the government purchasing price has a positive effect, while imported rice has a negative but not significant effect.
4. Indonesian demand was significantly and positively affected by the previous year's Indonesian demand. The population and price of corn have a positive but not significant effect. Price is not included in the equation due to its unexpected positive impact on demand, contrary to the normal negative effect on demand [21]. This suggests that rice is not considered a normal good in Indonesia.
5. Harvested area is positively affected by the previous year's productivity significantly. Additionally, changes in irrigated areas have a negative impact. As indicated by Kementerian Pertanian [16], Indonesia's irrigated area is progressively diminishing due to a decline in its irrigation function. If this decline is rectified, the harvested area is expected to expand.
6. Indonesian productivity is positively and significantly affected by the price of paddy. Conversely, the price of TSP and changes in irrigated areas have a negative but not significant effect.
7. Indonesian imports are positively and significantly affected by changes in imports, while world prices have a negative but not significant effect.
8. Indonesian exports are positively and significantly influenced by the Indonesian exchange rate. The previous year's world price had a negative effect, although not significant, and Indonesian demand had a positive effect, albeit not significant.

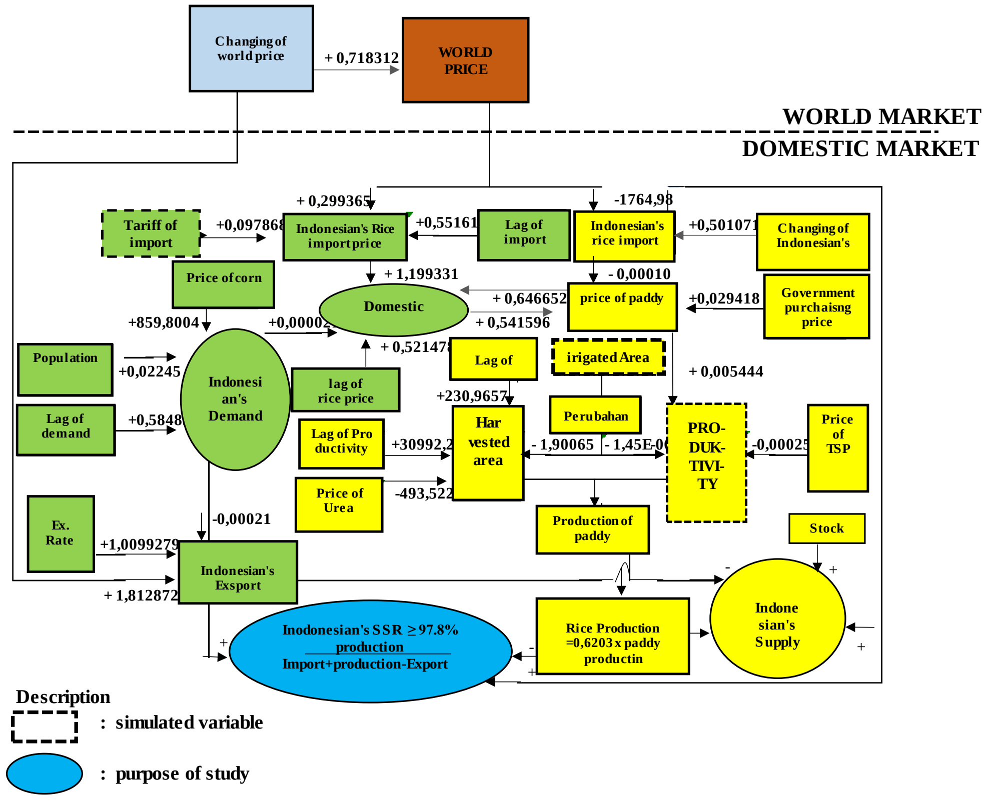

Fig. 2. Relationships among determinants in the Indonesian domestic rice market.

Table 2. Responses of the dependent variable to the independent variables in the Indonesian rice market.

Equation	Variable	Estimation parameter	Deviation standard	t-value	Pr>t
Price of imported rice					
Intercept	Intercept	-2.69127	47.4003	-0.06	0.9554
PW	World price of rice	0.299365***)	0.0712	4.20	0.0007
TMIna	Import tariff of rice	0.097868	0.0646	1.52	0.149
LPMIna	Lag of price of imported rice	0.551616***)	0.0898	6.14	<.0001
Price of rice in the domestic market					
Intercept	Intercept	-536.386	1.073.6420	-0.50	0.6246
DIna	Indonesian demand	0.000021	0.00006	0.33	0.7453
LPB	Lag of Indonesian price of rice	0.521478***)	0.14166	3.68	0.0022
PMIna	Price of imported rice	1.199331	1.10379	1.09	0.2944
PGIna	Indonesian price of paddy	0.646652	0.48222	1.34	0.1999
Price of paddy					
Intercept	Intercept	29.67437	525.3518	0.06	0.9557
HPP	Government purchasing price	0.029418	0.1893	0.16	0.8785
PBIna	Indonesian price of rice	0.541596***)	0.0852	6.36	<.0001
MIna	Indonesian imported rice	-0.0001	0.0001	-1.69	0.1112

Equation	Variable	Estimation parameter	Deviation standard	t-value	Pr>t
Indonesian demand					
Intercept	Intercept	8173427	10,976,953.10	0.74	0.4673
PopIna	Population of Indonesia	0.022458	0.0661	0.34	0.7386
PJIna	Indonesian price of maize	859.8004	1.198.3730	0.72	0.4834
LDIna	Lag of Indonesian demand	0.584831**)	0.2268	2.58	0.0202
Harvested area					
Intercept	Intercept	-2,,068,539	1.902,141	- 1.09	0.2940
LPrIna	Lag Indonesian productivity	309692.2***)	55,051	5.63	<.0001
LPGIna	Lag of Ind. price of paddy	230.9657	356.1624	0.65	0.5265
PUr	Price of Urea	-493.522	424.0981	- 1.16	0.2627
SAIIna	Changing of irrigated area	-1.90065***)	0.5669	- 3.35	0.0044
Indonesian productivity					
Intercept	Intercept	30,91505	3,5079	8,81	<.0001
PGIna	Price of paddy	0,005444***)	0,0007	7,40	<.0001
PTSP	Price of TSP	-0,00025	0,0012	-0,21	0,8353
SAIIna	Changing of irrigated area	-1,45E-06	1,7590E-06	-0,83	0,421
Indonesian imported rice					
Intercept	Intercept	1,936,022	711,129.7000	2.78	0.0145
PW	World price of rice	-1,764.98	1,707.6330	1.03	0.3158
SMIna	Changing Ind. imported rice	0.501071***)	0.1666	3.01	0.0079
Indonesian export					
ERIna	Indonesian exchange rate	1.099279**)	0.544390	2.02	0.0595
LPW	Lag of world price	1.812872	26.81878	0.07	0.9469
DIna	Indonesian demand	-0.00021	0,000384	-0.55	0.5918

3.3 Simultaneous equation model validation

The validation of the simultaneous equation model revealed that 75% of the equations demonstrated a prediction value, as denoted by an RMSPE value below 20%. However, it is noteworthy that only Indonesian imports and exports exhibited an RMSPE value exceeding 100%. This observation aligns with the UM, US, and UC criteria, where all equations demonstrated a U value below 0.1 (refer to Table 3). Consequently, the validation test affirms that the simultaneous equation model in this study is representative and possesses commendable predictive capabilities.

Table 3. Validation of simultaneous equation models.

Simultaneous equation	Validation of simultaneous equation model test				
	RMSPE	U^M	U^S	U^C	$U^M + U^S + U^C$
Ind. price of imported rice	8.916	0.00	0.21	0.79	1.00
Ind. domestic price of rice	13.862	0.00	0.43	0.57	1.00
Indonesian price of paddy	5.098	0.00	0.18	0.82	1.00
Indonesian demand	5.098	0.00	0.36	0.64	1.00
Indonesian harvested area	3.324	0.02	0.10	0.88	1.00
Indonesian produktivity	5.412	0.00	0.61	0.39	1.00
Indonesian import	162.700	0.20	0.09	0.72	1.01
Indonesian export	2,664.8	0.03	0.41	0.57	1.01

3.4 National alternative policy for rice

3.4.1 Policy simulation on Increasing irrigated area and productivity

Policy simulation involving a 15% expansion of the irrigated area, aligned with the government's program from 2015 to 2019, aims to gradually restore the declining irrigation facility function, which decreased by 70% until 2015 [16]. Theoretically, irrigation is crucial for regulating water availability in rice fields, ultimately leading to more frequent and extensive harvests. Additionally, irrigation ensures adequate optimisation of the plant water supply, growth, and productivity [24]. This heightened productivity is expected to result in increased production levels. The initial policy simulation (S1), entailing a 15% enlargement of irrigated area, led to a 0.13% augmentation in harvested area, a 0.03% rise in productivity, a 0.16% surge in both paddy and rice production, and a 0.0053% elevation in SSR (refer to Table 4).

Table 4. The impact of increasing irrigated area by 15%, productivity by 15%, and a combination of increasing irrigated area by 15% and increasing productivity by 15%.

Variable	Unit	Base value	Simulation result (%)		
			S1	S2	S3
Price of import	USD/ton	424.40	0.00	0.00	0.00
Price of rice	IDR/kg	6,080.80	0.00	0.00	0.00
Price of paddy	IDR/kg	3027.,20	0.00	0.00	0.00
Indoensian demand	tons	40,297,954	0.00	0.00	0.00
Import	tons	1,222,157	0.00	0.00	0.00
Harvested area	ha	12,982,904	0.13	0.00	0.13
Productivity	quintal/ha	48.43	0.03	15.0	15.03
Paddy production	tons	63,100,133	0.16	15.0	15.19
Rice production	tons	39,765,704	0.16	15.0	15.19
Indonesian export	tons	5,806.2	0.00	0.00	0.00
Indonesian supply	tons	46,064,822	0.14	12.95	13.11
SSR	%	96.9948	0.0053	0.3792	0,2876
SSR after simulation			97.0001	97.3740	97.3787

In the second policy simulation, a 15% increase in productivity led to a concurrent 15% increase in both paddy and rice production, resulting in a 12.95% boost in supply and a 0.3792% improvement in SSR. Theoretically, this productivity surge can be achieved through mechanisation and intensification. Employing harvesting machines in industrialisation can minimise losses [25], while automation enhances efficiency, driving productivity upwards. Intensification involves various strategies, such as the application of organic fertiliser [26], proper use of urea, optimising seed quantity, and implementing an effective planting system [27].

The third policy simulation entailed a combined 15% increase in both irrigated areas and productivity. This combination yielded a 0.13% expansion in the harvested area. Additionally, productivity surged by 15.03%, resulting in a 15.19% increase in both paddy and rice production. Furthermore, the SSR showed a 0.2876% improvement, reaching 97.3787%. Unfortunately, this SSR value fell short of the targeted SSR value, necessitating further policy simulations.

3.4.2 Policy simulation to reach targeted self-sufficiency ratio

The targeted SSR in this study mirrors the 97.8% SSR observed in the 2004-2015 period. With this goal in mind, subsequent policy simulations were conducted as follows: (S4) a substantial 38% increase in productivity; (S5) a combined increase of 3.75% in productivity and 15% in irrigated areas; and (S6) a combined increase of 3.7% in productivity, 15% in irrigated areas, and a 10% rise in rice import tariffs.

In the fourth policy simulation, a substantial 38% increase in productivity was implemented. Considering that the average productivity from 2008 to 2018 was 4.48 tons, this increase substantially boosted to 6.18 tons. This is plausible due to technological advancements such as smart farming [28,29] and the utilisation of hybrid seeds [30]. The impact of this productivity surge included a 0.13% increase in harvested area, a staggering 37.93% increase in both paddy and rice production, and a substantial 32.74% increase in supply. Additionally, SSR experienced a notable increase of 0.8035%, reaching 97.7983 (as illustrated in Table 5). With a 15% increase in irrigated area combined with a 37.5% increase in productivity, SSR could be achieved at 97.7985% (S5).

The sixth policy simulation entailed a 10% increase in rice import tariffs. This led to simultaneous effects, including a 0.0978 increase in the price of imported rice, a 1.1993 increase in rice in the domestic market, and a 0.5451 increase in paddy. The improved paddy pricing serves as an incentive for farmers, potentially boosting productivity by 0.0054. The addition of a 10% increase in rice import tariffs to the combination of a 10% increase in irrigated area and a 37% increase in productivity resulted in an SSR value of 97.7896% (S6).

Table 5. The impact of increasing productivity by 38%, combined with increasing productivity by 3.75% and irrigated area by 15%, combined with increasing productivity by 3.7%, irrigated area by 15%, and import tariffs of rice by 10%.

Variable	Unit	Base value	Simulation result (%)		
			S4	S5	S6
Price of import	USD/ton	424.40	0.00	0.00	1.39
Price of rice	IDR/kg	6,080.80	0.00	0.00	0.00
Price of paddy	IDR/kg	3,027.20	0.00	0.00	0.18
Indoensian demand	tons	40,297,954	0.00	0.00	0,18
Import	tons	1,222,157	0.00	0.00	0.00
Harvested area	ha	12,982,904	0.13	0.22	0.13
Productivity	quintal/ha	48.43	37.74	37.56	37.13
Paddy production	tons	63,100,133	37.93	37.88	37.31
Rice production	tons	39,765,704	37.93	37.88	37.31
Indonesian export	tons	5,806.2	0.00	0.00	0.00
Indonesian supply	tons	46,064,822	32.74	32.70	32.21
SSR	%	96.9948	0.8035	0.8037	0.7948
SSR after simulation			97.7983	97.7985	97.7896

4 Conclusions and policy recommendations

This study proposed three national alternative rice policies aimed at achieving a 97.8% SSR: (1) a 38% increase in productivity, (2) a combination of a 15% expansion in irrigated area alongside a 37.5% boost in productivity, and (3) a joint approach involving a 15% expansion in irrigated area, a 37% improvement in productivity, and a 10% rise in rice import tariffs.

Based on these findings, several policy implications emerge: (1) Sustain efforts to expand irrigated areas to ensure optimal land irrigation; (2) Implement hybrid seeds, mechanisation, and biotechnology and adopt smart-farming techniques for higher productivity; and (3) foster ongoing coordination, collaboration, and synergy between the government, farmers' groups, agricultural advisors, financial institutions, investors, academics, and other pertinent stakeholders. This collective effort is essential for significantly enhancing rice productivity and production.

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