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ARTICLE

Do International Oil Prices, Exchange Rates and Agricultural Credit Matter for Farmers' Term of Trade in Indonesia? Empirical Evidence of Multiple Thresholds and Asymmetric Effects

Arintoko Arintoko *, ***Herman Sambodo, Rakhmat Priyono***

Department of Economics and Development Studies, Faculty of Economics and Business, Universitas Jenderal Soedirman, Purwokerto 53122, Indonesia

ABSTRACT

Farmers still survive as a livelihood for some of the Indonesian population as the dominant economic sector shifts from agriculture to industry and services. This study investigates the influence of international prices of crude oil, fertilizer, and animal feed ingredients, as well as exchange rates, domestic inflation, agricultural credit, and food production indices on farmers' terms of trade (TOT). The study applies a Nonlinear Autoregressive Distributed Lag model with multiple thresholds. The data used are monthly data for the period January 2010 to October 2023. Through multiple thresholds, the negative impact of world oil prices is significant in the middle level of changes in oil prices on farmers' TOT. Fuel subsidies to farmer households allow the impact of significant changes in oil prices to dampen farmers' TOT. Depreciation of the rupiah exchange rate significantly reduces farmers' TOT. Conversely, appreciation significantly increases farmers' TOT. Domestic inflation has significantly pressured farmers' TOT in the short run, while agricultural credit significantly increased farmers' TOT. The food industry production index significantly encourages an increase in farmers' TOT. The subsidy programs, especially fuel and fertilizer subsidies directly to farmers, are the action to reduce the impact of rising prices of imported crude oil and fertilizer.

Keywords: Farmers' Terms of Trade; Nonlinear Autoregressive Distributed Lag Model; Multiple Thresholds;

*CORRESPONDING AUTHOR:
Arintoko Arintoko, Department of Economics and Development Studies, Faculty of Economics and Business, Universitas Jenderal Soedirman, Purwokerto 53122, Indonesia; Email: arintoko@unsoed.ac.id

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Asymmetric Effects; Fuel and Fertilizer Subsidies

1. Introduction

The agricultural sector is now increasingly considered vital in line with the shift in the economy from the agricultural sector to the industrial and service sectors as the largest contributor to output. The agricultural sector still has a major role in reducing poverty in rural areas, providing food, and being a source of food security, which requires sustainability [1]. The agricultural sector has become a key sector after the crisis due to the COVID-19 pandemic [2]. The sustainability of the agricultural sector cannot be separated from the role of farmers, who are one of the agricultural sector actors who still survive by making agriculture a livelihood. The current challenge of the agricultural sector in Indonesia is that fewer young farmers want to engage in the agricultural sector as a livelihood, while the existing farmers are getting older and decreasing in number. The regeneration of the profession as a farmer will depend significantly on whether the farming business can guarantee adequate income to meet one's living needs.

FTOT is one of the main indicators to reflect the performance of the agricultural sector [3]. The performance of the agricultural sector is closely related to the performance of agricultural businesses managed by farmers as one of the key actors in the agricultural sector in obtaining their income. One crucial measure that is still in use today to assess the viability of farming as a livelihood is the farmers' terms of trade (TOT). The farmers' TOT is a comparison between the price index received and the price index paid by farmers. As long as there are no other suitable indicators, farmer's TOT serves as a valuable indicator that can be used to measure the level of farmer welfare [4], because it measures the ability of the products produced by farmers to meet their needs for both the production process and household consumption [5]. Farmer's TOT with a value of more than 100 means that the results of farming can meet the needs of the farming household, whereas a value of less than 100 means that the results of farming cannot meet their living needs. An increase in farmers' TOT signifies a boost in farmer welfare, as it indicates that farming businesses are becoming more profitable in supporting farming operations and household consumption. Consistently increasing farmer's TOT will support the sustainability of farming as a reliable livelihood as a source of income to meet the needs of farmer households.

Indonesia is a prominent agricultural region. According to the World Bank report [6], around 43 percent of Indonesia's population lives in rural areas, and the workforce working in the agricultural sector is almost 29 percent. The contribution of primary agricultural production is 13.7 percent of GDP in 2020. The production performance of the Indonesian agricultural sector is currently still supported by imported products related to imported commodities, which are used as inputs and supporting materials, mainly fuel, fertilizer, and animal feed ingredients. The performance of agricultural businesses for farmers, who are the majority of actors in the agricultural sector, will be affected by the dynamics of imported commodity prices, which will impact net income and farmer welfare. On the other hand, apart from the local currency exchange rate, domestic factors such as inflation, agricultural sector credit, and production indices from the food industry have the potential to influence farmers' TOT.

So far, studies on farmer welfare as measured by farmers' TOT or similar measures in developing countries are still very limited. In general, previous studies on the price effects of oil, fertilizer and other agricultural inputs [7–14] only reaches the effects on the performance and results of agricultural activities and does not yet link it to the welfare of farmers as the main actors. Expressly in Indonesia, previous studies [15–19] regarding farmers' TOT are still limited to the country's macroeconomic and specific factors to agricultural conditions and farmer households. Few studies link farmers' TOT to the prices of inputs or supporting materials imported into the agricultural production process, even with asymmetric effects analysis.

This research develops the NARDL model to focus on asymmetric effects by applying thresholds for changes in international oil prices and the distinction between depreciation and appreciation of local currency on farmers' TOT, together with other explanatory variables. The emphasis is on asymmetric effects and global prices of crude oil, fertilizer, and animal feed ingredients because it considers these commodities, which are imported as inputs and supporting materials in the agricultural production process in Indonesia, in line with the dynamics of global market prices.

The asymmetric effect of oil prices, which is the focus of analysis in this study, is based on the premise that fuel oil is a supporting material in every agricultural production process. The impact of oil price changes is expected to differ for each level. Meanwhile, the asymmetric effect of exchange rate changes allows for an incomplete asymmetric exchange rate to pass through into import prices of agricultural inputs used in the agricultural production process. A previous study [20, 21] reported asymmetric effects of world oil prices and exchange rates on consumer prices, but the study has not linked this to farmers' TOT. The existence of an asymmetric exchange rate effect shows a difference in the effect between depreciation and appreciation of the local currency on farmers' TOT through its impact on production costs, which influence the price index farmers pay. Other explanatory variables, which are internal variables of a country, include the consumer price index (CPI), agricultural credit, and the food industry production index.

2. Literature Review

Farmers' TOT is the ratio of the price index received and paid by farmers. It is an indicator to measure farmers' level of ability or purchasing power in rural areas [22]. Farmers' TOT also shows the exchangeability (terms of trade) of agricultural products for goods and services consumed and production costs. The price index received by farmers depends on the price and sales volume of agricultural commodities. Meanwhile, the price index paid depends on the general price level, including the prices of goods and services required for farmer household expenditure, as well as the prices of inputs and supporting materials used in the production process.

World oil prices empirically increase the production costs of agricultural commodities [14]. The increase in oil prices has increased the production costs of food crops, and the increase in production costs, on the one hand, is transmitted to higher commodity prices and, on the other hand, causes a decrease in production levels [7]. In the farmers' TOT concept, an increase in production costs will reduce production and, in turn, reduce the price index received so that farmers' TOT decreases. From the expenditure aspect, an increase in imported oil prices will increase domestic fuel prices, increasing the price index paid by farmers and causing farmers' TOT to decrease. In economic theory, an increase in oil prices can increase agricultural prices through increases in input prices and transportation costs. The increase in global oil prices empirically increases domestic food prices, especially at high prices [23]. However, if production falls and farmer household expenditure increases, farmers' TOT can ultimately decline.

Fossil fuels are usually used to operate agricultural machinery [24]. Energy consumption in the agricultural sector is intended for various agricultural activities ranging from agricultural land preparation to the distribution of agricultural products [25, 26]. Energy consumption in agricultural activities generally depends on fossil fuels; for example, diesel fuel is needed for tractor and machine operations, and natural gas is used in irrigation activities, food processing, and fuel use in other agricultural activities [27]. The increase in oil and fertilizer prices contributes to increased production costs in agricultural activities because oil and fertilizer are the main production factors [13]. Rising energy prices also increase agricultural input costs [28]. The increase in oil prices directly impacts production costs and indirectly through increases in input prices, such as fertilizer, whose production process is affected by the increase in oil prices.

In agricultural activities, fertilizer is the primary input. An increase in fertilizer prices will reduce demand and use of fertilizer, thereby reducing farmers' production and income [9]. Empirically, increasing fertilizer prices reduces crop yields [8]. A decrease in crop yields certainly reduces farmers' income. The input costs of fertilizer provide a significant proportion of the total costs of rice farming, and an increase in fertilizer prices can reduce rice productivity [29]. A decrease in lowland rice productivity can reduce farmers' TOT, where food farming has a major contribution in determining farmers' TOT in Indonesia.

Global prices of animal feed ingredients can influence farmers' TOT. Consumption of feed containing high protein derived from soybean meal has been proven to increase the live weight of chickens [12], has an impact on improving fish growth performance [10], provides high protein nutrition to dairy cattle [11], increasing carcass in goat livestock [30]. So, soybean meal is generally the main ingredient for animal feed to increase livestock production. Changes in global soybean meal prices can affect the price of imported soybean meal as an animal feed ingredient in the country. The results of previous studies [31] reveal that reducing the price of soybean meal can reduce the price of chicken. On the other hand, an increase in feed costs generally increases the price of chickens and reduces demand for chickens.

Depreciation of the local currency impacts increasing import prices for agricultural inputs, thereby increasing production costs and reducing agricultural production. In previous research [7], empirical evidence was found of the negative impact of the exchange rate on the decline in food production, which led to reduced food availability. The impact of local currency depreciation on the import price of imported agricultural products is through incomplete exchange rate pass-through (ERPT) [32]. The incomplete ERPT allows changes in exchange rates to influence agricultural production costs that use imported inputs. The increase in production costs due to the ERPT impact can increase the price index paid by farmers who use imported agricultural inputs, ultimately reducing farmers' TOT. Previous research [19] has confirmed the negative effect of exchange rates on farmers' TOT.

Inflation impacts household spending. Previous research [33] shows that inflation significantly increases household expenditures. However, when inflation causes household purchasing power to fall, it can impact decreasing demand for agricultural products. Studies related to this issue [34] reveal that inflation, mainly from food inflation, has reduced demand for food. For farming households, inflation has the impact of increasing the price index paid relative to the price index received. Consequently, farmers' TOT will decrease, reducing farmer welfare. Likewise, a decrease in food demand because household purchasing power decreases due to inflation will impact farmers' sales, so the price index received decreases relative to the price index paid, reducing the farmers' TOT. Previous research [35] provides empirical evidence that inflation significantly reduces farmers' TOT in Indonesia.

Empirically, at the micro level, credit for farmers has an impact on increasing labor productivity and output. Previous research [36] provides empirical evidence that access to credit by rice farmers has increased farmer productivity and production. On the other hand, credit constraints farmers face negatively impact farmers' income and welfare. Empirically, previous research [37] reveals that credit constraints from banks have a negative impact on the welfare and income of wheat farmers. Agricultural credit is vital in agricultural investment, especially in procuring tools and machines used in various agricultural activities. Agricultural mechanization requires agricultural equipment and machines to increase productivity [38] In the context of farmer TOT, increasing productivity and output and access to credit will increase the price index received relative to the price paid index, thereby increasing farmers' TOT and, in turn, farmer welfare. Previous research [39] has confirmed the positive impact of credit on farmers' TOT.

Agricultural and industrial development can be integrated through agricultural and retail processing industries [40]. With the close link between the farm sector and the processing industry, agricultural businesses can have a positive impact through increasing demand for farm products when production in the food processing industry rises. Increasing food processing processes can increase demand for agricultural products. Previous research [41] states that the growth of the food industry has increased demand for agricultural products as inputs and raw materials, which has an impact on increasing welfare due to improving livelihoods for poor households in rural and urban areas. The increase in demand for agricultural products by the food industry will positively impact farmers' TOT through an increase in the price index received by farmers.

The linkage between the agricultural and industrial sectors can be related to the backward and forward linkage between the two sectors. However, a previous study [42] provides findings that backward linkage in the food industry is greater than forward linkage. It means that progress in the food industry will have a greater impact on encouraging the agricultural sector through demand for agricultural products as input for the food industry rather than supporting other sectors. This condition can positively impact the rural farming sector and farmers' TOT.

Based on the previous literature discussion regarding the determining factors of farmers' TOT, this study proposes the following hypotheses.

H1. *International oil prices have a negative effect on farmers' TOT.*

H2. *International fertilizer prices have a negative effect on farmers' TOT.*

H3. *International soybean meal prices have a negative effect on farmers' TOT.*

H4. *Exchange rate has a negative effect on farmers' TOT.*

H5. *Inflation has a negative effect on farmers' TOT.*

H6. *Credit of agricultural sector has a positive effect on farmers' TOT.*

H7. *Food industry production indexes have a positive effect on farmers' TOT.*

3. Research Methodology

3.1. Research Object

This study's object is farmers' TOT, which measures farmers' welfare from the income received from their farming business to meet their living needs. This study covers the Indonesian region, where farmers live in rural areas. Farmers' TOT data was obtained from BPS-Statistics Indonesia, which surveyed farmers throughout Indonesia through its samples and calculated farmers' TOT.

Indonesia is the largest archipelagic country in the world, flanked by two continents, Asia and Australia, and two oceans, the Indian and Pacific, as shown in **Figure 1**. Indonesia has a tropical climate because its territory is located along the equator. The tropical climate is suitable for plant growth, with sufficient sunlight, good rainfall, and an extended planting season that supports the sustainability of agricultural activities that are a source of livelihood for farmers, especially in rural areas. Because it gets a lot of sunlight and high rainfall, Indonesia has fertile soil that is very supportive of agricultural land that is suitable for farming activities for food crops, horticulture, plantations, and also inland fisheries. Meanwhile, marine and coastal areas also support fishing and marine fisheries activities. Moreover, most of the land in Indonesia is volcanic soil that contains high nutrients, so it is suitable for agriculture and plantations. These geographical conditions are advantageous for Indonesia as a country with an agricultural region that supports agrarian activities.

Figure 1. Map of Indonesia.

Indonesia's geographical conditions also greatly benefit world trade because its territory is part of the route passed by international trade. This condition also supports trading activities of production inputs and agricultural commodities.

Farmers who generally live in rural areas have different socio-economic characteristics from people who have other jobs in urban areas' formal and modern sectors. Farmers typically have lower education levels but larger family sizes than people in urban areas. Farmer households in rural areas also have relatively low levels of environmental sanitation. The farmer's welfare level depends on the land area, farming experience, and income received. Generally, the average level of farmer income is lower than that of non-agricultural workers, primarily found in urban regions' formal and modern sectors.

The agricultural environment in Indonesia is usually faced with various conditions and problems. Land degradation is the most critical problem. The wrong opening of new land, shifting cultivation, and forest burning are the main factors causing land degradation. In addition, damage to the soil body is also the main factor that causes agricultural land problems. The causes include high rainfall, erosion-sensitive soil, land slope, bad habits in opening new land, and burning forests. In addition, the decline in soil quality that can reduce land productivity can be due to excessive fertilization. Environmental disturbances are due to pesticide dependence to eradicate pests and plant diseases. Farmers generally have limited land in other environmental conditions and are getting narrower due to population growth, increasing settlements, and industrial areas. Typically, agricultural businesses are now also faced with the problem of climate change.

In the face of existing conditions and problems, how is the level of farmer welfare as measured by farmers' TOT influenced by factors outside environmental conditions. Through economic study and its backgrounds, these factors are international prices of agricultural input commodities, including oil, fertilizer, and soybean meal. In addition, exchange rates, inflation, agricultural credit, and food industry production that require input from agriculture also affect farmers' TOT.

3.2. Data and Variables

The explanatory variables in the model contain a set of external and internal variables of the country's economy. External variables include international prices of crude oil, fertilizer, and soybean meal and as exogenous variables of the country's economy and farmers' TOT. Meanwhile, internal variables include the local currency exchange rate, inflation, agricultural sector credit, and the food industry production index as exogenous variables of farmers' TOT. The definitions and measurements of the explanatory variables are summarized in **Table 1**.

The data analyzed in the study are monthly from January 2010 to October 2023. The beginning of this period was determined because the data used was wholly available and was in line with the start of data publication by BPS-Statistics Indonesia as the official data provider institution in Indonesia, especially for farmers' TOT and food industry production index. Apart from BPS-Statistics Indonesia, the data sources are Bank Indonesia and the World Bank. Bank Indonesia provides data for exchange rates, inflation, and credit in the agricultural sector. Meanwhile, the World Bank is the source of international crude oil, fertilizer, and soybean meal price.

3.3. Model

This research applies the Nonlinear Autoregressive Distributed Lag model previously developed[43] by applying several thresholds to international oil prices and combining them with exchange rates divided into depreciation and appreciation. Models with multiple thresholds have been developed in previous research[44, 45]. In this study, the multiple thresholds determine two thresholds of oil prices, i.e., 0.25 and 0.75. Applying this threshold is based on the assumption that the impact of rising oil prices is different at all levels. The effect of increasing oil prices on farmers' TOT can differ between low, moderate, and high levels, so there is an asymmetric effect. Specifically for the exchange rate, the impact on farmers' TOT is differentiated between increases and decreases in the exchange rate. An increase means depreciation of the rupiah, and a decrease means appreciation of the rupiah because the exchange rate is expressed in Rupiah per US Dollar. The influence of unfavorable and favorable changes in the exchange rate is expected to have an asymmetric effect on farmers' TOT. Other variables in the model are not substantively differentiated between increases and decreases and are assumed to have symmetric impacts. The general form of the NARDL model estimated in this study is expressed in Equation (1).

$$\begin{aligned} LFTOT_t = {} & \varphi_0 + \sum_{i=1}^{k} \beta_{1i} LFTOT_{t-i} + \sum_{i=0}^{l} \\ & \left(\beta_{2i}^{(\phi 1)} LPOIL_{t-i}^{(\phi 1)} + \beta_{2i}^{(\phi 2)} LPOIL_{t-i}^{(\phi 2)} + \right. \\ & \left. \beta_{2i}^{(\phi 3)} LPOIL_{t-i}^{(\phi 3)}\right) + \sum_{i=0}^{m} \beta_{3i} LPFER_{t-i} + \\ & \sum_{i=0}^{n} \beta_{4i} LPSM_{t-i} + \sum_{i=0}^{p} (\beta_{5i}^{+} LEXR_{t-i}^{+} + \\ & \beta_{5i}^{-} LEXR_{t-i}^{-}) + \sum_{i=0}^{q} \beta_{6i} LCPI_{t-i} + \\ & \sum_{i=0}^{s} \beta_{7i} LCRE_{t-i} + \sum_{i=0}^{w} \beta_{8i} LPIF_{t-i} + \varepsilon_t \end{aligned} \tag{1}$$

Table 1. Description of the variables in the model.

Variable	Abbreviation	Definition	Measurement	Data Source
Farmers' terms of trade	FTOT	Terms of trade from agricultural products to goods and services consumed and production costs	The ratio of the price index received and paid by farmers	BPS-Statistics Indonesia
Oil price	POIL	World average crude oil price of Brent, Dubai, and West Texas Intermediate (WTI) crude oil are the three main benchmarks for oil prices	US Dollar per barrel	World Bank
Fertilizer price	PFER	The world price of fertilizer, a composite of natural phosphate rock, phosphate, potassium, and nitrogen, is 16.9, 21.7, 20.1, and 41.3 percent, respectively.	Monthly indices based on nominal US dollars, 2010=100	World Bank
Soybean meal price	PSM	The price of soybean meal as an animal feed ingredient contains vegetable protein.	US Dollar per metric ton	World Bank
Exchange rate	EXR	The exchange rate is the exchange rate of the rupiah against the US dollar.	Rupiah per US Dollar	Bank Indonesia
Consumer price index	CPI	The consumer price index is a price index that measures the average price of all goods and services consumed by households.	Expressed in an index with a base year of 2012	Bank Indonesia
Credit of agricultural sector	CRE	Credit is provided by commercial banks, including rural banks, in rupiah and foreign currency for the sectors of agriculture, forestry, and fisheries.	Expressed in billions of rupiah	Bank Indonesia
Food industry production index	PIF	The monthly industry production index, specifically for large and medium industries, is classified under the food industry category	Expressed in an index with a base year of 2010	BPS-Statistics Indonesia

Note: all variables in the model are expressed in natural logarithms (ln).

From Equation (1), the NARDL model, which contains long-run and short-run parameters is expressed in Equation (2).

$$\begin{aligned}\Delta LFTOT_t &= \varphi_0 + \varphi_1 LFTOT_{t-1} + \varphi_2^{(\phi 1)} LPOIL_{t-1}^{(\phi 1)} \\ &+\varphi_2^{(\phi 2)} LPOIL_{t-1}^{(\phi 2)} + \varphi_2^{(\phi 3)} LPOIL_{t-1}^{(\phi 3)} + \varphi_3 LPFER_{t-1} \\ &+\varphi_4 LPSM_{t-1} + \varphi_5^{+} LEXR_{t-1}^{+} + \varphi_5^{-} LEXR_{t-1}^{-} + \\ &\varphi_6 LCPI_{t-1} + \varphi_7 LCRE_{t-1} + \varphi_8 LPIF_{t-1} + \\ &\sum_{i=1}^{k-1} \delta_{1i} \Delta LFTOT_{t-i} + \sum_{i=0}^{l-1} \left(\delta_{2i}^{(\phi 1)} \Delta LPOIL_{t-i}^{(\phi 1)}\right. \\ &\left.+\delta_{2i}^{(\phi 2)} \Delta LPOIL_{t-i}^{(\phi 2)} + \delta_{2i}^{(\phi 3)} \Delta LPOIL_{t-i}^{(\phi 3)}\right) + \\ &\sum_{i=0}^{m-1} \delta_{3i} \Delta LPFER_{t-i} + \sum_{i=0}^{n-1} \delta_{4i} \Delta LPSM_{t-i} + \\ &\sum_{i=0}^{p-1} \left(\delta_{5i}^{+} \Delta LEXR_{t-i}^{+} + \delta_{5i}^{-} \Delta LEXR_{t-i}^{-}\right) + \\ &\sum_{i=0}^{q-1} \delta_{6i} \Delta LCPI_{t-i} + \sum_{i=0}^{s-1} \delta_{7i} \Delta LCRE_{t-i} + \\ &\sum_{i=0}^{w-1} \delta_{8i} \Delta LPIF_{t-i} + \varepsilon_t\end{aligned} \quad (2)$$

Multiple threshold calculations with two thresholds specific to the 25th and 75th quantiles are as follows.

$$LPOIL_t^{(\phi 1)} = \sum_{i=1}^{t} \Delta LPOIL_i^{(\phi 1)} = \sum_{i=1}^{t} \Delta POIL_i | \left(\Delta POIL_i \leq \tau_{25}\right) \quad (3a)$$

$$LPOIL_t^{(\phi 2)} = \sum_{i=1}^{t} \Delta LPOIL_i^{(\phi 2)} = \sum_{i=1}^{t} \Delta POIL_i | \left(\tau_{25} < \Delta POIL_i \leq \tau_{75}\right) \quad (3b)$$

$$LPOIL_t^{(\phi 3)} = \sum_{i=1}^{t} \Delta LPOIL_i^{(\phi 3)} = \sum_{i=1}^{t} \Delta POIL_i | \left(\Delta POIL_i > \tau_{75}\right) \quad (3c)$$

Meanwhile, each is stated as follows to calculate the increase and decrease in the exchange rate.

$$LEXR_t^{+} = \sum_{j=1}^{t} LEXR_j^{+} = \sum_{j=1}^{t} max\left(LEXR_j, 0\right) \quad (4a)$$

$$LEXR_t^- = \sum_{j=1}^{t} LEXR_j^- = \sum_{j=1}^{t} min\left(LEXR_j, 0\right) \quad (4b)$$

From Equation (2), the long-run estimated and expected asymmetric parameters include the following.

$$-\frac{\varphi_2^{(\phi_1)}}{\varphi_1} < 0, -\frac{\varphi_2^{(\phi_2)}}{\varphi_1} < 0, -\frac{\varphi_2^{(\phi_3)}}{\varphi_1} < 0,$$
$$-\frac{\varphi_2^{(\phi_1)}}{\varphi_1} \neq -\frac{\varphi_2^{(\phi_2)}}{\varphi_1}, -\frac{\varphi_2^{(\phi_2)}}{\varphi_1} \neq -\frac{\varphi_2^{(\phi_3)}}{\varphi_1}, -\frac{\varphi_2^{(\phi_1)}}{\varphi_1} \neq -\frac{\varphi_2^{(\phi_3)}}{\varphi_1}$$
$$-\frac{\varphi_3}{\varphi_1} < 0, -\frac{\varphi_4}{\varphi_1} < 0,$$
$$-\frac{\varphi_5^+}{\varphi_1} < 0, -\frac{\varphi_5^-}{\varphi_1} < 0, -\frac{\varphi_5^+}{\varphi_1} \neq -\frac{\varphi_5^-}{\varphi_1}$$
$$-\frac{\varphi_6}{\varphi_1} < 0, -\frac{\varphi_7}{\varphi_1} > 0, -\frac{\varphi_8}{\varphi_1} > 0$$

The short-run model with error correction term (ECT) from Equation (2) is as follows.

$$\begin{aligned}&\Delta LFTOT_t = \varphi_0 + \textstyle\sum_{i=1}^{k-1} \delta_{1i} \Delta LFTOT_{t-i} + \\ &\textstyle\sum_{i=0}^{l-1} \left(\delta_{2i}^{(\phi 1)} \Delta LPOIL_{t-i}^{(\phi 1)} + \delta_{2i}^{(\phi 2)} \Delta LPOIL_{t-i}^{(\phi 2)} + \right. \\ &\left. \delta_{2i}^{(\phi 3)} \Delta LPOIL_{t-i}^{(\phi 3)}\right) + \textstyle\sum_{i=0}^{m-1} \delta_{3i} \Delta LPFER_{t-i} + \\ &\textstyle\sum_{i=0}^{n-1} \delta_{4i} \Delta LPSM_{t-i} + \sum_{i=0}^{p-1} \left(\delta_{5i}^{+} \Delta LEXR_{t-i}^{+} + \right. \\ &\left. \delta_{5i}^{-} LEXR_{t-i}^{-}\right) + \textstyle\sum_{i=0}^{q-1} \delta_{6i} \Delta LCPI_{t-i} + \\ &\textstyle\sum_{i=0}^{s-1} \delta_{7i} \Delta LCRE_{t-i} + \sum_{i=0}^{w-1} \delta_{8i} \Delta LPIF_{t-i} + \\ &ECT_{t-1} + \varepsilon_t\end{aligned} \quad (5)$$

and the equation of ECT:

$$\begin{aligned}&ECT_{t-1} = LFTOT_{t-1} - (\gamma_1^{(\phi 1)} LPOIL_{t-1}^{(\phi 1)} + \\ &\gamma_1^{(\phi 2)} LPOIL_{t-1}^{(\phi 2)} + \gamma_1^{(\phi 3)} LPOIL_{t-1}^{(\phi 3)} + \\ &\gamma_2 LPFER_{t-1} + \gamma_3 LPSM_{t-1} + \gamma_4^{+} LEXR_{t-1}^{+} \\ &+\gamma_4^{-} LEXR_{t-1}^{-} + \gamma_5 LCPI_{t-1} + \gamma_6 LCRE_{t-1} \\ &+\gamma_7 LPIF_{t-1})\end{aligned} \quad (6)$$

The expected ECT value is between -1 and 0, indicating that the short-run disequilibrium will be corrected towards equilibrium in the long run.

To ensure the robustness of the NARDL model in this study, a comprehensive battery of unit root tests was conducted. These tests rigorously confirm that all variables are stationary at level, I(0) and/or at the first difference, I(1), and that there are no variables that are stationary at the second difference, I(2). Model estimation results, based on the selected model with optimal lag, require further relevant tests, such as testing for the existence of long-run relationship, asymmetric effects, model stability, and model diagnostic, particularly related to serial correlation and heteroscedasticity problems. Unit root tests employ the augmented Dickey-Fuller (ADF), DF GLS, and Phillips–Perron (PP) tests. The existence of a long-run relationship is tested using the bound test.

4. Results and Discussion

4.1. Results

A statistical description of the variables in the model is shown in **Table 2**. The statistical description shows the various statistics for each variable. Farmers' TOT (FTOT) has the lowest variation in statistical characteristics, as indicated by the slightest standard deviation and range. Farmers' TOT of more than 100 means that the results of the farming business can meet the needs of the farmer's household, while less than 100 means that the results of the farming business cannot meet the living needs of the farmer's household. The range is the difference between the maximum and minimum values. Among the three international commodity prices, crude oil and soybean meal prices have a relatively large standard deviation-range ratio compared to fertilizer prices. Statistical characteristics show that crude oil and soybean meal prices are the most volatile.

Table 2. Descriptive statistics of the variables.

Variable	Mean	Median	Maximum	Minimum	Std. Dev.
FTOT	103.7537	103.0150	115.7800	99.4700	2.8554
POIL	75.1514	74.3500	117.7900	21.0400	23.9795
PFER	115.8015	100.3350	293.7300	67.8200	47.0829
PSM	444.1719	422.3450	651.3500	319.1300	85.3867
EXR	12639.02	13424.50	16367.00	8508.000	2247.217
CPI	123.6246	126.4450	154.7900	88.2600	19.6154
CRE	284381.6	291853.5	513132.0	69249.00	131524.7
PIF	169.5850	170.6450	249.5100	91.8000	43.3795

Meanwhile, exchange rates (EXR) tend to be more volatile among internal variables. An increase in the exchange rate indicates depreciation of the rupiah, and conversely, a decrease in the exchange rate indicates appreciation of the rupiah. However, internal variables, i.e., the exchange rate, CPI, agricultural credit, and the food industry production index, fluctuate but tend to increase in the long run.

Table 3 summarizes the correlation between farmers' TOT and each explanatory variable with two lags and two leads. With increasing lag and lead, the absolute correlation coefficients decrease with varying degrees. The strongest correlation occurs between farmers' TOT and the soybean meal prices, while the weakest correlation occurs between farmers' TOT and the food industry production index. The statistical characteristics related to correlation with lag and lead are in line with the properties of the NARDL model, which is a dynamic model. Explanatory variables can influence farmers' TOT, which is possible by requiring a time lag.

Table 3. Correlation between variables in the model.

Correlation		i	Lag	Lead
With Lag	With Lead			
LFTOT, LPOIL(ϕ1)(−i)	LFTOT, LPOIL(ϕ1)(+i)	0	−0.3784	−0.3784
		1	−0.3753	−0.3332
		2	−0.3737	−0.2945
LFTOT, LPOIL(ϕ2)(−i)	LFTOT, LPOIL(ϕ2)(+i)	0	0.4772	0.4772
		1	0.4744	0.4334
		2	0.4691	0.3943
LFTOT, LPOIL(ϕ3)(−i)	LFTOT, LPOIL(ϕ3)(+i)	0	0.5217	0.5217
		1	0.5162	0.4686
		2	0.5102	0.4233
LFTOT, LPFER(−i)	LFTOT, LPFER(+i)	0	0.7491	0.7491
		1	0.7474	0.7143
		2	0.7469	0.6769
LFTOT, LPSM(−i)	LFTOT, LPSM(+i)	0	0.5572	0.5572
		1	0.5407	0.5443
		2	0.5236	0.5261
LFTOT, LEXR+(−i)	LFTOT, $LEXR^+$(+i)	0	0.2928	0.2928
		1	0.2830	0.2537
		2	0.2752	0.2196
LFTOT, LEXR−(−i)	LFTOT, $LEXR^-$(+i)	0	−0.3978	−0.3978
		1	−0.3934	−0.3507
		2	−0.3894	−0.3103
LFTOT, LCPI(−i)	LFTOT, LCPI(+i)	0	0.2703	0.2703
		1	0.2594	0.2358
		2	0.2490	0.2050
LFTOT, LCRE(−i)	LFTOT, LCRE−(+i)	0	0.2438	0.2438
		1	0.2316	0.2107
		2	0.2194	0.1814
LFTOT, LPIF(−i)	LFTOT, LPIF(+i)	0	0.2417	0.2417
		1	0.2384	0.1909
		2	0.2333	0.1564

The results of unit root tests with the ADF, DF GLS, and Phillips-Perron tests, reported in **Table 4**, show that all variables are not stationary at the level except for the food industry production index (LPIF). These variables are stationary at the first difference. So, all variables are I(1), except LPIF, which is I(0). The order of integration combination of I(0) and I(1) in this model suggests that NARDL can be applied.

Table 4. Unit root test results.

Variable		ADF Test	DF GLS Test	PP
In level	LFTOT	−0.4848	−1.1327	−0.2596
	LPOIL(ϕ1)	−2.4995	−1.5395	−2.4079
	LPOIL(ϕ2)	−1.7349	−1.7394	−1.7573
	LPOIL(ϕ3)	−1.3417	−0.8941	−1.0756
	LPFER	−1.3281	−1.3917	−1.4532
	LPSM	−2.7891	−2.8121*	−1.7430
	LEXR$^+$	−1.6614	−1.6058	−1.9959
	LEXR$^-$	−1.8653	−1.7428	−2.0417
	LCPI	−1.2811	−0.3958	−1.0431
	LCRE	−2.4605	−0.3402	−2.2608
	LPIF	−4.0407***	−3.1107**	−5.7988***
In first difference	LFTOT	−9.2739***	−9.0929***	−9.2166***
	LPOIL(ϕ1)	−8.3999***	−8.3314***	−7.2378***
	LPOIL(ϕ2)	−13.275***	−12.677***	−13.2725***
	LPOIL(ϕ3)	−9.6698***	−8.7485***	−9.4112***
	LPFER	−10.385***	−9.9497***	−10.5068***
	LPSM	−8.3192***	−7.8212***	−7.7580***
	LEXR$^+$	−10.9618***	−10.446***	−11.0243***
	LEXR$^-$	−12.4045***	−9.8980***	−12.4126***
	LCPI	−11.0211***	−10.6332***	−9.0784***
	LCRE	−10.9203***	−4.5050***	−13.9996***
	LPIF	−9.0182***	−18.7726***	−26.0066***

*** significant at α = 0.01 ** significant at α = 0.05 * significant at α = 0.1.

The results of the bound test on the NARDL model show that there is a long-run relationship between farmers' TOT and a set of explanatory variables. **Table 5** reports that the F-statistics of the bound test exceed the critical values of the lower and upper bound at p-values 0.1, 0.05, and 0.01. This result rejects the null hypothesis and means a long-run relationship exists between farmers' TOT and the explanatory variables in the model. The selected NARDL model based on the optimal lag is ARDL(3, 1, 0, 0, 2, 5, 1, 0, 1, 2, 4) from ARDL(k, l(ϕ1), l(ϕ2), l(ϕ3), m, n, p(+), p(−), q, s, w) as in Equation (1).

The model with the selected optimal lag, which contains long-run relationships based on the CUSUM test, satisfies the model stability in the studied period, as shown in **Figure 2**. The diagnostic test results on the model also conclude that the model has passed the problems of serial correlation and heteroscedasticity. The results of the Breusch-Godfrey Serial Correlation LM test with a p-value of $\chi^2\,(5)$ accept the null hypothesis, which states there is no serial correlation. The results of the ARCH test with a p-value of $\chi^2\,(5)$ also conclude that the null hypothesis, which states no conditional heteroscedasticity of the residual series, is accepted, which means there is no heteroscedasticity. For the model stability test, the test results with the CUSUM test, as shown in **Figure 2**, show that the model stability assumption is met.

Table 6 summarizes the NARDL estimation results for long-run parameters along with asymmetric effect tests for multiple threshold effects of changes in oil prices and asymmetric effects for exchange rate changes, namely between depreciation and appreciation. In the long run, changes in oil prices have a significant negative impact on farmers' TOT only between the 25th and 75th quantiles. Changes in oil prices in the middle quantile (LPOIL(ϕ2)) have a significant negative impact on farmers' TOT, while changes in oil prices in the lower (LPOIL(ϕ1)) and upper (LPOIL(ϕ3)) quantiles are not significant. At the lower quantile, the decrease in oil prices does not significantly increase the farmers' TOT; at the upper quantile, the increase in oil prices does not considerably reduce the farmers' TOT. An increase in oil prices significantly reduces farmers' TOT in the middle quantile. Therefore, a significant asymmetric effect ex-

Table 5. Bound tests for long-run relationship.

F-Statistic	p-Value	I(0)	I(1)	Conclusion
4.8432	0.1	1.76	2.77	Ho is rejected
	0.05	1.98	3.04	
	0.01	2.41	3.61	

H_0: No long-run relationships.

ists between the lower, middle, and upper quantiles, especially between the lower and middle quantiles, and between the middle and upper quantiles, as shown in the Wald test results reported in **Table 6**. Meanwhile, the price of fertilizer and soybean meal significantly positively affects farmers' TOT in the long run.

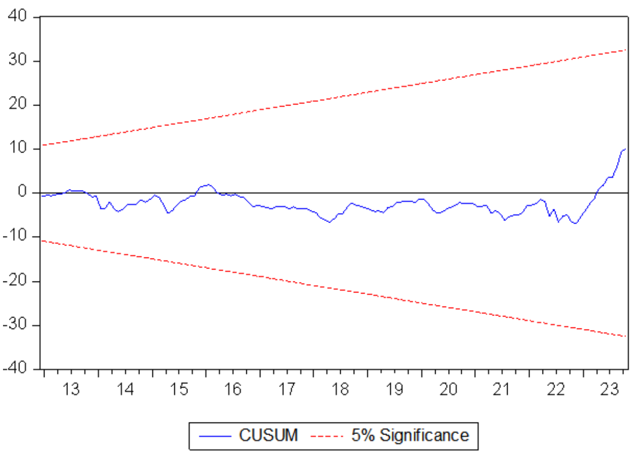

Figure 2. Model stability test result.

Changes in exchange rates have a significant impact on farmers' TOT. Depreciation of the rupiah ($LEXR^+$) significantly reduces farmers' TOT; conversely, appreciation of the rupiah ($LEXR^-$) increases farmers' TOT. The parameter differences are estimated to be insignificant using the Wald test, so it is concluded that there is no asymmetric effect on the influence of the exchange rate on farmers' TOT. Meanwhile, inflation has no significant impact on farmers' TOT. However, agricultural credit has a negative effect on farmers' TOT. Finally, the food industry production index significantly positively affects farmers' TOT in the long run.

The results of short-run parameter estimation as presented in **Table 7** show that farmers' TOT in the past months drove farmers' TOT. The decline in oil prices at the lower quantile decreases farmers' TOT. Meanwhile, changes in fertilizer prices have significantly driven down farmers' TOT. However, changes in soybean meal prices do not substantially affect farmers' TOT based on total effects. Likewise, the rupiah depreciation does not significantly reduce farmers' TOT. In the short run, inflation significantly reduces farmers' TOT, while agricultural credit significantly increases farmers' TOT. This empirical evidence is in line with expectations. However, the food industry production index has a negative effect on farmers' TOT in the short run. A small ECT value indicates that the short-run imbalance corrected to reach long-run equilibrium requires a long adjustment time of approximately 1/0.0895 or 11.17 months.

Farmers' TOT estimation applying the NARDL model provides estimation results that are close to the actual farmers' TOT as shown in **Figure 3**. These results indicate a minimum error term that is stochastic in nature. Therefore, the NARDL model applied in this study shows its ability to explain the dynamics of farmers' TOT by a set of variables that influence it.

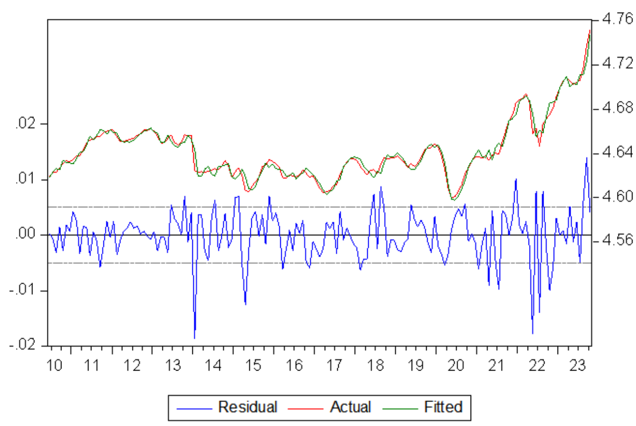

Figure 3. Actual and estimated farmers' TOT.

4.2. Discussion

The increase in crude oil prices only significantly reduces farmers' TOT in the middle quantile. According to Fukuda [14], an increase in oil prices can increase the production costs of agricultural commodities. The increase in production costs can then cause an increase

Table 6. Results of the multiple threshold nonlinear ARDL and asymmetric effect estimation for long-run model (Response variable: LFTOT).

Regressor	Coefficient	Wald T Statistic for Asymmetric Test	Conclusion
LPOIL(ϕ1) LPOIL(ϕ2) LPOIL(ϕ3)	−0.0363 −0.3900** −0.0299	1.8446* (H0: $-\frac{\varphi_2^{(\phi_1)}}{\varphi_1} = -\frac{\varphi_2^{(\phi_2)}}{\varphi_1}$) −1.9134* (H0: $-\frac{\varphi_2^{(\phi_2)}}{\varphi_1} = -\frac{\varphi_2^{(\phi_3)}}{\varphi_1}$) −0.1627 (H0: $-\frac{\varphi_2^{(\phi_1)}}{\varphi_1} = -\frac{\varphi_2^{(\phi_3)}}{\varphi_1}$)	Asymmetric effect between level changes in world oil prices
LPFER LPSM	0.0545** 0.1266**		
LEXR$^+$ LEXR$^-$	−0.5274** −0.8030**	1.0350 (H0: $-\frac{\varphi_5^+}{\varphi_1} = -\frac{\varphi_5^-}{\varphi_1}$)	No asymmetric effect between depreciation and appreciation of rupiah
LCPI LCRE LPIF	0.4698 −0.3744** 0.9358**		

** significant at α = 0.05 * significant at α = 0.10.

in the price index paid by farmers. At the upper level, the increase in oil prices does not significantly reduce farmers' TOT, which is made possible by fuel subsidies' impact on farmers. The advantage of fuel subsidies when world crude oil prices increase for farmers is that farmers' expenditure is more controlled, especially for fuel expenditure in the composition of household expenditure and agricultural production costs, so that the increase in the index paid by farmers can be relatively restrained. On the other hand, increasing market prices for agricultural commodities triggered by high oil price increases can benefit farmers by increasing the index farmers receive.

International fertilizer prices do not significantly impact farmers' TOT but even show a positive impact. The role of fertilizer subsidies for farmers is to save expenditure on fertilizer so that it has a positive effect on reducing the index paid by farmers, and efficiency in fertilizer expenditure can also increase production and income, thereby increasing the price index received by farmers. Previous studies provide empirical evidence that fertilizer subsidies to farmers can increase production and income [46] and the productivity of smallholder farmers [47]. On the other hand, the potential increase in market prices for agricultural commodities triggered by an increase in fertilizer prices, in general, could positively impact farmers because agricultural product revenues could increase. This condition can encourage an increase in farmers' TOT.

The price of soybean meal does not significantly negatively affect farmers' TOT. Therefore, soybeans may not significantly affect production costs and livestock prices, so they do not significantly negatively affect the farmers' TOT, where livestock activities are only part of the farming business, which is considered in the farmers' TOT. In livestock production, flexibility in the use of soybean meal is possible because soybean meal is substituted for corn in the animal feed composition [31, 48]. Efficiency due to the substitution of soybean meal with other ingredients, on the one hand, and the trend of increasing agricultural commodity prices triggered by the increase in global agricultural commodity prices can positively impact farmers through an increase in farmers' TOT.

In the short run, the increase in CPI, which indicates significant inflation, reduces farmers' TOT. Inflation has a negative impact on farmers' TOT because inflation tends to increase the index of prices paid relative to the index of prices received by farmers, thereby reducing farmers' TOT. The increase in inflation has an unfavorable impact on the index of prices paid by farmers through increases in household expenditure and production costs rather than the index of prices received from selling their products. These results are in line with previous research findings [35, 49].

In the short run, credit provided to the agricultural

Table 7. Estimated short-run parameters and error-correction term (ECT).

Regressor	Coefficient	Total Effect	Wald T Statistic
LFTOT(−1) LFTOT(−2)	0.1189** 0.1777***	0.2966	2.5202**
LPOIL(ϕ1)	0.0141**	0.0141	1.8706**
LPFER LPFER(−1)	0.0044 −0.0219***	−0.0175	−1.7990*
LPSM LPSM(−1) LPSM(−2) LPSM(−3) LPSM(−4)	0.0208*** −0.0093 0.0009 −0.0052 −0.0272***	−0.0200	−1.2352
LEXR$^+$	0.0119	0.0119	0.3914
LCPI	−0.4026***	−0.4026	−3.9506***
LCRE LCRE(−1)	0.0595*** 0.0456**	0.1052	2.0873**
LPIF LPIF(−1) LPIF(−2) LPIF(−3)	0.0333*** −0.0384*** −0.0285*** −0.0157**	−0.0493	−1.7762*
ECT(−1)	−0.0895***		

*** significant at α = 0.01 ** significant at α = 0.05 * significant at α = 0.10.

sector significantly increases farmers' TOT. Access to bank credit supports ease in fulfilling financing, especially working capital in production operations, thereby increasing farmers' TOT. These findings support previous research [39]. Agricultural credit in Indonesia is generally given to farmer groups. Farmers' TOT can increase through increasing efficiency and productivity due to increasing credit access. Access to credit significantly increases the efficiency and productivity of farming [50] and increases production and income, improving farmer welfare [51]. Farmers' access to credit determines their decisions to use quality seeds and fertilizer, impacting crop productivity [52]. Also, credit with cheap interest for farmers as an implementation of agricultural credit priorities is aimed at not burdening interest costs, which allows an increase in the price index paid by farmers, thereby reducing farmers' TOT in the long run.

The study results provide empirical evidence that increasing the food industry production index significantly increases farmers' TOT in the long run. These results confirm the results of previous research [41, 42] that increasing food industry production increases demand for agricultural commodities as production inputs, increasing farmers' welfare. The demand for agricultural commodities impacts increasing the index received by farmers.

5. Conclusion and Policy Implication

5.1. Conclusions

In the long run, the increase in world oil prices at the middle level and the depreciation of the rupiah significantly reduce farmers' TOT, while the appreciation of the rupiah and the food industry production index increase farmers' TOT, which is in line with the hypothesis expectations in the research model. The fuel and fertilizer subsidy program helps farmers when global crude oil and fertilizer prices increase, which can prevent a decrease in farmers' TOT. In the short run, increases in fertilizer prices and inflation significantly reduce farmers' TOT, while increases in agricultural credit significantly increase farmers' TOT. Changes in farmers' TOT in Indonesia may be more determined by changes in the price index paid by farmers, which are more responsive to the factors that influence it. Meanwhile, changes in the price index received by farmers are relatively slow and rigid due to changes in factors that influence it, for example, due to the low bargaining position of farmers. Adjustments to market prices for agricultural products are slower than adjustments to commodity prices paid by farmers, such as fuel, fertilizer, inputs, and other supporting materials, making them vulnerable to a decrease in farmers' TOT.

5.2. Policy Implication

The results of this study provide several policy implications and suggestions. The existing fuel and fertilizer subsidy program needs to be improved so that its implementation system is better targeted at farmers and livestock breeders. Fuel subsidies must again focus on special fuel subsidies for machinery and equipment and supporting materials in the agricultural process, including providing fuel gas stations for agriculture. Associations of farmer groups need to be involved in determining subsidy recipients so that they are right on target.

Stabilization of inflation and exchange rates in monetary policy will really help farmers' welfare to keep farmers' TOT from declining if extreme depreciation and inflation spikes occur. Furthermore, agricultural financing priorities in supporting food security and farmers' prosperity need to be supported by agricultural credit policies with systems and implementation that continue to be improved. Agricultural credit with low interest will be able to help farmers' welfare by increasing farmers' TOT in the long run. Development of integrated economic sectors to focus more on strengthening links between the agricultural and industrial sectors so that the food industry is able to support the agricultural sector.

Author Contributions

Model design, data collection and data analysis, and final manuscript, A.A.; research problem formulation, literature review, and final article approval, H.S.; results discussion, conclusion formulation and final article review and approval, R.P.

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Not applicable.

Data Availability Statement

Data will be provided and can be accessed upon request.

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Conflicts of Interest

All authors declare no any conflict of interest.

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