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Oil Price Effects on Land Use Competition – An Empirical Analysis

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Oil Price Effects on Land Use Competition

An Empirical Analysis

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Matthias Diermeier and Torsten Schmidt¹

Oil Price Effects on Land Use Competition – An Empirical Analysis

Abstract

The increasing use of food commodities for biofuel production has substantial impact on prices and quantities of these and other food commodities. It is therefore likely that this trend also intensifies the competition for arable land. However, evidence for this hypothesis is generated by calibrated models while empirical evidence is rare. In this paper we analyze the effects of crude oil price and prices of input factors for biofuel production on prices, areas and quantities of selected food commodities empirically performing Granger causality and cointegration tests as well as calculating impulse response functions. On the world aggregated level we reveal that the crude petroleum price only Granger causes the price of maize and wheat but the area used for the production of maize, soybean oil, sugar and wheat. The effect on wheat indicates an indirect effect on land use. Moreover, the price index of fats and oils has a stronger effect on prices, areas and quantities of other food commodities. At the country level, we identify that for the U.S., the maize price is the key variable influencing area and quantity of cereals. Additionally, in Indonesia and Malaysia we find that the palm oil price has significant effects on the area and quantity of rice. Despite these positive effects of commodity prices on land use we find no evidence for direct land competition between oil crops and cereals..

JEL Classification: L71, Q11, Q42, C32

Keywords: Biofuel; food commodity prices; crude oil price; Granger causality; cointegration

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1. Introduction

Biodiesel and ethanol production have seen an impressive growth in the last decades that will likely proceed or even accelerate in the future. Biofuel has become an energetic alternative of growing importance due to limited supply of fossil fuels and a lasting period of historically high crude oil prices. Rising demand from upcatching developing countries will likely further enhance the importance of alternative fuels. Although possibly being a less greenhouse gas (GHG) emitting source of energy, the production of biofuel are associated with high financial costs (Peters, Thielmann 2008). In addition, rising demand for energy crops is likely to increase competition for arable land, implying the risk of further pressure on food commodity prices and deforestation.

The relations between crude petroleum prices, food commodity prices and land use competition have been analyzed in several studies. The link between crude petroleum prices and food commodity prices has been investigated mainly empirically. The overall results indicate that there are effects from crude petroleum prices to food commodity prices but their strength varies between commodities and time periods. In addition, several studies argue that a causal link between biofuel production and land use exists. However, most of these studies use general equilibrium models. Within these models a direct land competition effect and an indirect displacement effect are distinguished. The effect of indirect land use competition (iLUC) leads to deforestation due to oil crops replacing cereals, which have to move to forested grounds.¹ These models are based on assumptions about causal relationships that have not been tested. This means that whether these channels are empirically significant is still an open question.

In this study, we analyze the effects of commodity price movements on land use change empirically. Following the studies on the oil-food price co-movement, we perform Granger causality tests of price changes and land use change as well as cointegration tests. In fact, we find that after controlling for economic activity on an aggregated world level, crude petroleum prices Granger cause the prices of maize and wheat. In addition, we find significant effects from crude petroleum prices to the area harvested of maize, soybean oil, sugar and wheat. The effect on the area of wheat can be regarded as evidence of indirect land use competition. However, for other

¹ The iLUC concept defines the conversion of areas to cropland due a displacement of acres for the cultivation of oil crops (Kim and Dale 2011).

important input factors for biofuel production such as palm oil we find no Granger causal effects from crude petroleum prices. As indicated by impulse responses most of these effects are positive. We thereby fail to find a direct displacement effect of land use competition – which would have been e.g. soybean acres negatively influencing wheat acres.

Analyzing the influence of an increase in the fats and oils price index, we find an indirect effect on area and quantities of the main alimentation crops. We conclude that on a world aggregated level there seems to be sufficient waste arable land so that there is no direct competition between oil crops and cereals. Nevertheless, the use of area harvested for the production of biofuel seems to lead to indirect land use change (iLUC) increasing the acres of most of the analyzed crops.

To gain further insights in the direct and indirect effects on land use change we analyze crude petroleum price effects as well as the effects of maize price changes in the US as well as palm oil prices changes in Indonesia and Malaysia in more detail. Our results suggest that the oil price triggers the area and quantity of cereals and maize in conjunction with an accelerating second round effect from maize prices on cereals and wheat. This substitution effect is caused by the use of a high percentage of U.S. maize in the ethanol production.² Additionally, for the two main palm oil³ producers Indonesia and Malaysia (accounting for 85% of palm oil production FAO 2012) we reject a first round effect from the petroleum to the rice area but find an effect from the palm oil price on the area and quantity of rice.

The outline of the paper is as follows: Section 2 summarizes the main findings of the recent literature. Section 3 presents the data and the empirical methods used. The results are discussed in section 4. Section 5 concludes.

2. Literature Review

Empirical findings on price linkages between the crude petroleum and food commodity markets are ambiguous. Rosegrant (2008) on the one hand, claims that food prices and fuel prices are highly correlated. He states that from the pre-crisis commodity price hike 2000-2007 even 30% of the grain price increase was accounted for by skyrocketing biofuel demand. On the other hand,

² The proportion of US-maize used for ethanol production is already above 25% (USDA 2012).

³ Palm oil is the most important edible oil. A share of more than 20% is used for industrial production. The largest share is used for biodiesel production (USDA 2010).

Campiche et al. (2007) investigate the price behavior of crude oil, corn, soybean and several edible oils using weekly data from 2003-2007 and reject a significant correlation between crude oil and corn. However, they do find a significant relation between crude oil and soybeans changing from negative to positive for the periods 2003-2006 and 2007, respectively. A cointegration test reveals cointegration with oil prices for both corn and soybeans in the period 2006-2007, though. In addition, Muhammad and Kebede (2009) claim that maize and oil prices are highly connected and influences on the price of maize have a spillover effect on related agricultural products. Saghaian (2010), in contrast, does find strong correlation linkages between commodity and oil prices in his underlying monthly dataset for 1996-2008. Using pairwise Granger causality tests, he shows bidirectional links between ethanol and corn and unidirectional Granger causation from wheat and soybean prices to ethanol.

Shifting their focus to edible oils, Yu et al. (2006) use Granger causalities and impulse response functions to identify price relations to the crude oil market. They fail to find a significant effect of crude oil prices on the main vegetable oils used for biofuel production. In contrast, they find a cointegration vector between the different oil prices and argue that crude oil's influence might increase in the future. Zhang and Reed's (2008) results match into this analysis and do not proof any influence of the crude oil price on the Chinese pork market.

However, to answer the question about direct effects from crude oil to commodity prices it is important to control for other factors. Harri et al. (2009) stress the importance of exchange rates. Using monthly data from 2000-2008, they find several cointegration relationships linking commodity prices, oil prices and the exchange rate. This finding fits into the discussion about excess co-movement triggered by Pindyck and Rotemberg (1990). This concept shows that a co-movement exists even between unrelated commodity prices that cannot be explained by underlying common macroeconomic factors.

This review shows that there is neither a consensus about the empirical significance nor about the likely direction of the effect between crude petroleum and food commodities. To analyze the effect of crude oil prices on land use it is therefore necessary to test the relation between crude oil and commodity prices in the dataset used before proceeding with analyzing the effects on land use. This empirical test of the effects on land use is important because most of these analyses are performed in general equilibrium models.⁴ For example Gurgel et al. (2007) use a Computable

⁴ For a further discussion of different modeling approaches in agricultural displacement and deforestation see Angelsen (1999).

General Equilibrium model to show that a massive increase in land required for cellulosic biofuel production only cause a 5 to 10% increase in agriculture prices in the long run. Elobeid et al. (2007) investigate the effect of U.S. ethanol production and find that a corn acre expansion will be needed in order to satisfy the rising demand of the corn-ethanol industry. The computed 21% rise in corn acres mostly crowds out soybean production meanwhile it triggers the wheat price to rise about 20%.

Applying a General Equilibrium (MIRAGE) trade model Al-Riffai et al. (2010) demonstrate that positive biofuel demand shocks from the U.S. and EU have beneficial impacts reducing the GHG emissions, only modestly impacting food prices and rising the export values of agricultural crops. A closer analysis reveals a displacement effect of cropland taking over pasture in Brazil.⁵ Searchinger et al. (2008), in contrast, focus on the iLUC effect in a global model and find indirect GHG emissions from the conversion of forest or grassland to oil crop acres. A recent study of Andrade et al. (2010) combines the analysis of both direct and indirect effects in a partial equilibrium model context. A direct land competition effect is modeled with ethanol crops replacing food production and forested areas. Increasing food prices, thereafter, lead to further deforestation and displacement of other crops, finally, resulting in an equilibrium with still higher food prices, less area harvested with food crops, and deforested area. However, Murphy et al. (2010) argue that research and development activity may lead to higher productivity in biofuel production and reduces the speed of land use change.

The variety of model results underlines the necessity to investigate the direct and indirect effects of crude petroleum price and food commodity price changes on land use change empirically. In addition, Kim and Dale (2011) argue that these models rely on assumptions that have not always proven to hold in economic reality. These authors use a correlation test to investigate iLUC in the US. They attribute their neglect of causality between changes in cropland for corn and biofuel production to either the non existence of iLUC or to flaws in their methodology.

⁵ Micro data seem to confirm that additional oilcrops in Brazil displace pasture and not forested area. However, there presumably is an indirect effect of pasture replacing former rainforest – deforestation (Barona et al. 2010; Walter et al. 2008; Rathman et al. 2010). Additionally, disaggregated satellite data can be obtained from the Brazilian space research institute (INPE).

3. Methodology and data

To analyze the link between crude petroleum prices and land use change empirically we exploit the Food and Agriculture Organization's (FAO 2012) production database using a dataset of annual frequency from 1975-2009. Additionally, we obtained price data from the World Bank's (2011) Pink sheet. We examine data of area harvested, quantity produced and the prices of maize, palm oil, rice, soybean oil, soybeans, sugar, sunflower oil, wheat, an aggregate of cereals and a price index of fats and oils. In addition, to measure world economic activity we use real US GDP per capita.⁶ All series are transformed in natural logs.

For the empirical analysis we employ a vector autoregressive (VAR) model. We estimate this model with the level of the crude petroleum price index and the level of the price, quantity or area of selected food commodities, respectively. In addition, we estimate a three variable VAR controlling for the level of real US GDP per capita. In total we get 122 estimated VAR models. This approach allows us to analyze the causal relationship under relatively weak assumptions about the causal relationships between the variables. To prepare the VAR analysis we perform an Augmented Dickey Fuller (ADF) test of each time series. If the ADF confirms nonstationarity, the first difference of the variable is tested to find its order of integration. We take the median of the following Information criteria to determine the lag length of each VAR: sequential modified LR statistic (LR), Final Prediction Error (FPE), Aikake information criterion (AIC), Schwarz-information criterion (SC), Hannan-Quinn information criterion (HQ). We limit the maximum lag length to four years.

To detect the relations between the variables we perform cointegration tests, Granger causality tests and calculate impulse response functions. While these tests are related they highlight a specific feature of the relation between the variables. We start the empirical exercise by testing for cointegration between the crude oil price and the price, quantity and area for selected food commodities because our aim is to analyze long run co-movements. In addition, we test for Granger causality between the same variables. We perform these tests within the VAR in levels to test short and long run Granger causality jointly. This test indicates the lead-lag-relationship between the variables that is sometimes interpreted as causal relation. However, the results offer no information whether the effect is positive or negative. To get this information we compute

⁶ As a measure of economic activity we use U.S. GDP because world GDP data is only available from 1980 on.

impulse response functions from the estimated VAR model. In addition, these results account for the interactions with world economic activity and offers information about the significance of the relationships throughout time.

4. Empirical Results

As an initial step we test for unit roots in all series used in this analysis. The results of the ADF tests are reported in Table 1. Depending on the time series properties of the variables we tested against a stationary process or a deterministic trend. With regard to worldwide areas and prices we find that most of the series have a unit root. Exceptions are areas and prices of sunflower oil and sugar at the five percent level. For quantities the test rejects the unit root at least at the five percent level for cereals, maize, soybean oil and sugar. Regarding Indonesian and Malaysian areas and quantities of palm oil and rice we find that all series are $I(1)$. In contrast, for the US the test rejects a unit root for all series under consideration. These results reduce the number of variables for the cointegration analysis but they leave the Granger causality and the calculations of impulse response functions unaffected.

For the assessment of the link between crude petroleum prices, food commodity prices and cultivation area it is important whether it is a long run common trend or a short term co-movement driven by business cycle or other short-run developments. We therefore use the Johansen trace statistic to test for cointegration between crude petroleum prices and variables related to food commodities (Table 2). We find strong evidence for a common stochastic trend for soybean area and oilpalm area as well as for the prices of rice and wheat and the quantities of palm oil. In addition, we only find evidence at the ten percent significance level for the maize price as well as the quantities of sunflower oil and rice. These results indicate a long run co-movement between crude petroleum prices and some food commodities that are important for biofuel production. However, whether petroleum prices are related to prices, quantities or the area varies between food commodities. Moreover, the common trend of petroleum price and the price and quantities of rice could indicate an indirect effect of oil price movements.

To get a more accurate picture of the dynamic relations between crude petroleum prices and food commodity variables we perform Granger causality tests. We estimate for each food commodity variable a three variable VAR model including the crude petroleum price and U.S. GDP per capita. We use the same VAR model to calculate impulse response functions of a petroleum price shock. This approach allows us to include food commodity variables without a unit root. The

results for the Granger causal effects from oil prices to food commodity variables are presented in Table 3. The main findings of these tests are that crude petroleum prices Granger cause area, quantity and prices of the world aggregates of maize. Moreover, we find Granger causal effects for areas and quantities of soybean oil and sugar, for areas and prices of wheat and quantities of sunflower oil.⁷

The impulse response functions calculated from the same VAR model specifications as for the Granger causality tests are presented in Figures 1 to 3. The overall picture is that an increase in crude petroleum prices leads to increases in areas, quantities and prices of food commodities. The significance of the impulse responses confirms in most cases the results of the Granger causality tests. However, there are also some differences. The impulse responses indicate significant price effects for cereals and soybean oil in addition to maize and wheat (Figure 1). With regard to areas the impulse response function is insignificant for maize but significant for cereals (Figure 2). For oilpalm and sugar areas we find negative effects of an oil price shock. The impulse responses for quantities indicate significant positive effects for maize, soybean oil and palm oil and a negative effect for sugar.

In summary, these results indicate that crude oil price movements directly Granger cause prices (maize and soybean oil) as well as harvested areas (maize, soybean oil, sugar) of some food commodities that are important for the biofuel production. However, the influence in particular on wheat, though, cannot be explained by this argument. The influence on food commodities not used for biodiesel or ethanol production seems to be an indirect effect due to land use competition. However, as indicated by the impulse responses the effects of land use competition between the variables under consideration are still positive.

As our results suggest crude petroleum price movements have an important impact on food commodity markets but they are clearly not the only source for the recent developments. It is therefore also interesting to analyze how changes in the areas, quantities and prices of single food commodities are related to price movements of input factors for biofuel and biodiesel production. We use the price index for fats and oils as a proxy for the prices of these input factors and test the effects on maize, rice and wheat. The Granger causality test (Table 4) as well as the impulse response functions (Figure 4) reveal a much stronger impact of fats and oil price changes on area,

⁷ We also tested for the reverse causation. We find Granger causal effects from area and quantity of soybean oil, sunflower oil quantity and area of sugar as well as area of maize in the US on crude petroleum prices.

quantity and prices of these commodities than the effect from crude petroleum prices. The results reveal an effect on prices but also a push in area and quantity of wheat, maize and rice produced. However, this means not that oil crops replace wheat or rice. Instead, we see rising prices of fats and oils leading to a rising production and land use of other food commodities such as rice, wheat, maize and cereals. One possible explanation is that food commodities not directly used for biofuel production are used as substitutes in other areas. These are the indirect effects of higher biofuel production on land use competition. However, if the areas for these crops are increased other areas have to be reduced. It is therefore likely that areas unused for agriculture so far – waste arable land, pasture or forested areas – are taken over. A somehow puzzling result, however, is that we neither find Granger causalities nor cointegration relations between the crude petroleum price and the fats and oils price index. A positive relation between both variables would have strengthened our conclusion above.

Furthermore, we verify our findings for the world data by examining land use competition in the U.S. as well as in Indonesia and Malaysia. A vast discussion relates to the use of maize for ethanol production in the U.S. (Searchinger et al. 2008; Elobeid et al. 2007; Gurgel et al. 2007; Muhammad and Kebede 2009). Applying the same procedure as for the world data, we look for first and second round effects. The results for the U.S. are reported in Table 5. We are able to reject the hypothesis of no Granger causality from the crude petroleum price to the area and quantity produced of maize and cereals but we find no effect for rice and wheat.

In addition, we analyze second round effects from biofuel production on land use change by testing for Granger causal effects from the maize price on area and quantity of cereals, maize, rice and wheat. The results indicate highly significant Granger causal effects for all variables except for the area and quantity of rice and the quantity of wheat. The Granger causal effect from the maize price on the area of wheat is evidence for the indirect land use competition (Harvey and Pilgrim 2010). Our results are also in line with Henderson and Gloy's (2007) conclusion that ethanol demand is not only driving commodity prices but also farmland values in the U.S.. One could even interpret the price increases of cereals outlined above as an explanation how biofuel demand has become a driver of farmland values in general.

Indonesia and Malaysia are important producers of palm oil which is used for biodiesel production.⁸ Moreover, in both countries rice production is important, e.g. Indonesia is the third

⁸ An overview of the development and influence of palm oil in the region of Malaysia and Indonesia is given by Lam et al. (2008).

biggest rice producer of the world. Because both countries only produce negligibly small amounts of maize and wheat we focus on the rice production. Testing for first and second round effects of oil price changes in these countries we concentrate on palm oil and rice. To analyze first round effects we perform Granger causality tests from crude petroleum prices on prices, areas and quantities of palm oil and rice (Table 6). We only find a significant Granger causal effect from oil price on the quantity of rice. To account for additional effects we perform Granger causality tests with the palm oil price and area and quantity of palm oil as well as prices, areas and quantities of rice. Our results suggest significant Granger causal effects of the palm oil price changes on the quantity of palm oil as well as the area and quantity of rice. These effects of the palm oil price on rice variables indicate an indirect effect.

5. Conclusion

This paper addresses the effects of crude oil and food commodity prices on land use empirically. So far the majority of analysis of this topic uses general equilibrium models. These models are able to quantify the effects and show whether it is economically important. However, it is still an open question whether the link between oil prices, food commodity prices and land use change is statistically significant. To fill this gap we estimate VAR models using annual data for crude petroleum prices as well as areas, prices and quantities for important food commodities at the world level, for the U.S and Indonesia and Malaysia. We perform cointegration and Granger causality tests as well as an impulse response analysis.

Our results reveal that crude petroleum prices only have statistically significant impact on some food commodities which is in line with the excess co-movement discussion. For world aggregates we find Granger causal effects on the prices of maize and wheat. More important for our analysis however, we find Granger causal effects on the areas of maize, soybean oil, sugar and wheat. For the others commodities used we find no such a Granger causal effect. This indicates that oil prices on average over this long time horizon are not the dominant factor for the dynamics in food commodity markets. In the same direction points the finding that our tests fail to detect a significant link between crude petroleum prices and the price index for fats and oils.

Using the price index of fats and oils as a measure for prices of inputs for biofuel production we find a substantial impact of these prices on prices and area of food commodities even if they are not directly used for ethanol production. Due to this positive effect and the fact that the impulse response functions of some cereals to the crude petroleum price were significantly positive we

conclude that on a world aggregated level there seems to be sufficient waste arable land so that there is no direct competition between oil crops and cereals.

We also find evidence that in the U.S. the maize market is the trigger, because maize is the main ingredient for the U.S. ethanol production. We find a first and second round effect for the U.S. that might have led to skyrocketing commodity prices in the past and high growth of the area harvested of maize. In Indonesia and Malaysia the links between crude petroleum prices and the variables of rice and palm oil are weaker. However, we find a significant effect from the palm oil price to the Indonesian and Malaysian area and quantity of rice which we interpret to be iLUC. The iLUC bears the risk that it leads to even higher prices or the displacement of other areas such as pasture or forest in the future.

However, much more empirical work is needed for a better understanding of the interrelations of oil prices and food commodity markets and land use change. For example, an empirical analysis including a direct displacement effect of expanding crops to see how deforestation and the influence of a rising demand for meat are to be classified into the discussion.

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Appendix

Table 1: ADF test results

	Price	Area	Quantity
World			
Crude oil	-1.35	--	--
Fats and Oils	-1.81	--	--
Cereal	-2.81	-2.39	-4.25**
Maize	-2.89	-2.74	-5.19***
Palm oil	-2.03	-2.97	-3.21*
Rice	-2.44	-3.29*	-2.13
Soybean oil	-2.63*	-2.22	-4.10**
Sunflower oil	-4.88***	-3.59**	-2.38
Sugar	-3.02**	-4.44***	-4.64***
Wheat	-3.01	-3.32*	-2.5
Indonesia & Malaysia			
Palm oil	--	-1.69	-2.77
Rice	--	-3.05	-1.94
United States			
Cereals	--	-4.63***	-5.99***
Maize	--	-4.52***	-6.12***
Rice	--	-3.04**	-4.89***
Wheat	--	-3.48*	-3.99***

*, **, *** indicate significance at the 10%, 5%, 1% level.

Table 2: Johansen cointegration test results for food commodity variables with crude petroleum price

	None CI	At most 1 CI
Prices		
Fats and Oils	6.40	1.30
Cereals	15.47**	2.89*
Maize	14.18*	2.37
Palm oil	8.41	1.75
Rice	15.53**	1.16
Soybean oil	12.68	1.34
Wheat	16.86**	2.40
Area		
Cereals	9.29	2.79
Maize	6.92	2.49
Oil palm	25.07***	2.13
Rice	6.67	2.68
Soybean	22.12**	3.52
Wheat	6.38	1.58
Quantity		
Palm oil	28.58***	2.33
Rice	18.44*	2.32
Sunflower oil	20.07*	3.00
Wheat	13.51	2.27

*, **, *** indicate rejection at the 10%, 5%, 1% significance level.

Table3: Granger causality test results for world aggregates for food commodity variables with crude oil price

	Price	Area	Quantity
Fats and oils	1.60	--	--
Cereals	1.90	3.88	4.57
Maize	3.66*	2.88*	5.49**
Palm oil	1.43	3.20 ^b	2.84
Rice	2.25	0.06	1.00
Soybean oil	2.59	11.73*** ^a	5.12**
Sugar	0.28	10.05***	13.60***
Sunflower oil	2.29	1.71	23.15***
Wheat	3.26*	6.08**	2.88

*, **, *** rejection at the 10, 5, 1% significance level respectively.

^a area equal to soybean area

^b area equal to oil palm area

Table 4: Granger causality test results for food commodity variable and the fats and oils price index

	Price	Area	Quantity
Cereals	15.21***	11.32**	9.05**
Maize	1.08	3.49*	18.31***
Rice	27.12***	13.67***	12.06***
Wheat	4.63	15.40***	6.12

*, **, *** rejection at the 10, 5, 1% significance level respectively.

Table 5: Granger causality test results for food commodity variables for the U.S.

		Crude petroleum price	Maize price
Cereals	Area	2.82*	12.12***
	Quantity	4.61**	18.63***
Maize	Area	18.25***	20.50***
	Quantity	3.25*	18.33***
Rice	Area	0.16	0.13
	Quantity	0.1	0.19
Wheat	Area	0.04	14.77***
	Quantity	0.24	1.41

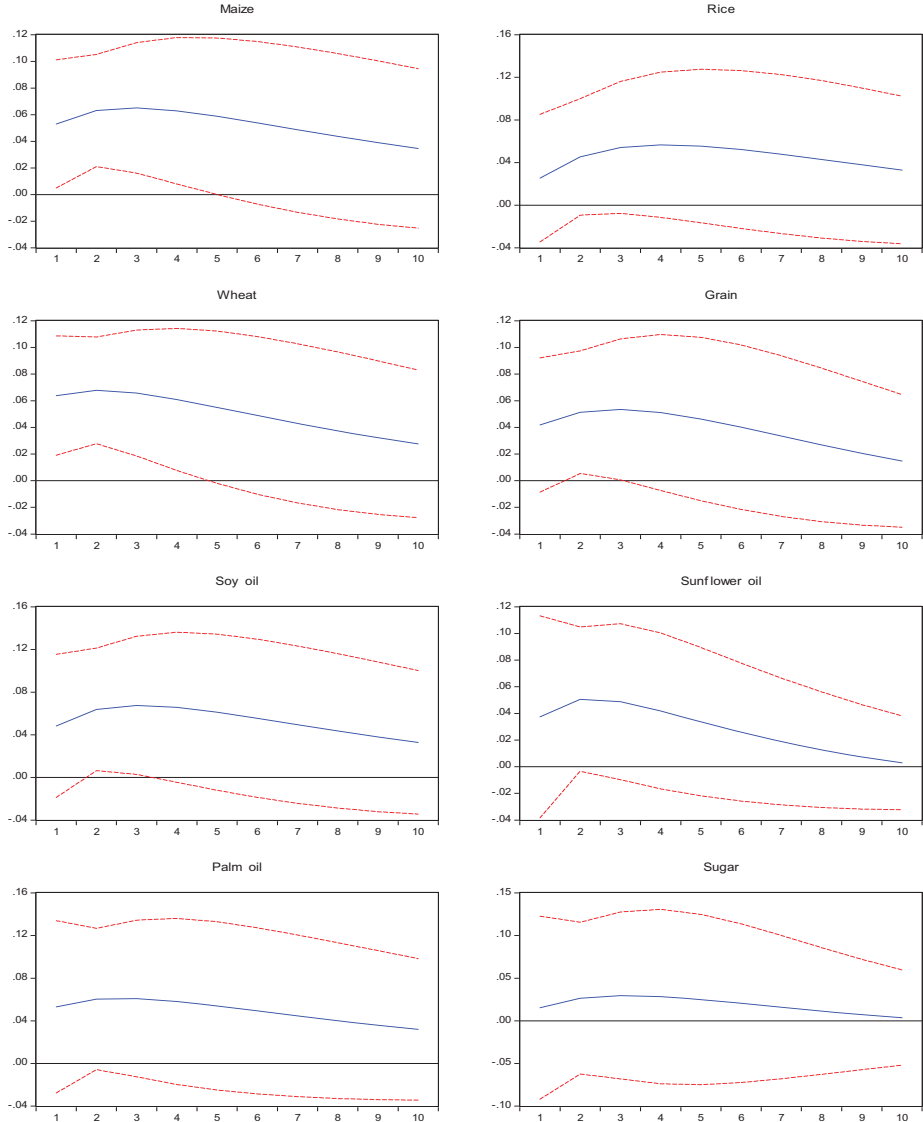
*, **, *** rejection at the 10, 5, 1% significance level respectively.

Table 6: Granger causality test results for food commodity variables for Indonesia and Malaysia

		Crude petroleum price	Palm oil price
Palm oil	Area	0.10	4.74
	Quantity	2.26	11.49***
Rice	Area	0.75	11.48***
	Quantity	8.79**	8.46**

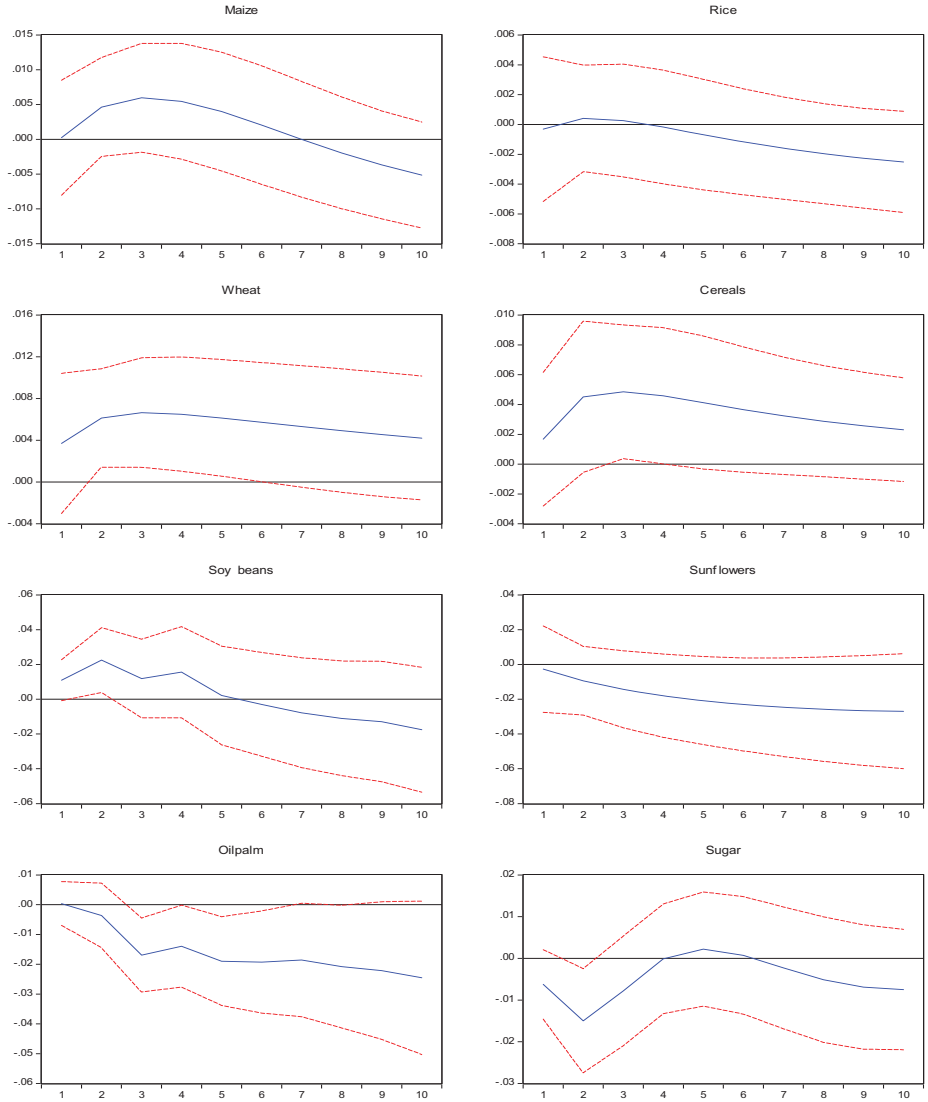
*, **, *** rejection at the 10, 5, 1% significance level respectively.

Figure 1: Impulse responses of prices of selected food commodities to a crude petroleum price shock



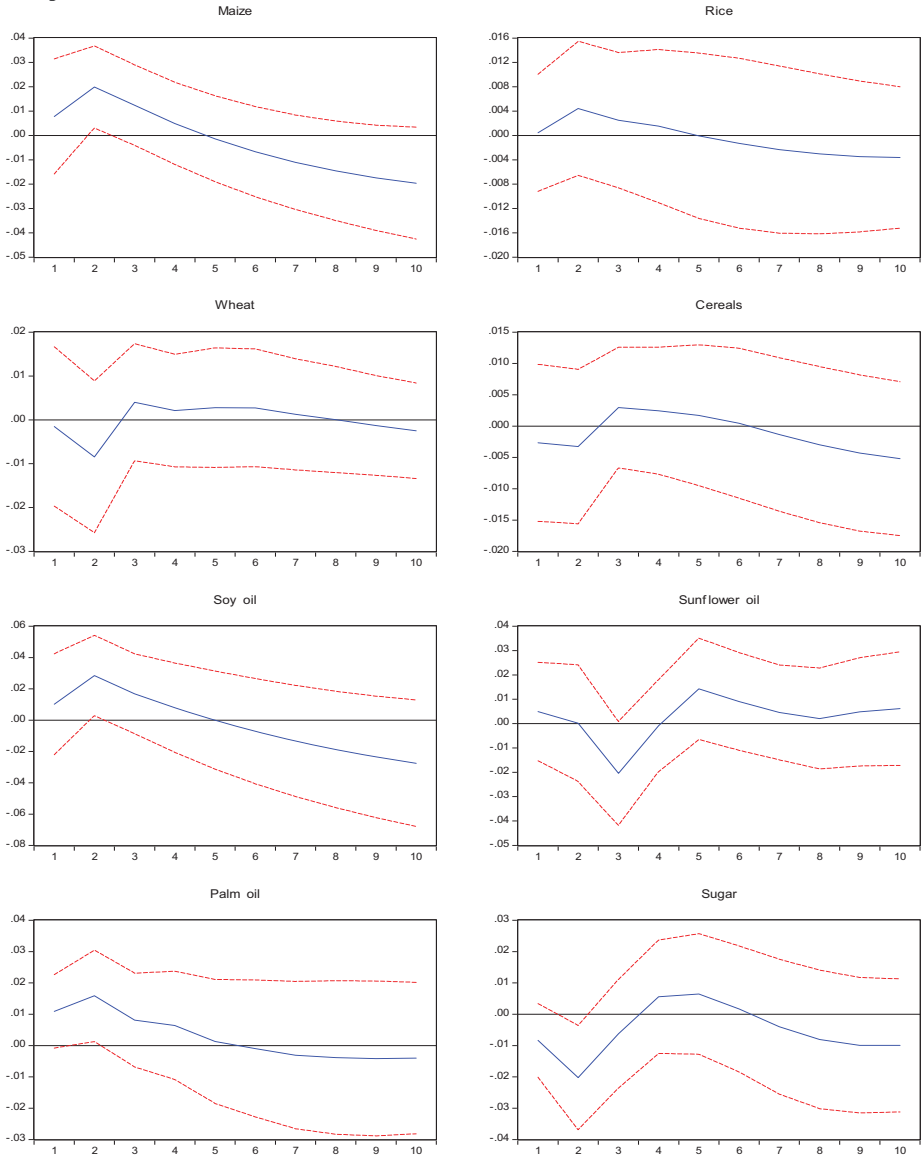
Responses of food commodity prices to a generalized one standard deviation innovation of the crude petroleum prices.

Figure 2: Impulse responses of areas of selected food commodities to a crude petroleum price shock



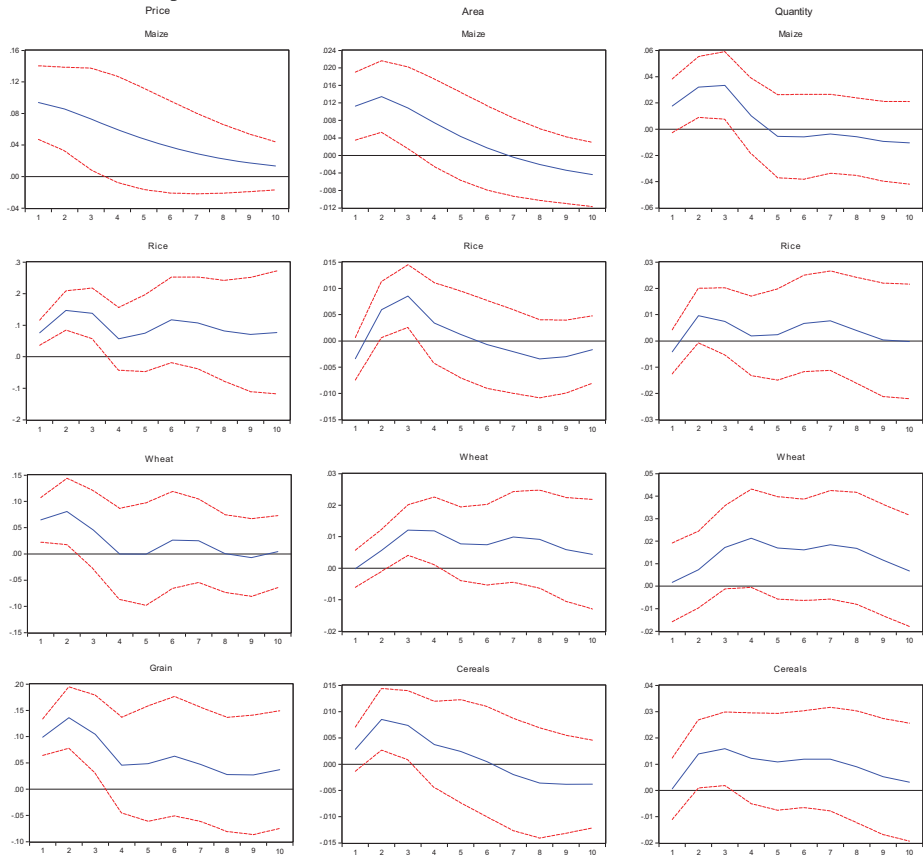
Responses of food commodity planted areas to a generalized one standard deviation innovation of the crude petroleum prices.

Figure 3: Impulse responses of quantities of selected food commodities to a crude petroleum price shock



Responses of food commodity quantities to a generalized one standard deviation innovation of the crude petroleum prices.

Figure 4: Impulse responses of area, quantity and prices of selected food commodities to a fats and oils price index shock



Responses of a food commodity variable to a generalized one standard deviation innovation of the fats and oils price index.