A Global Demand Analysis of Vegetable Oils for Food and Industrial Use:

A Cross-Country Panel Data Analysis with Spatial Econometrics

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This article analyzes global demand for major edible and non-edible vegetable oils using cross-country panel data from 1991 to 2011. A fixed effects model, accounting for spatial dependence of the residuals, is specified. Compared to food use, income elasticities are significantly higher for industrial use, suggesting that demand for non-edible vegetable oils is expected to increase with the rise of global wealth in the future. Income elasticities will be useful for simulation research of estimating how much agricultural land needs to be developed in the future in order to meet an expected increase in demand for biofuel feedstocks.

Key words: vegetable oil, demand analysis, cross-country panel data, fixed effects model, spatial dependence, soybean oil, rapeseed oil, palm oil, sunflower oil

JEL codes: Q11, Q41, C21, C23

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Vegetable oils have become one of the global topics of interest due to several factors: (i) rising global demand for vegetable oils due to increased global wealth; (ii) rising awareness of health problems related to trans fatty acids, or TFA (U.S. FDA 2003, 2013); (iii) increasing use of vegetable oils for biofuel feedstock supply as a substitute for fossil fuels and (iv) mounting international concerns over the environmental impacts of deforestation through palm logging and conversion of rainforest to cropland for soybean production (Morton et al. 2006). Given these circumstances, analyzing food and industrial demand for vegetable oils from a global perspective is important to clarify the demand characteristics of vegetable oils.

The objective of the current research is to investigate global demand characteristics of major vegetable oils for future research and policy analysis by using a cross-country panel data of 165 countries from 1991 to 2011 in estimating demand functions for vegetable oils for food use and for industrial use. For food use, the focus of this research is on the global markets of four vegetable oils: soybean oil, rape and mustard oil (including canola oil), palm oil, and sunflower oil.[1] These four vegetable oils dominate more than 70% of global vegetable oils consumption for food use during the 2000's (table 1). For each of these vegetable oils, global own-price and cross-price elasticities as well as income elasticities were estimated using cross-country panel data from FAOSTAT. Differences in own-price elasticities and income elasticities by GDP category (four groups ranging from lower-income to higher-income country) are identified and analyzed.

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[1] Mustard oil is grouped with rapeseed oil in FAOSTAT (Food and Agriculture Organization Corporate Statistical Database), but world production of mustard seed takes up only about 1% of world production during the period analyzed in this article. Therefore, rape and mustard oil is hereafter referred to as rapeseed oil.

For industrial use, the focus of this research is on the global markets of three vegetable oils: soybean oil, rapeseed oil and palm oil. These three vegetable oils dominate more than 70% of global vegetable oils consumption for industrial use during the 2000's.

[Insert table 1 here]

There have been growing numbers of papers which conduct theoretical and/or empirical analysis on markets of food, biofuel and energy policy. The primary aim of this article is to contribute to those authors conducting policy research by providing global demand elasticity estimates of several major vegetable oils.

Global Consumption Trends

FAOSTAT has data on each country' commodity balances in food balance data category. They are classified into six category elements: feed, seed, waste, processing, food and other uses. For edible vegetable oils, data on food category was used, while for non-edible oils such as those used for industrial use, data on the "other uses" category was used. Data on feed/seed/waste/processing was not used in this analysis. The quantities of food available for human consumption relate to the quantities of food reaching the consumer. For all of the four major vegetable oils, food use accounted for about 51% among the above categories, 48 % for other uses and 1% for feed/seed/waste/processing in 2011. For example, the processing ratio was only 0.3% in 2011. The data of processing category does not have enough information for many countries between 1991 and 2011. Other uses include quantities put into the manufacture of non-food uses, such as biofuel, heating oil and oleochemicals. Oleochemical applications are diverse: plastics, metal soaps, washing and cleaning agents, soaps, cosmetics, alkyd resins, dyestuffs, textile, leather and paper, rubber, lubricants (Appalasami 1990). Other uses may include some used for food manufacturing, but not captured in the food use category.

Per capita edible oil consumption of the four major vegetable oils has increased from 6.8kg to 7.8kg between the period 1991-2000 and 2001-2011, increasing in their total share from 72% to 73% (table 1). The consumption share of soybean oil and palm oil has increased from 30% to 31% and from 14% to 17%, respectively. The consumption shares of rapeseed oil and sunflower oil have slightly declined. Due to increasing global demand for vegetable oils for industrial use, consumption per capita of three major vegetable oils (palm oil, soybean oil and rapeseed oil) has increased from 2.3kg to 5.8kg between the two periods, increasing their total shares from 62% to 74% (table 1).

The consumption ratio of soybean, palm, rapeseed and sunflower oil between food and other uses was 75:25 in 1995 and by 2010 the ratio was about 50:50. China, Brazil, United States, India, and Argentina are the top five countries for non-edible soybean oil. China, Germany, France, United States and Mexico are the top five consumers for non-edible rapeseed oil, while Indonesia, China, India, Germany, United Kingdom are the top five consumers for non-edible palm oil.[2]

Demand for edible vegetable oils has increased in the Americas, Asia & Oceania and Europe regions. Demand for soybean oil has increased mainly in the Americas region, palm oil in the Asia & Oceania region, and sunflower oil in the Europe region. By GDP category, per capita consumption for soybean oil has increased in high and middle-high income countries (Group 1: real GDP per capita of 15,000 or more US$ and Group 2: 4,000-14,999 US$), while per capita consumption for palm oil increased in low-income countries (Group 4: 0-999 US$). Per capita

[2] Russia, China, Turkey, Netherlands, Spain are the top five countries for non-edible sunflower oil consumption.

consumption of rapeseed oil and sunflower oil has decreased in Africa and in Africa and Americas, respectively. World consumption per capita of rapeseed oil and sunflower oil remained similar over time.

Demand for major non-edible vegetable oils has increased in all of the regions. Demand for soybean oil has mainly increased in the Americas and Asia & Oceania regions, while there is an increase in demand for rapeseed oil in the Europe region and for palm oil in the Africa, Asia & Oceania and Europe regions. Per capita consumption of non-edible soybean oil has increased in middle income countries (Group 2 and Group 3: 1,000-3,999 US$), while that of non-edible rapeseed oil has increased in high income countries (Group 1). Per capita consumption of non-edible palm oil has increased in both low and high income countries (Group 1 and 4). For the total of non-edible vegetable oils, the increase in consumption per capita is greater for higher-income countries than for lower-income countries.

Literature Review

In recent years there have been growing numbers of papers which conduct theoretical and/or empirical analysis of food, biofuel and energy markets. There are mainly three types of approaches, (1) theoretical models; (2) cointegration analyses; and, (3) partial and general equilibrium (CGE) models. Theoretical models study the channels of adjustment among markets of agriculture, bioenergy and energy (Gardner 2007; de Gorter and Just 2008, 2009). Cointegration analysis estimates the long-term relationship between the fuel (energy such as crude oil) and agricultural commodity prices (Yu, Bessler and Fuller 2006; Hameed and Arshad 2008; Peri and Baldi 2010). CGE model simulates the interdependence among markets of agriculture, bioenergy and energy (Arnt et al. 2008; Kancs and Wohlgemuth 2008). The drawback of CGE models, on the other hand, is that their results heavily depend on price transmission elasticities which are just arbitrarily assumed.

Goddard and Glance (1989) analyzed demand relationships among twelve fats and oils in United States, Canada and Japan using data from 1962 to 1986. Based on a translog indirect utility function, they estimated the translog demand system and derived uncompensated price elasticities. For the United States, they obtained uncompensated price elasticities for 10 fats and oils: butter, lard, edible tallow, coconut oils, corn oil, cottonseed oil, soybean oil, palm oil, palm kernel oil and peanut oil. They did not include rapeseed and sunflower oils in their model. In recent years, rapeseed oil and sunflower oil have become one of the major vegetable oils in the global market. One novelty in this article is that these oils are included in the analysis.

Demand analysis has not been conducted on major vegetable oils for food and industrial use from a global perspective. Demand elasticity estimates, such as own-price, cross-price and income elasticity, will be useful for future research and policy analysis related to the area of agriculture, food and bioenergy. Elasticity estimates are important for use in simulation, forecasting, and equilibrium displacement studies. For policy analysis in agriculture, food and bioenergy, major determinants of global demand for each major vegetable oil need to be examined and demand elasticity estimates need to be identified for food and industrial use, respectively.

Data

Vegetable oils' consumption and price data for 165 countries from 1991 to 2011 were obtained from FAOSTAT, while data on real GDP per capita (in 2005 US$) was obtained from USDA ERS International Macroeconomic Data Set. In order to eliminate data for very small countries as well as outliers, countries with population of less than 100,000 were removed from the analysis. For food and industrial use, some observations were eliminated as outliers if the real price of vegetable oil is extremely low or extremely high (e.g., lower than about 0.3 US dollar/kg and higher than about 10 US dollar/kg). The real prices are roughly 1.0 US dollar/kg on average between 1991 and 2011. The nominal prices were deflated using Consumer Price Index (World Bank, World Development Indicators, 2005 =100). In addition, when estimating demand function for food and industrial use, only countries that have more than 10 tons of annual consumption of vegetable oil are included.

Table 2 shows summary statistics for average annual consumption per capita for the 1991-2000 and the 2001-2011 periods by food and industrial use based on cross-country panel data used in the demand analysis of this article. It should be noted that table 2 is different from table 1. Table 2 shows average annual consumption per capita calculated using final panel data used in the analysis while average annual consumption per capita in table 1 were calculated through averaging each year's consumption per capita obtained by dividing an aggregated world consumption by world population in each year.

[Insert table 2 here]

Table 3 shows summary statistics for real average price (base year = 2005) based on cross-country panel data with the same conditions as described for table 2. Consumer prices of vegetable oils were not available for many countries. Therefore, using import price and export price, the volume weighted average import and export prices of each vegetable oil for each country were calculated, such as in Schroeder, Barkley, and Schroeder (1995). Trade data (value and quantity of import and export) of FAOSTAT from 1991 to 2011 was used. This weighted average price were deflated by the consumer price index (CPI) of each country, downloaded from World Development Indicators Database of the World Bank (base year = 2005). This weighted average price was used as a proxy for price in each country. For these reasons, it should be noted that table 3 does not necessarily reflect average prices in international major markets of each vegetable oil. The bottom of table 3 shows the rate of change in real price. The numbers suggest that average real prices of vegetable oils decreased from the 1991-2000 period to the 2001-2011 period for food and for industrial use. Real average price of crude oil has, however, increased between these two periods due to crude oil price surge during the 2000's.

[Insert table 3 here]

Table 4 shows summary statistics for GDP by four GDP categories over 21 years (Group 4: 0-999 US$, Group 3: 1,000-3,999 US$, Group 2: 4,000-14,999 US$, and Group 1: >=15,000US$). As a result of data elimination for very small countries[3], the cross-country panel data consists of at most 161 countries over 21 years from 1991 to 2011. Because of missing data in some years for some countries, panel data in the analysis is unbalanced.

[Insert table 4 here]

Model Specification

Because each country is expected to have unobservable time-invariant preference to a certain type of vegetable oil to some extent, a fixed-effects model (Wooldridge 2002) is used. These country-specific preferences to a particular type of edible and non-edible vegetable oil can vary from country to country due to historical factors such as food culture, eating habits, religious reason in each country and also due to infrastructural, technological, industrial factors for biodiesel, oil heating, oleochemical applications. Prevailing transportation means, heating facilities (furnaces,

[3] Data on four countries, such as Antigua and Barbuda, Bermuda, Dominica, and Saint Kitts and Nevis, were dropped from the sample due to small populations of less than 100,000.

boilers) in buildings, and oleochemical industry development are different from country to country as well. Such preferences account for individual heterogeneity, which can be country-specific. These preferences can potentially change for over a century; over the course of decades, however, it can be assumed to be time-invariant and forms one of the strong determinants for vegetable oil demand even during a severe recession. The extent of those preferences can be approximated from past consumption levels to some extent; however, those preferences cannot be measured in an exact manner because the consumption levels were affected by other factors, such as own price, substitutes price, income level and others at the same time. These unobserved factors representing preferences that affect vegetable oils demand in a certain year will also affect the demand in the next year. Therefore, the observations for vegetable oil consumption are not independently distributed across time. While a fixed-effects model does not identify the effects of variables such as unobserved preferences that are constant over time or across countries, it is well-suited to the estimation objective of this article in isolating the effect of own price, y, and real income per capita on demand for vegetable oils from the individual-level effect (unobserved preferences) in each country.

A fixed effects demand model (equation 1) was estimated for major edible vegetable oil j (j = 1…4: soybean oil, rapeseed oil, palm oil, and sunflower oil) with consumption per capita, $C_{ji,t}$ as the dependent variables for country i in year t. A double-log demand model for food use is specified as follows:

(1) $$ln\, C_{j,it} = a_j + \sum_{k=1}^{4} \gamma_{jk}\, lnp_{k,it} + \beta_j lnGDP_{j,it} + FE_{j,i} + \varepsilon_{j,it} \qquad (j = 1\ldots4)$$

(i = country, t = time 1991…2011, j = edible vegetable oils 1…4)

where $FE_{j,i}$ captures time-invariant preference to edible vegetable oil j for country i. a_j is a constant term of vegetable oil j's global demand function. $p_{k,it}$ is the real price of vegetable oil k (k = 1…4) for country i in year t, GDP_{it} is real GDP per capita for country i in year t. For edible oil use, real prices of four major edible vegetable oils were used. Both price and GDP are deflated by each years' CPI in each country as a type of homogeneity restriction. γ_{jk} and β_j are parameters to be estimated. γ_{jk} is the elasticity of demand (own-price elasticities or cross-price elasticities) with respect to the kth price (k = 1…4), and β_j is the income elasticity of demand.

Three separate fixed effects demand models were estimated representing the three major non-edible vegetable oil j (j = 1…3: soybean oil, rapeseed oil and palm oil and). For industrial oil use, real prices of three major non-edible oils were used and real crude oil price was included to account for the substitution effect between vegetable oils and crude oil. The average price of crude oil (World Bank Commodity Price Data: Brent, Dubai and WTI) was computed and the price series were deflated by each year's CPI for each country. The deflated crude oil price in the previous marketing year (during October-September) was used as an explanatory variable for a dependent variable in the present year in order to analyze demand response to change in crude oil price in the past, as follows:

(2) $$ln\, C_{j,it} = a_j + \sum_{k=1}^{4} \gamma_{jk}\, lnp_{k,it} + \beta_j lnxGDP_{j,it} + FE_{j,i} + \varepsilon_{j,it} \qquad (j = 1\ldots3)$$

(i = country, t = time 1991…2011, j = non-edible vegetable oils 1…3) ,

Incomplete models of constant elasticity demands with double-log form for major vegetable oils were estimated. Because of the lack of accurate data for expenditure share of vegetable oils in each country over two decades, complete system of demand equations such as AIDS model (Deaton and Muellbauer 1980) and Rotterdam demand system (Theil 1965; Johnson, Hassan, and Green 1980) were computational inefficient. Similarly, a compensated double-log demand model (Alston, Chalfant, and Piggott 2002; Kastens and Brester 1996) was not specified.

The estimation results of the double-log model, without restriction, used here should be viewed as an approximation.

Statistical Consideration and Estimation Results

When demand functions were estimated for vegetable oils for food and industrial use, a robust Hausman test was implemented for each vegetable oil to decide fixed or random effects. The preferred model was the fixed effects model for each function. To test for unit roots, a Fisher-type test with Phillips-Perron test option was used to test the null hypothesis that all the panels contain a unit root. One lag was chosen to remove higher-order autoregressive components of the series. To mitigate the effects of cross-sectional dependence, the cross-sectional averages were also subtracted from the series. Results show that the null hypothesis was rejected for all of variables in the panel datasets. To test multicollinearity of predict variables, the variance inflation factor (VIF) was computed. No multicollinearity among the variables in each fixed effects model was detected.

Heteroskedasticity tests were conducted using a modified Wald test for group-wise heteroskedasticity and confirmed the presence of heteroskedasticity of the residuals in each model. Serial correlation was tested for using a Lagrange-Multiplier test and confirmed the first-order autocorrelation of the residuals in each model. Tests for cross-sectional dependence (contemporaneous correlation, spatial dependence) of the residuals across entities were conducted using Moran's I test for each vegetable oil for each year (Moran 1950).[4] Although the spatial

[4] Because the time dimension of the panel is smaller than the cross-sectional dimension, Pasaran CD (Cross-sectional dependence) test was used (Pasaran 2004), but the results were not obtained in each model due to missing data in different countries at different years.

dependence is not present each year, the data confirms weak spatial dependence of the residuals for both food and industrial use.

The Driscoll and Kraay (DK) standard error estimator was used to arrive at robust standard errors in the estimations of each fixed effects model with lag-1 autocorrelation of the residuals. DK standard errors estimates are robust to disturbances being heteroskedastic, autocorrelated with MA(1), and cross-sectionally dependent (Hoeche 2007). For comparison purpose, clustered standard errors estimates were obtained (Rogers 1993), which is heteroskedasticity and autocorrelation consistent.

Table 5 shows estimation results of demand function of edible and non-edible oils. Own-price, cross-price and income elasticities are presented at global level. Weak spatial dependence of the residuals was already observed in both food and industrial use in some years. The DK approach provided for more significant predictors than Roger approach (table 5). In the presence of spatial dependence of the residuals across entities, the analysis confirms that robust standard errors estimates are appropriate.

[Insert table 5 here]

In the following section, the estimation results resulting from the DK estimator are explained. For food use, own-price elasticities are -0.42 for soybean oil, -0.68 for rapeseed oil, -0.46 for palm oil, and -0.54 for sunflower oil. For industrial use, own-price elasticities are -0.49 for soybean oil, -0.94 for rapeseed oil, and -0.29 for palm oil. All cross-price elasticities, which are statistically significant at least at the 10 % level, indicate (gross) substitution effect on demand for each vegetable oil. Results suggest that edible rapeseed oil and sunflower oil, whose consumption per capita remained constant over time, tend to have sensitive demand to a change in own price and substitute price. Edible soybean oil and palm oil are less sensitive to a change in own price and substitute price than edible rapeseed oil and sunflower oil. As for industrial use, demand for rapeseed oil is more sensitive to change in own price, to soybean oil price, and to crude oil price compared to the other vegetable oils (table 5).

Income elasticities are statistically significant for all of vegetable oils except rapeseed oil for food use (table 5). Income elasticities of rapeseed oil and palm oil for industrial use are larger compared to those for food use. As for industrial use, income changes have a stronger effect on demand than crude oil price changes.

Demand separation

In order to identify difference in own-price elasticities by GDP category, interaction terms between own price and dummy variables (GDP category) were added (table 6). As for soybean oil and palm oil for food use, no significant differences are found for own-price elasticities by GDP category. Rapeseed oil and sunflower oil for food use indicate a significant difference in own-price elasticities by GDP category. For edible rapeseed oil and sunflower oil, as GDP decreases, own-price elasticities become more negative. This result suggests that demand for edible rapeseed oil and sunflower oil is more sensitive to own price change in lower-income countries than in higher-income countries.

[Insert table 6 here]

To conserve space, results for industrial oil use is not reported in table format. As for soybean oil for industrial use, own-price elasticities are more negative in lower income countries of Group 2 and Group 4 than reference category country (Group 1). Especially, Group 2 (mid-high income country group) has significantly increased non-edible soybean oil consumption from 1990's to 2000's and has become the largest consuming group in 2000's. In particular, the

Americas and Asia & Oceania are the major consumption regions of non-edible soybean oil. Demand for non-edible soybean oil are sensitive to own-price change in mid-high income countries in these regions.

In addition, in order to identify difference in income elasticities by GDP category, interaction terms between income and dummy variables (GDP category) were also added. Estimation results with this interaction terms for food use are shown in table 7. No significant differences in income elasticities by GDP category are found for either food use or industrial use. Income elasticity for edible rapeseed oil is not statistically significant in all of four GDP categories and income elasticity for edible sunflower oil is small compared to edible lower value vegetable oils such as soybean oil and palm oil. Income elasticity of edible palm oil is relatively high in all of four GDP categories compared to the other edible vegetable oils, indicating that the income effect on the demand for edible palm oil is worldwide and comparatively strong.

[Insert table 7 here]

To conserve space, results for industrial oil use is not reported in table format, but a summary of the findings are as follows. Income elasticity for non-edible rapeseed oil is significantly high. Income elasticity for non-edible palm oil is higher than that of non-edible rapeseed oil. For rapeseed oil and palm oil for industrial use, the income elasticities are remarkably higher than crude oil price elasticity of demand for each vegetable oil. Income changes play the most important role in the determination of demand for vegetable oils for industrial use.

Concluding Remarks

In this article, demand characteristics of major vegetable oils for food use and industrial use were identified by estimating a fixed effects model using cross-country panel data of 161 countries.

Empirical results yield global estimates of own-price, cross-price and income elasticities of each of the major vegetable oils.

From the first round of estimations, heteroskedasticity, first-order autocorrelation, (weak) spatial dependence of the residuals were found in the estimated demand models for each vegetable oil. Therefore, using Driscoll and Kraay (DK) approach, standard errors estimates that are robust to disturbances being heteroskedastic, autocorrelated with MA(1), and cross-sectionally dependent were obtained. A comparison was conducted between the DK standard errors estimates with Roger's standard errors estimates, which is heteroskedasticity and autocorrelation consistent. The DK approach indicates more significant predictors than with Roger's estimation approach. In the presence of spatial dependence of the residuals across entities, standard errors estimates that are robust to disturbances being cross-sectionally dependent were confirmed to lead to more efficient standard error estimates.

Concerning food use, the current research finds that per capita consumption of higher value edible vegetable oils, such as rapeseed oil and sunflower oil, is susceptible to a change in own prices and substitute prices compared to lower value edible vegetable oils, such as soybean oil and palm oil. For higher value edible vegetable oils, own-price elasticities become more negative as GDP per capita declines, suggesting that demand for those higher value edible vegetable oils is more sensitive to own price change in lower-income countries than in higher-income countries. Income elasticities are higher for lower value edible vegetable oils relative to for higher value edible vegetable oils.

Lower value edible vegetable oils are more price competitive than higher value edible vegetable oils. Income elasticity of edible palm oil is relatively high in all of four GDP categories compared to the other edible vegetable oils. The result for a relatively higher income elasticity for edible palm oil indicates that as GDP per capita increases demand for edible palm oil is expected to increase in developing countries. Thus, countries such as Indonesia and Malaysia may continue to be sought to supply the growing global demand for palm oil as consumer prosperity grows in developing countries. If countries like Indonesia and Malaysia face supply restrictions in the future the demand structure for vegetable oils will have to adjust.

Concerning policy and regulation, for example, the World Health Organization / Food and Agriculture Organization (WHO/FAO 2003) recommended in 2003 that human diets should provide a very low intake of trans fats (trans fatty acids: TFA)[5]. The WHO/FAO pointed out that "intake of saturated fatty acids is directly related to cardiovascular risk (WHO/FAO 2003, p.88)." As a result, an increasing number of developed countries have sought regulations imposing labeling rules for food containing TFA for these exact health concerns[6]. And, by 2015 the U.S. Food and Drug Administration announced the phase-out of "generally recognized as safe"

[5] "The high degree of unsaturation of soybean oil, and particularly the significant level of linolenic acid, limits its food application because of its low oxidative stability. Partial hydrogenation is used to increase the melting temperature and, at the same time, to improve the oxidative stability of soybean oil." (Wang 2011). During the production of margarine, spreads, and shortenings via catalytic hydrogenation when hydrogen atoms are added to liquid oils to produce more solid fats than oils, the process catalyzes the production of some TFA (Enig et al. 1983). Through hydrogenation, oil becomes a semi-solid fat with elevated melting point, and partially hydrogenated oils (PHOs) are useful in certain food applications in keeping food shelf-stable and preserving flavor. However, concerns about possible associations between TFA and certain type of cancer (Ip 1997) have motivated some groups to seek reduction in the levels of TFA or elimination of TFA in foods (Moreau 2002).

[6] In March 2003, Denmark became the first country to introduce laws strictly regulating the sale of many foods containing TFA. In the United States, the U.S. Food and Drug Administration (FDA) amended its regulations on nutrition labeling in July 2003 (effective in January 2006) to require that TFA be declared in the nutrition label of conventional foods and dietary supplements (U.S. FDA 2003). The FDA announced the preliminary determination that partially hydrogenated oils (PHOs), the primary dietary source of artificial trans-fat in processed foods, are not "generally recognized as safe (GRAS)" (U.S. FDA 2013). The FDA finalized its determination that PHOs are not GRAS for use in human food, and set a three-year time limit for removal of the GRAS recognition from all processed foods (U.S. FDA 2015).

assumption for partially hydrogenated vegetable oils. Those regulatory factors will more likely change demand structure for vegetable oils. In particular, canola oil (rapeseed oil) has been mainly consumed in higher-income countries as a heart-healthy oil because canola oil is the lowest in saturated fat among commodity vegetable oils and has the best fatty acid composition among all commodity oils for health (Przybylski 2011). Rapeseed oil demand is, however, vulnerable to change in own price and substitute prices from a global perspective as seen in the analysis of this article. The TFA issue will also favor palm oil consumption because it can be used without full or partial hydrogenation. Although the disadvantage of palm oil is a high content of saturated fats (49.3%; the USDA National Nutrient Database), palm oil is naturally semi-solid in nature and there is little necessity for solidification through hydrogenation which leads to the undesirable presence of TFA in the frying oil. The advantages of using palm oil products include cheap raw material, good availability and low cost of processing, since hydrogenation is not necessary (Siew 2011). It is vital to keep track of information on developments of policy and regulation concerning health issue in each country.

Concerning industrial use, demand for rapeseed oil is sensitive to changes in own price, in soybean oil price, and in crude oil price compared to the other vegetable oils. In particular, own-price elasticity of non-edible rapeseed oil is relatively high compared to the other lower value vegetable oils. Therefore, unless rapeseed oil becomes more cost competitive, it is difficult to expect demand to grow in the Africa, Asia & Oceania, and Americas where soybean oil and/or palm oil are mainly used for industrial use. By contrast, income elasticity of non-edible palm oil is positive and considerably high in all GDP categories. This suggests that strong demand growth of non-edible palm oil can be expected in a region that will experiences GDP growth in the future.

Deforestation through palm logging and forest conversion for soybean production are mounting international concerns over their environmental impacts. Income elasticities will be useful in simulating total future demand for vegetable oils with population data, and in estimating how much agricultural land needs to be developed in the future in order to meet an expected increase in demand for biofuel feedstocks with the rise of global wealth.

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Table 1: Average Consumption Per Capita in the World: Food and Other Uses from 1991-2000 to 2001-2011

	Food Use						Other Uses (Industrial Use)				
	Average (Kg/Capita)			Share			Average (Kg/Capita)			Share	
	1991-2000	2001-2011	Rate of Change	1991-2000	2001-2011		1991-2000	2001-2011	Rate of Change	1991-2000	2001-2011
Soybean Oil	2.85	3.37	19%	30%	31%	Palm Oil	1.28	3.09	142%	35%	39%
Palm Oil	1.29	1.84	42%	14%	17%	Soybean Oil	0.58	1.57	171%	16%	20%
Rape and Mustard Oil	1.39	1.37	-1%	15%	13%	Rape and Mustard Oil	0.43	1.15	167%	12%	15%
Sunflowerseed Oil	1.27	1.25	-2%	13%	12%	Oilcrops Oil, Other	0.50	0.59	19%	13%	8%
Groundnut Oil	0.72	0.66	-9%	8%	6%	Palmkernel Oil	0.20	0.46	129%	5%	6%
Cottonseed Oil	0.54	0.52	-2%	6%	5%	Sunflowerseed Oil	0.16	0.33	106%	4%	4%
Olive Oil	0.34	0.40	16%	4%	4%	Coconut Oil	0.23	0.20	-11%	6%	3%
Coconut Oil	0.30	0.31	4%	3%	3%	Cottonseed Oil	0.11	0.17	51%	3%	2%
Maize Germ Oil	0.24	0.29	21%	3%	3%	Groundnut Oil	0.07	0.16	133%	2%	2%
Oilcrops Oil, Other	0.22	0.25	13%	2%	2%	Olive Oil	0.05	0.06	14%	1%	1%
Palmkernel Oil	0.12	0.24	101%	1%	2%	Sesameseed Oil	0.01	0.04	257%	0%	0%
Ricebran Oil	0.10	0.11	20%	1%	1%	Ricebran Oil	0.03	0.04	10%	1%	0%
Sesameseed Oil	0.10	0.11	3%	1%	1%	Maize Germ Oil	0.04	0.02	-62%	1%	0%
All Vegetable Oils	9.47	10.71	13%	100%	100%	All Vegetable Oils	3.70	7.88	113%	100%	100%
Four Major Oils	6.79	7.83	15%	72%	73%	Three Major Oils	2.29	5.81	154%	62%	74%

Note: Averages in 1991-2000 and in 2001-2011 were calculated by averaging each year's data on average consumption per capita.
Source: Authors' calculations based on FAOSTAT

Table 2: Summary Statistics of Data Used in Panel Data Analysis: Consumption Per Capita

Food Use		Consumption Per Capita (kg/per year/per capita)				
		Obs	Mean	Std. Dev.	Min	Max
1991-2000	Soybean Oil	829	2.9	3.6	0.00121	23.0
	Rapeseed Oil	585	2.2	3.2	0.00037	18.2
	Palm Oil	599	2.2	2.4	0.00070	11.1
	Sunflower Oil	817	2.1	2.8	0.00041	12.7
2001-2011	Soybean Oil	1,239	3.3	3.5	0.00195	23.2
	Rapeseed Oil	801	2.0	3.2	0.00020	17.5
	Palm Oil	868	2.8	2.5	0.00037	11.1
	Sunflower Oil	1,202	2.5	3.4	0.00013	15.9
1991-2011	Soybean Oil	2,068	3.1	3.5	0.00121	23.2
	Rapeseed Oil	1,386	2.1	3.2	0.00020	18.2
	Palm Oil	1,467	2.6	2.4	0.00037	11.1
	Sunflower Oil	2,019	2.3	3.2	0.00013	15.9
Rate of Change	Soybean Oil		12.2%			
from 1991-2000	Rapeseed Oil		-9.6%			
to 2001-2011	Palm Oil		30.9%			
	Sunflower Oil		19.0%			

Industrial Use		Consumption Per Capita (kg/per year/per capita)				
		Obs	Mean	Std. Dev.	Min	Max
1991-2000	Soybean Oil	348	1.8	2.2	0.00051	12.4
	Rapeseed Oil	513	1.4	2.3	0.00023	16.2
	Palm Oil	800	2.4	4.0	0.00035	33.5
2001-2011	Soybean Oil	584	2.7	4.1	0.00134	56.5
	Rapeseed Oil	632	3.7	6.5	0.01014	52.0
	Palm Oil	1,226	4.3	7.6	0.00068	120.9
1991-2011	Soybean Oil	932	2.4	3.5	0.00051	56.5
	Rapeseed Oil	1,210	2.5	5.1	0.00023	52.0
	Palm Oil	2,026	3.5	6.5	0.00035	120.9
Rate of Change	Soybean Oil		48.2%			
from 1991-2000	Rapeseed Oil		176.6%			
to 2001-2011	Palm Oil		82.7%			

Note: Data were obtained from FAOSTAT. Cross-country panel data was used for the analysis in this article if a country has a population of 100,000 or more. In addition, for both food use and industrial use, some observations were eliminated as outliers if the real price is less than about 0.3 US dollar/kg or more than about 10 US dollar/kg. The data were used if a country has more than 10 tons of annual consumption. The prices are deflated by Consumer Price Index (World Bank, World Development Indicators, 2005 =100).

Table 3: Summary Statistics of Data Used in Panel Data Analysis: Real Average Price

Food		Real Price (US$/Kg: Base year = 2005)				
		Obs	Mean	Std. Dev.	Min	Max
1991-2000	Soybean Oil	829	1.21	0.89	0.30	6.39
	Rapeseed Oil	585	1.30	1.05	0.31	8.75
	Palm Oil	599	1.07	0.79	0.34	7.04
	Sunflower Oil	817	1.43	1.17	0.36	9.39
2001-2011	Soybean Oil	1,239	0.80	0.34	0.31	6.80
	Rapeseed Oil	801	0.97	0.45	0.31	4.97
	Palm Oil	868	0.70	0.29	0.31	3.80
	Sunflower Oil	1,202	0.98	0.41	0.32	6.83
1991-2011	Soybean Oil	2,068	0.97	0.65	0.30	6.80
	Rapeseed Oil	1,386	1.11	0.78	0.31	8.75
	Palm Oil	1,467	0.85	0.58	0.31	7.04
	Sunflower Oil	2,019	1.17	0.84	0.32	9.39
Rate of Change	Soybean Oil		-33.8%			
from 1991-2000	Rapeseed Oil		-25.2%			
to 2001-2011	Palm Oil		-34.3%			
	Sunflower Oil		-31.5%			

Industrial Use		Real Price (US$/Kg: Base year = 2005)				
		Obs	Mean	Std. Dev.	Min	Max
1991-2000	Soybean Oil	348	1.01	0.75	0.40	5.73
	Rapeseed Oil	513	1.32	1.10	0.30	9.83
	Palm Oil	800	1.16	1.03	0.34	8.95
	Crude Oil (Per Litre)	909	0.22	0.17	0.08	1.65
2001-2011	Soybean Oil	584	0.80	0.40	0.35	6.80
	Rapeseed Oil	697	1.02	0.45	0.35	4.00
	Palm Oil	1,226	0.73	0.30	0.30	3.80
	Crude Oil (Per Litre)	1,289	0.33	0.12	0.14	1.12
1991-2011	Soybean Oil	932	0.88	0.57	0.35	6.80
	Rapeseed Oil	1,210	1.14	0.81	0.30	9.83
	Palm Oil	2,026	0.90	0.72	0.30	8.95
	Crude Oil (Per Litre)	2,198	0.29	0.15	0.08	1.65
Rate of Change	Soybean Oil		-21.1%			
from 1991-2000	Rapeseed Oil		-22.6%			
to 2001-2011	Palm Oil		-37.7%			
	Crude Oil (Per Litre)		49.9%			

Note: Data were obtained from FAOSTAT. Cross-country panel data was used for the analysis in this article if a country has a population of 100,000 or more. In addition, for both food use and industrial use, some observations were eliminated as outliers if the real price is less than about 0.3 US dollar/kg or more than about 10 US dollar/kg. The data were used if a country has more than 10 tons of annual consumption. The prices are deflated by Consumer Price Index (World Bank, World Development Indicators, 2005 =100).

Table 4: Summary Statistics of Data Used in Panel Data Analysis: Real GDP per Capita

1991-2011 Real GDP Per Capita (in 2005 US$)	Obs	Mean	Std. Dev.	Min	Max	Population
Group4: GDP 0-999 US$	1,103	488	240	28.42	999.96	>0
	1,103	488	240	28.42	999.96	>=100,000
Group3: GDP 1,000-3,999 US$	972	2,302	881	1,000.03	3,993.88	>0
	958	2,283	873	1,000.03	3,993.88	>=100,000
Group2: GDP 4,000-14,999US$	760	7,285	2,970	4,006.59	14,954.34	>0
	707	7,235	3,009	4,006.59	14,954.34	>=100,000
Group1: GDP 15,000 US$-	630	33,133	12,313	15,064.44	80,286.68	>0
	609	32,003	10,767	15,064.44	68,839.66	>=100,000
All Groups	3,465	8,423	13,099	28.42	80,286.68	>0
	3,377	8,093	12,441	28.42	68,839.66	>=100,000

Note: Real GDP data were obtained from U.S. Census Bureau, International Data Base organized into ERS/USDA Baseline Data Files (USDA ERS International Macroeconomic Data Set).

Table 5: Model Estimates by Fixed Model with Robust Standard Errors (Driscoll and Krray Standard Errors vs Rogers Standard Errors)

FOOD USE	Dependent Variable: Per Capita Consumption							
	Ln Soybean Oil		Ln Rapeseed Oil		Ln Palm Oil		Ln Sunflower Oil	
Explanatory Variable	Driscoll-Kraay	Rogers (Clustered)	Driscoll-Kraay	Rogers (Clustered)	Driscoll-Kraay	Rogers (Clustered)	Driscoll-Kraay	Rogers (Clustered)
Ln Soya Oil Deflated Price	-0.42 ***	-0.42 ***	0.00	0.00	0.11 **	0.11	-0.10	-0.10
	(-7.61)	(-3.23)	(0.00)	(0.00)	(2.26)	(1.02)	(-1.24)	(-0.85)
Ln Rape Oil Deflated Price	0.11 *	0.11	-0.68 ***	-0.68 ***	0.09 ***	0.09	0.03	0.03
	(1.89)	(1.55)	(-5.19)	(-3.27)	(2.75)	(1.28)	(0.43)	(0.38)
Ln Palm Oil Deflated Price	-0.06	-0.06	0.37 **	0.37 *	-0.46 ***	-0.46 ***	0.41 ***	0.41 ***
	(-1.17)	(-0.58)	(2.25)	(1.77)	(-6.53)	(-3.25)	(4.29)	(4.34)
Ln Sunf Oil Deflated Price	0.11 **	0.11	0.58 ***	0.58 ***	0.09	0.09	-0.54 ***	-0.54 ***
	(2.12)	(1.28)	(3.29)	(3.47)	(1.22)	(0.95)	(-7.21)	(-3.77)
Ln Per Capita Real GDP	0.73 ***	0.73 ***	0.20	0.20	1.07 ***	1.07 ***	0.47 ***	0.47 *
	(4.91)	(3.09)	(1.11)	(0.68)	(6.27)	(4.30)	(6.24)	(1.94)
Average value of the fixed effects	6.76 ***	6.76 ***	7.53 ***	7.53 ***	3.78 **	3.78 *	7.99 ***	7.99 ***
	(5.20)	(3.35)	(4.35)	(2.94)	(2.45)	(1.84)	(10.55)	(3.74)
Observations	2068	2068	1386	1386	1467	1467	2019	2019
Groups	143	143	107	107	105	105	141	141
F	28.7	5.4	6.4	5.0	22.24	5.50	44.14	6.85
within R-squared	0.09	0.09	0.06	0.06	0.11	0.11	0.06	0.06
R-squared	0.84	0.84	0.86	0.86	0.82	0.82	0.92	0.92
Adj R-squared	0.83	0.83	0.85	0.85	0.80	0.80	0.91	0.91

INDUSTRIAL USE	Dependent Variable: Per Capita Consumption					
	Ln Soybean Oil		Ln Rapeseed Oil		Ln Palm Oil	
Explanatory Variable	Driscoll-Kraay	Rogers (Clustered)	Driscoll-Kraay	Rogers (Clustered)	Driscoll-Kraay	Rogers (Clustered)
Ln Soya Oil Deflated Price	-0.49 ***	-0.49 **	0.45 **	0.45 *	-0.09	-0.09
	(-3.14)	(-2.09)	(2.18)	(1.96)	(-1.12)	(-0.70)
Ln Rape Oil Deflated Price	0.11	0.11	-0.94 ***	-0.94 ***	0.10	0.10
	(0.85)	(0.56)	(-8.35)	(-3.20)	(1.27)	(1.02)
Ln Palm Oil Deflated Price	0.28 ***	0.28	0.24	0.24	-0.29 **	-0.29 **
	(2.72)	(1.48)	(1.20)	(1.09)	(-2.56)	(-2.29)
Ln Crude Oil Deflated Price	0.00	0.00	0.62 ***	0.62 ***	0.22 ***	0.22
	(0.03)	(0.02)	(4.39)	(3.32)	(2.76)	(1.64)
Ln Per Capita Real GDP	0.84 ***	0.84	1.97 ***	1.97 ***	2.79 ***	2.79 ***
	(4.37)	(1.64)	(7.44)	(4.70)	(11.74)	(6.52)
Average value of the fixed effects	-0.52	-0.52	-9.59 ***	-9.59 **	-14.53 ***	-14.53 ***
	(-0.26)	(-0.10)	(-3.72)	(-2.24)	(-6.19)	(-3.62)
Observations	932	932	1210	1210	2026	2026
Groups	68	68	82	82	144	144
F	5.6	2.1	24.6	15.2	212.0	30.0
within R-squared	0.04	0.04	0.20	0.20	0.29	0.29
R-squared	0.78	0.78	0.80	0.80	0.75	0.75
Adj R-squared	0.76	0.76	0.78	0.78	0.73	0.73

Note: The robust t-statistics are reported in parentheses. Asterisks denote statistical significance at the *10%, **5%, and ***1% levels.
Driscoll and Kraay standard errors estimates are robust to disturbances being heteroskedastic, autocorrelated with MA(1), and cross-sectionally dependent.
Rogers (Clustered) standard errors are heteroskedasticity and autocorrelation consistent.

Table 6: Model Estimates with Interaction Terms between Own Price and GDP Category Dummy Variables

FOOD USE	Dependent Variable: Per Capita Consumption			
	Driscoll and Kraay standard errors estimates			
Explanatory Variable	Ln Soybean Oil	Ln Rapeseed Oil	Ln Palm Oil	Ln Sunflower Oil
Ln Deflated Own Price	-0.41 ***	-0.51 ***	-0.47 ***	-0.40 ***
	(-7.21)	(-4.11)	(-4.31)	(-5.42)
Ln Deflated Own Price * Group 1 (D)	Omitted	Omitted	Omitted	Omitted
Ln Deflated Own Price * Group 2 (D)	0.02	-0.06 **	-0.04	-0.10 ***
	(1.07)	(-2.18)	(-1.04)	(-4.12)
Ln Deflated Own Price * Group 3 (D)	-0.03	-0.17 *	0.02	-0.16 ***
	(-0.77)	(-1.97)	(0.25)	(-4.09)
Ln Deflated Own Price * Group 4 (D)	-0.03	-0.20 *	0.04	-0.19 ***
	(-0.70)	(-1.93)	(0.43)	(-3.62)
Ln Soya Oil Deflated Price		-0.02	0.12 **	-0.11
		(-0.10)	(2.32)	(-1.34)
Ln Rape Oil Deflated Price	0.12 **		0.07 **	0.04
	(1.98)		(2.07)	(0.56)
Ln Palm Oil Deflated Price	-0.06	0.37 **		0.41 ***
	(-1.29)	(2.18)		(4.08)
Ln Sunf Oil Deflated Price	0.12 **	0.58 ***	0.09	
	(2.19)	(3.34)	(1.18)	
Ln Per Capita Real GDP	0.68 ***	-0.01	1.13 ***	0.27 **
	(4.72)	(-0.07)	(5.34)	(2.51)
Average value of the fixed effects	7.11 ***	9.19 ***	3.31 *	9.51 ***
	(5.47)	(4.56)	(1.86)	(10.49)
Observations	2068	1386	1467	2019
Groups	143	107	105	141
F	33.0	5.8	26.3	37.5
within-R-squared	0.09	0.06	0.11	0.07
R-squared	0.84	0.86	0.82	0.92
Adj R-squared	0.83	0.85	0.80	0.91

Note: The robust t-statistics are reported in parentheses. Asterisks denote statistical significance at the *10%, **5%, and ***1% levels.

Group 1: Countries with Annual Real GDP per Capita>=15,000US$

Group 2: Countries with Annual Real GDP per Capita>=4,000US$, <15,000US$

Group 3: Countries with Annual Real GDP per Capita>=1,000US$, <4,000US$

Group 4: Countries with Annual Real GDP per Capita>=0US$, <1,000US$

(D): Dummy variable

Table 7: Model Estimates with Interaction Terms between Income and GDP Category Dummy Variables

FOOD USE	Dependent Variable: Per Capita Consumption			
	Driscoll and Kraay standard errors estimates			
Explanatory Variable	Ln Soybean Oil	Ln Rapeseed Oil	Ln Palm Oil	Ln Sunflower Oil
Ln Soya Oil Deflated Price	-0.42 ***	-0.02	0.11 **	-0.11
	(-7.53)	(-0.16)	(2.24)	(-1.24)
Ln Rape Oil Deflated Price	0.12 **	-0.64 ***	0.08 **	0.04
	(1.99)	(-5.32)	(2.37)	(0.55)
Ln Palm Oil Deflated Price	-0.07	0.37 **	-0.46 ***	0.42 ***
	(-1.32)	(2.16)	(-6.59)	(4.18)
Ln Sunf Oil Deflated Price	0.12 **	0.57 ***	0.09	-0.55 ***
	(2.23)	(3.33)	(1.21)	(-7.56)
Ln Per Capita Real GDP * Group 1 (D)	0.68 ***	-0.08	1.09 ***	0.38 ***
	(5.21)	(-0.43)	(5.82)	(3.69)
Ln Per Capita Real GDP * Group 2 (D)	0.71 ***	-0.13	1.09 ***	0.33 ***
	(5.12)	(-0.68)	(5.64)	(3.22)
Ln Per Capita Real GDP * Group 3 (D)	0.68 ***	-0.22	1.10 ***	0.31 ***
	(5.07)	(-1.04)	(5.49)	(2.71)
Ln Per Capita Real GDP * Group 4 (D)	0.66 ***	-0.31	1.11 ***	0.29 **
	(5.14)	(-1.36)	(5.29)	(2.28)
Average value of the fixed effects	7.14 ***	10.61 ***	3.58 **	9.14 ***
	(5.97)	(5.38)	(2.09)	(9.60)
Observations	2068	1386	1467	2019
Groups	143	107	105	141
F	35.4	8.6	20.8	33.5
within R-squared	0.09	0.07	0.11	0.07
R-squared	0.85	0.86	0.82	0.92
Adj R-squared	0.83	0.85	0.80	0.91

Note: The robust t-statistics are reported in parentheses. Asterisks denote statistical significance at the *10%, **5%, and ***1% levels.

Group 1: Countries with Annual Real GDP per Capita>=15,000US$
Group 2: Countries with Annual Real GDP per Capita>=4,000US$, <15,000US$
Group 3: Countries with Annual Real GDP per Capita>=1,000US$, <4,000US$
Group 4: Countries with Annual Real GDP per Capita>=0US$, <1,000US$
(D): Dummy variable