An implication of potential variations on rice yields using stochastic analysis

–major exporting countries' potential rice yield projections with fertiliser price variations–

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Abstract

Crop production has been gradually increasing in the most of countries for the last several decades, and a yield as one of significant drivers has contributed to growing crop production in the global market and most of local markets. However the yield has varied from year to year with fluctuations occasionally. This paper seeks for one of approaches to evaluate the impact of major crop yields, especially rice in some selected countries, with fluctuations using stochastic analysis (Furuya_and Meyer, 2006, 2008). It would show potential stochastic ranges of major crop yields, the rice case in this paper, in the future based on their historical variations and could seek for future's risks by drawing on available yields with some agricultural materials, especially fertiliser, and evaluating the resulting variations in the rice yield and an agricultural material as the case of fertiliser for the markets. This analysis takes historical variations in rice yield as a market driver of food supply in some selected major rice exporters (Thailand, India, Vietnam, U.S. and so on), including fertiliser as an agricultural material, and assumes that the historical variability of this factor continues into the future due to some risk and uncertainties of selected domestic rice markets and the global rice market.

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1. Introduction

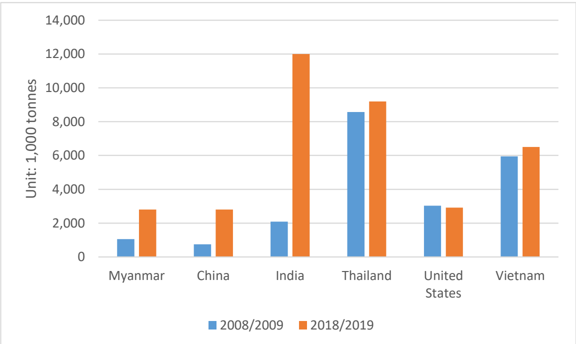
Crop production has been gradually increasing in the most of countries for the last several decades, and a yield as one of significant drivers has contributed to growing crop production in the global market and most of local markets. However the yield has varied from year to year with fluctuations occasionally. This paper seeks for one of approaches to evaluate the impact of major crop yields, especially rice in some selected countries, with fluctuations using stochastic analysis (Furuya_and Meyer, 2006, 2008). It would show potential stochastic ranges of major crop yields, the rice case in this paper, in the future based on their historical variations and could seek for future's risks by drawing on available yields with some agricultural materials, especially fertiliser, and evaluating the resulting variations in the rice yield and an agricultural material as the case of fertiliser for the markets. This analysis takes historical variations in rice yield as a market driver of food supply in some selected major rice exporters (Thailand, India, Vietnam, U.S. and so on), including fertiliser as an agricultural material, and assumes that the historical variability of this factor continues into the future due to some risk and uncertainties of selected domestic rice markets and the global rice market.

2. Overview of the global rice market

The world trade in rice market in 2018 was approximately 460 million metric tons and was increased up 60% for the last decade from approximately 280 million metric tons. At this moment, global trade was expanding at a faster rate than global rice production growth (USDA FAS, 2019).

In terms of rice exports (See figure 1), rice exports from major selected countries – India, Thailand, Vietnam, the United States and so on– were higher than the last decade in 2008 behind emerging economies' growths without the United States, especially India, currently the top exporter in the global rice trade, rapidly increased rice exports and reached to 12 million tonnes in 2018. The following Thailand, the previous top exporter, and Viet Nam were close to 10 and 7 million tonnes of their exports respectively. The U.S.'s domestic consumption has moderately grown and the U.S. has somewhat kept the same export level through the last decade. Additionally, Myanmar has been an emerging exporter in the global market. As a consequence, India, Thailand, Vietnam and the United States have currently been top four rice exporters.

Figure 1. Major countries' rice exports in 2008 and 2018

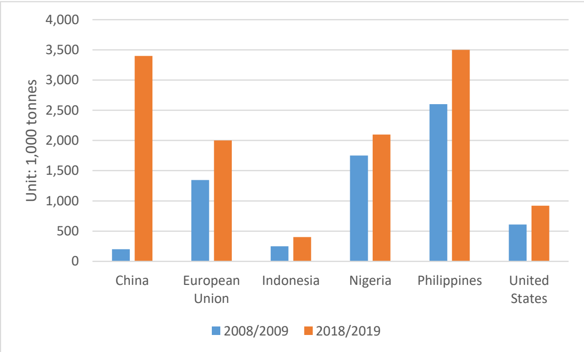


Source: USDA FAS (2019).

On rice imports (See figure 2), China and Philippines were top group of importers in 2018.

China has recently maintained its top group whilst it has big stocks and minimum purchase price policy for rice. Nigeria, one of five major importers includes the European Union, has moderately increased its imports behind population growth and African countries as a region follow Nigeria to increase rice imports because of demand continuing to outpace its production in the region.

Figure 2. Major countries' rice imports in 2008 and 2018

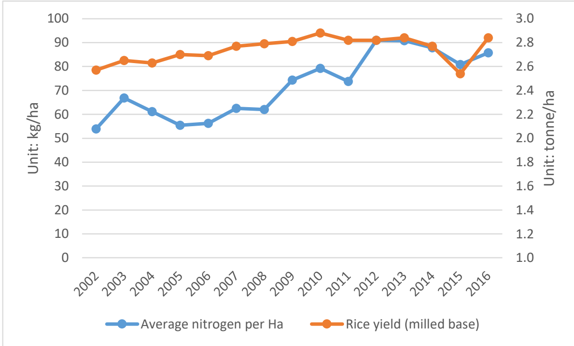


Source: USDA FAS (2019).

3. Yields and fertiliser sector

According to FAO report (FAO, 2017), consumption of the three primary fertiliser nutrients, nitrogen, phosphorus and potassium, is estimated to reach 187 million tonnes in 2016 on aggregate. The demand for the three fertiliser nutrients is expected to increase annually on average by approximately 2 percent from 2015 to 2020. In the next five years, the global capacity of the production of fertilisers would be needed to grow and raw materials of the fertiliser are also expected to increase. As the relationship between crops yield and fertiliser use is well-known (See figure 3 in the case of Thailand, one of major rice exporters), they are tied (FAO, 2015).

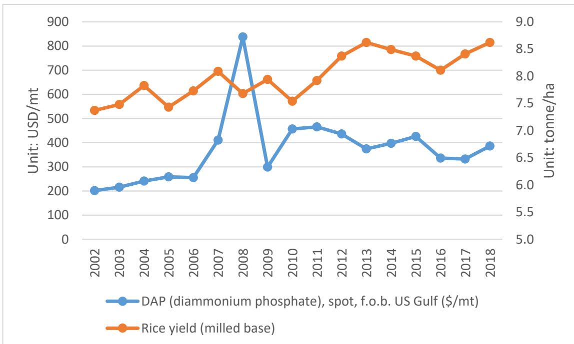
Figure 3. Rice yield and nitrogen use per a cropland hectare in Thailand



Source: USDA FAS (2019) and FAO (2019).

Behind continuously growing demand of crops including rice, fertiliser price and crop yields' relationship would somewhat intensify. Rosas (2011) specified the yield equation stated by some drivers, a time trend, an intensification component including indirectly fertiliser price through the cost of production. Fertilizer application was particularly interested as the intensification term because it induces its effect. For instance, the relationship between rice yield and fertiliser price in the case of U.S., seem to link (See figure 4). The DAP (diammonium phosphate) price of nutrient nitrogen as measured by the benchmark fertiliser price in the global market has gradually risen to USD 386/tonne in the 2018 since 2002 in nominal terms. Although the DAP price sharply increased in the period of the skyrocketing oil prices, the years of 2007-08, it remains favourable.

Figure 4. Rice yield and fertiliser price in the U.S.

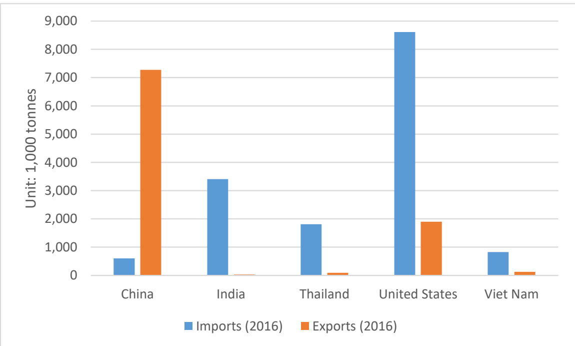


Note: In this paper, the DAP (diammonium phosphate) price of nutrient nitrogen is used as a fertiliser price.

Source: USDA FAS (2019), FAO (2019), World Bank (2019b) and World Bank (2019c).

As growing demand of fertiliser use in the world, major exporters in the global rice market has imported fertiliser. Although trade quantities are depending on the scale of agricultural sector, major exporters in the global rice market showed an excess of imports for fertiliser in 2016 (See figure 5). It may indicate international reference price of fertiliser affects each domestic fertiliser prices. Therefore the DAP price as an international reference price of fertiliser would be utilised for independent variable in a fertiliser price transmission behind import surplus of fertiliser in specific.

Figure 5. Selected countries' fertiliser trade in 2016



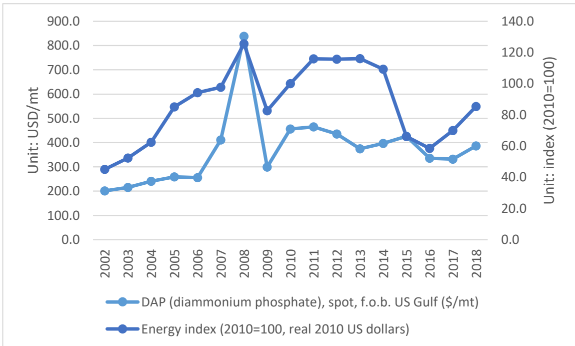
Source: FAO (2019).

4. Fertiliser and energy prices

High energy prices impact various cost segments, including fertiliser sector. Especially, they had impacts in the period of the skyrocketing oil prices. According to FAO (2015), the importance of natural gas (which accounts for about two-thirds of the production capacity of ammonia) should not be understated in relation to nitrogen fertiliser production. And fertiliser prices are significantly affected by the crude oil price (Chen et al., 2012). In addition, fertiliser price volatility has related to food and energy price volatilities. Price volatility indices are also calculated to analyse fertiliser price volatility and compare its developments to those of the volatility of food and energy prices (Ott, 2012). And the volatility effects of oil and natural gas prices on fertiliser prices were also significant (Sanyal et al, 2015).

The figure 6 shows the DAP (diammonium phosphate) price of nutrient nitrogen actually has been influenced by the energy price. The DAP price and energy index almost moved in parallel, especially after 2007. This energy index was calculated by the World Bank in the commodity markets outlook, and it would be used to estimate a price transmission equation instead of energy price.

Figure 6. Fertiliser and energy prices



Note: In this paper, the DAP (diammonium phosphate) price of nutrient nitrogen is used as a fertiliser price.

Source: World Bank (2019c)

5. Proposed approach

In terms of the relationship between fertiliser and energy prices, Baffes (2007, 2009) estimated its equation that was described by a linear logarithm equation. In the equation, fertiliser price was represented as a dependent variable. This paper would examine the price transmission from energy to non-energy commodities, feriliser, and it estimates transmission elasticities for fertiliser as non-energy price indices based on the following specification:

$log(FTPt) = \alpha + \beta1 * log(EGYPt)/log(DEFt) + \beta2 * TRD + \varepsilon t$, … (1)

FTP: International fertiliser reference price

EGYP: International energy price index

DEF: Deflator

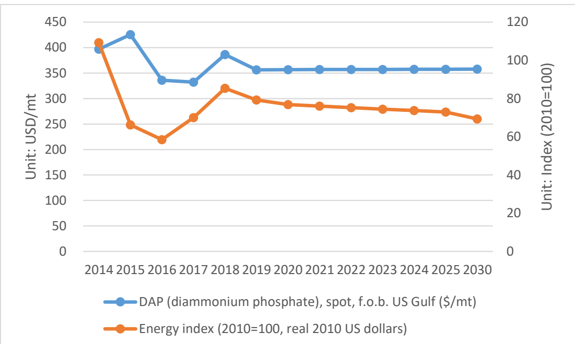
TRD: Trend term

t: time

where FTP denotes DAP (diammonium phosphate) price of nutrient nitrogen as fertiliser price based on US dollar at time t, EGY denotes the energy price index, DEF denotes the deflator, TRD is time trend, and ε denotes the error term, the properties of which will be subject to empirical investigation; α, $\beta1$ and $\beta2$ denote parameters to be estimated. Because the model is expressed in logarithms, the parameter estimates can be interpreted as elasticities.

As shown in the figure 7, World Bank (2019a) has forecasted DAP (diammonium phosphate) price of nutrient nitrogen as a fertiliser price and energy index as an energy indicator to 2030. As described in previous chapter, the fertiliser price has a close relation to the energy price. The forecasted energy index would be utilised as an exogenous variable for fertiliser price projections in this proposed approach through the equation (1).

Figure 7. Present and forecast of fertiliser and energy prices



Note: In this paper, the DAP (diammonium phosphate) price of nutrient nitrogen is used as a fertiliser price. Energy index is one of price indicators for energy.

Source: World Bank (2019a) and World Bank (2019c)

On the relationship between crop yield and some prices, crop yield responds to output prices (Keeney and Hertel, 2008). Keeney and Hertel (2008) sought to find better yield responses by a survey of historical literature on supply response as crop yield response to its price. OECD and FAO (2015) has the equations for crop yield that responds to prices including fertiliser and energy. Thompson at al., (2019) also specified an equation on crop yields. It has two prices, and one is the price of energy inputs in crop productivity and the other is the domestic cereal price. In this paper, the following equations would be examined as its relationship between rice yield with fertiliser price based on the following proposed specification:

$CIc,t = 100 * (FTPt * XRc,t) / (FTPt,2008 * XRc,2008)$, … (2)

CI: Fertiliser cost index (the year of 2008 = 100)

XR: Exchange rate

c: country, *t*: time,

$log(YLDc,t) = \delta + \theta1 * log(PPc,(t-1) / (CIc,(t-1)/CIc,2008)) + \theta2 * TRD + \varepsilon t$, … (3)

YLD: Rice yield

PP: Rice producer price

where CI denotes cost index as calculated from fertiliser price based on US dollar at time t and XR denotes exchange rate in country c. In the equation (3), where YLD denotes rice yield, PP is Rice producer price, and ε denotes the error term, the properties of which will be subject to empirical investigation; δ, θ1 and θ2 denote parameters to be estimated. On the premise of estimating the equation (3) for projection, the equation (2) would be calculated as a definition equation. Those data is sourced from FAO (2019), World Bank (2019b) and USDA FAS (2019).

In addition, a stochastic analysis of Furuya and Meyer (2006, 2008) would be referred in this proposed approach that would be examined as its potential variations applying to rice yields with fertiliser prices in selected major rice exporters, Thailand, India, Vietnam and the U.S., and possibly some major rice importers based on the following proposed framework (Figure 8). In practice, the equations that previously are described on the rice yield would stochastically be solved. The equations as a model would solve dynamically over a ten-year projection period. Thompson at al. (2011) also has a similar stochastic simulation. For example, instead of assuming a single path for the prices of fertiliser or taking trend yields based on average weather conditions, this stochastic simulation allow to make variations for fertiliser prices and/or possibly yield shocks from distributions based on historical variations and cross-variable correlations.

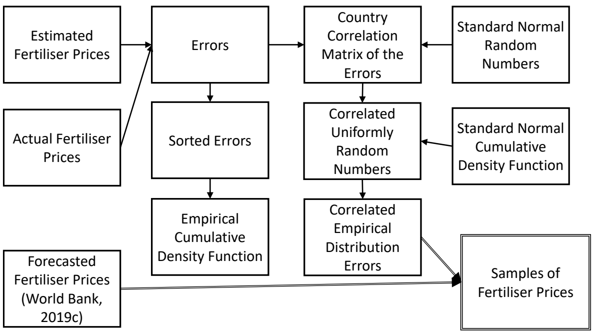


Figure 8. Flowchart for generating potential variations on correlated random fertiliser price variable

Source: Furuya and Meyer (2008)

The fertiliser price variable would be indirectly exogenous to the rice yield equation through the cost index, the equation (2). However the fertiliser price values must be endogenised in a stochastic model which they feed the equations in a projection period so that they can be evaluated for the impacts of changes in the rice yield on the global rice market and each domestic markets, as applying a methodology based on Furuya and Meyer (2006, 2008). Additionally sorting the stochastic results by fertiliser prices in the flowchart suggests how sensitive results of its scenario are to market circumstances (Westhoff at al., 2008). The distributions of the error terms can be expanded to stochastically simulate potential variations in future fertiliser price distributions (Figure 8).

6. Discussion

An implication is that potential variations of fertiliser price in the future within rice markets would have some impacts on rice supply through its yields in the global market and domestic markets in some major exporters. Depending on their projected price level in the stochastic simulation, increasing or decreasing exports might rise or decline of self-sufficiency in some rice importers, especially developing countries.

Additionally, this analysis would explore the sensitivity of these results to rice yield variations. The implication for food security could be examined by feeding the price changes under the simulations into a global food supply and demand model, and calculating the resulting changes in rice consumption.

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