Contribution of Agricultural Investments to Stabilizing International Rice Price Volatility under Climate Change – Simulation for eight ASEAN countries –

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Abstract
The role of agricultural investment growth in alleviating climate risks to rice production systems and rice markets was examined using a partial equilibrium model. The Rice Economy Climate Change (RECC) model covers the rice markets in 15 countries and regions. The rice yield in each economy is estimated from minimum and maximum temperatures, precipitation, and agricultural investments. The rice area harvested is estimated from rice and wheat producer prices and precipitation. We examine how future agricultural investments will affect the world rice market. The volatility of international rice prices in the baseline is expected to increase during 2010/12 to 2030 with climate change. However, a constant increase in agricultural investments in eight ASEAN countries will contribute to reducing international rice price volatility. In particular, investments in Thailand and Vietnam are most important for stabilizing international rice prices under future climate change conditions.

Introduction
There is a growing consensus about global warming and that our planet will continue to warm up as concentrations of greenhouse gases increase in the future (IPCC 2013). The increase in global mean surface temperatures for 2081-2100 relative to 1986-2005 is projected to be between 0.3°C to 4.8°C, depending on Representative Concentration Pathways (RCPs). Agricultural production will be affected by this climate change in many different ways, including changes in yield and area harvested. However, considerable debate continues on how harmful or beneficial climate change will be for a particular crop in a particular location.

Many studies have been made on how future climate change could impact global agricultural and rice production. Peng et al. (2004) examined how higher night temperature affected rice yield. Welch (2010) examined how minimum and maximum temperatures impacted the rice yields in tropical/subtropical Asia. Lobel (2007) examined the changes in diurnal temperature range and national cereal yield. Moreover, Furuya and Koyama (2005) examined the relationship between climate change and world food markets.

Food price volatility in recent years has hurt millions of people, undermining both nutritional status and food security. After remaining at historic lows for decades, food prices have become significantly higher and more volatile since 2007. Price volatility has a strong impact on food security, because it affects household income and purchasing power (FAO 2011). The volatility of world sugar prices is a crucial problem. FAO (2011) concluded that investment could reduce food price volatility through increased productivity and improved technical management of production and risk, especially in the face of climate change.

None of these studies, however, has examined how agricultural investment would impact international rice price volatility. This study is the first to evaluate how future climate change will affect world rice price volatility.

This study was supported by FAO and the Assessments of Climate Change Impacts and Mapping of Vulnerability to Food Insecurity under Climate Change (AMICAF) Project, funded by the Government of Japan.

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Received 23 April 2015; accepted 15 October 2015.
The purpose of this study is to conduct policy simulations for alleviating climate risks to rice production systems and rice markets, by utilizing a partial equilibrium model.

Structure of the RECC model

The Rice Economy Climate Change (RECC) model covers the rice markets in 15 countries and regions (Thailand, Vietnam, Indonesia, Malaysia, the Philippines, Cambodia, Lao PDR, Myanmar, China, Japan, South Korea, India, USA, EU27, and the rest of the world). The base year is 2010 (3-year average for 2010-2012). Each country’s market consists of production, consumption, exports, imports, and ending stock up to the year 2030. The RECC model includes equations for projecting the rice yield and area harvested affected by climate change (Fig. 1). We applied an Error Correction Model (ECM) to this study in order to evaluate the long-run equilibrium relationships among economic variables.

Paddy rice yield equation depends on the annual averages of minimum temperature, maximum temperature, precipitation, lagging investments in land development and agricultural machinery & equipment, and time trend as follows:

\[ \ln \left( \frac{Y_{t,c}}{Y_{t-1,c}} \right) = a_1 \ln \left( \frac{T_{\text{min},t,c}}{T_{\text{min},t-1,c}} \right) + a_2 \ln \left( \frac{T_{\text{max},t,c}}{T_{\text{max},t-1,c}} \right) + a_3 \ln \left( \frac{\text{PRC}_{t,c}}{\text{PRC}_{t-1,c}} \right) + a_4 \ln \left( \frac{\text{LD}_{t-1,c}}{\text{LD}_{t-2,c}} \right) + a_5 \ln \left( \frac{\text{AME}_{t-1,c}}{\text{AME}_{t-2,c}} \right) + a_6 \ln \left( \frac{T_t}{T_{t-1}} \right) \]  

where, \( Y \) is paddy rice yield, \( T_{\text{min}} \) is minimum temperature, \( T_{\text{max}} \) is maximum temperature, \( \text{PRC} \) is precipitation, \( \text{LD} \) denotes investments in land development, \( \text{AME} \) denotes investments in agricultural machinery/equipment, \( T \) is time trend, \( t \) is time, \( c \) are countries/region, and \( a_1-a_6 \) are parameters. Tables A1-1 and A1-2 list these estimated parameters. The planted area equation for paddy rice depends on the producer prices of rice and wheat, precipitation, lagging investments in land development, and time trend as follows:

\[ \ln \left( \frac{\text{APW}_{t,c}}{\text{APW}_{t-1,c}} \right) = a_7 \ln \left( \frac{\text{RP}_{t,c}}{\text{RP}_{t-1,c}} \right) + a_8 \ln \left( \frac{\text{WP}_{t,c}}{\text{WP}_{t-1,c}} \right) + a_9 \ln \left( \frac{\text{PRC}_{t,c}}{\text{PRC}_{t-1,c}} \right) + a_{10} \ln \left( \frac{\text{LD}_{t-1,c}}{\text{LD}_{t-2,c}} \right) + a_{11} \ln \left( \frac{T_t}{T_{t-1}} \right) \]  

where, \( \text{APW} \) is the planted area of rice, \( \text{RP} \) is the domestic rice price, \( \text{WP} \) is the domestic wheat price, \( a_7 \) is the own domestic price elasticity of rice, \( a_8 \) is the substitute price elasticity, and \( a_9-11 \) are other parameters. Tables A2-1 and A2-2 list these estimated parameters. The harvested area is derived from the difference between the planted area and abandoned area.

\[ \text{AHW}_{t,c} = \text{APW}_{t,c} - \text{ABD}_{t,c} \]  

Fig. 1. Structure of the RECC model in the case of Thailand
where, $AHW$ is harvested area and $ABD$ is abandoned area. Paddy rice production is calculated by multiplying the area harvested and the yield of paddy rice.

$$QPRP_{t,c} = AHW_{t,c} \times Y_{t,c}$$  \hspace{1cm} (4)

where, $QPRP$ denotes paddy rice production. Milled rice production is calculated by multiplying paddy rice production and the milling rate from paddy to milled rice. Table A3 lists the milling rates.

$$QPR_{t,c} = QPRP_{t,c} \times MIL_{t,c}$$  \hspace{1cm} (5)

where, $QPR$ is milled rice production and $MIL$ is the milling rate. Per capita rice consumption depends on income, domestic prices for rice, wheat and corn, and time trend. Rice consumption is calculated by multiplying the per capita rice consumption and the country’s population.

$$\ln (PQCR_{t,c} / PQR_{t-1,c}) = a_{12} \ln (PCGD_{t,c} / PCD_{t-1,c}) + a_{13} \ln (RP_{t,c} / RP_{t-1,c}) + a_{14} \ln (WP_{t,c} / WP_{t-1,c}) + a_{15} \ln (CGP_{t,c} / CGP_{t-1,c}) + a_{16} \ln (T_t / T_{t-1})$$  \hspace{1cm} (6)

$$QCR_{t,c} = PQCR_{t,c} \times POP_{t,c}$$  \hspace{1cm} (7)

where, $PQCR$ is the per capita consumption of rice, $PCGD$ is per capita GDP, $CGP$ is the domestic corn price, $QCR$ is rice consumption, $POP$ is population, $a_{12}$ is income elasticity, $a_{13}$ is the own domestic price elasticity of rice, $a_{14}$ and $a_{15}$ are substitute price elasticity, and $a_{16}$ is parameter. Tables A4-1 and A4-2 list these estimated parameters. For net rice exporting countries, rice imports depend on the international rice price, rice production, domestic rice price, and time trend. Rice exports are calculated by the exportable domestic market balance deficit remaining after the domestic market has been satisfied as follows:

$$\ln (EXR_{t,c} / EXR_{t-1,c}) = a_{21} \ln (IRP_{t,c} / IRP_{t-1,c}) + a_{22} \ln (QPR_{t,c} / QPR_{t-1,c}) + a_{23} \ln (RP_{t,c} / RP_{t-1,c}) + a_{24} \ln (T_t / T_{t-1})$$  \hspace{1cm} (8)

$$EXR_{t,c} = QPR_{t,c} - QCR_{t,c} + IMR_{t,c} - (ESR_{t,c} - ESR_{t-1,c})$$  \hspace{1cm} (9)

where, $IMR$ is rice imports, $IRP$ is the international rice price, $EXR$ denotes rice exports and $ESR$ the ending stocks of rice, and $a_{21}$-$a_{24}$ are parameters. Table A5 lists the estimated parameters. For net rice importing countries, rice imports depend on the international rice price, rice production, domestic rice price, and time trend. Rice imports are calculated by the exportable domestic market balance deficit remaining after the domestic market has been satisfied as follows:

$$\ln (EXR_{t,c} / EXR_{t-1,c}) = a_{25} \ln (DP_{t,c} / DP_{t-1,c}) + a_{26} \ln (T_t / T_{t-1})$$  \hspace{1cm} (10)

$$\ln (RP_{t,c} / RP_{t-1,c}) = a_{27} \ln (IRP_{t,c} / IRP_{t-1,c}) + a_{28} \ln (T_t / T_{t-1})$$  \hspace{1cm} (11)

$$\sum IMR_{t,c} = \sum EXR_{t,c}$$  \hspace{1cm} (12)

### Data for regression

Historical annual minimum/maximum temperatures and precipitation data are derived from CRU TS. 3.2 (University of East Anglia). For larger countries, the values for grids that correspond to the major rice producing areas in each country are averaged (West Java, Central Java, East Java, and Banten for Indonesia; Hunan, Hubei, and Jiangxi for China; Louisiana and Arkansas for the USA; West Bengal, Andhra Pradesh, Orissa, Chhattisgarh, and Tamil Nadu for India; Nueva Ecieja for the Philippines). For other countries, the values for all grids that cover the entire territory are spatially averaged. Historical planted area, yield, production, per capita consumption, imports, exports, and ending stock data for rice are derived from PSM & D (USDA). We define the rice producer price as the domestic rice price in this study. We also define wheat and corn producer prices as domestic wheat and corn prices. These producer prices are derived from FAOSTAT (FAO), and the data are used for regression in time-series analysis.
Simulations of the world rice market

1. Baseline assumptions

The baseline outlook adopts a set of assumptions for the general economy, agricultural policies, and technological changes without any policy shocks during the outlook period. The climate variables (minimum/maximum temperatures, precipitation) in each country and region are exogenous to the model. All climate variables for both the baseline outlook and policy scenario come from climate change projections by the Bergen Climate Model, version 2 (BCM2), a global climate model under the A2 greenhouse gas emissions scenario. Spatially averaged climate variables for each country are computed the same way as the historical climate data used for regression (see the previous section). The standard deviations of minimum and maximum temperatures in most of the countries1 are projected to increase during the decades from 1990-2010 to 2010-2030 (Figs. 2 and 3). The standard deviations of precipitation in Thailand, Vietnam, Lao PDR, India, China, and Japan are projected to increase during the same periods (Fig. 4), while those in other countries are projected to decrease. Table A9 lists the standard deviation data of minimum/maximum temperatures and precipitation in detail.

Population data for all countries were taken from the 2010 Revision (medium variant) of World Population Prospects, United Nations (2013). Per capita real GDP was also treated as an exogenous variable, and GDP growth rate assumptions were based on World Economic Outlook 2013 (IMF 2013) and USDA Agricultural Projections to 2022 (USDA 2013). These GDP growth rates are available up to the year 2022. This study assumes no growth in GDP from 2022 to 2030. International wheat and corn prices are derived from OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013). Table A10 lists the exogenous variables for per capita GDP growth rate, population, international wheat and corn prices, and others.

We also assumed that current agricultural policies will continue in all countries throughout the outlook period. Following generally adopted procedures, we assumed that historical rates of technological innovation would continue. The model does not take into account any new WTO agricultural agreements. Agricultural investments (land development, machinery & equipment) are exogenous variables for the baseline outlook.

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1 Bangladesh, with its 6% share of world rice production (calculated from FAOSTAT (FAO)), is considered to represent the “rest of the world” that accounted for 20% of total production in 2010-2012. Italy, with its 0.2% share of world rice production, is considered to represent the EU that accounted for 0.3% of total production in 2010-12 (calculated from FAOSTAT (FAO)).
Fig. 3. Standard deviation of annual maximum temperature

Fig. 4. Standard deviation of annual precipitation
We assumed zero (0) abandoned areas in all countries and regions, and a constant milling rate in all countries and regions during the outlook period.

Land development is the result of actions that lead to major improvements in the quantity, quality or productivity of land, or which prevent its deterioration. Activities such as clearing and contouring the land, digging wells, and creating watering holes are integral to land improvement. The concept of land development for the database of capital stock in agriculture includes field land improvements undertaken by farmers, such as marking boundaries and digging irrigation channels, as well as other activities undertaken by the government and other local bodies, such as work related to irrigation, soil conservation, and flood control structure. Categorized as a capital stock of agricultural investment in FAOSTAT, land development can be used not only for rice but also for other crops in the USA, EU27, China, and India. However, we assume that land development will be mainly used for rice production in eight ASEAN countries. Thus, we utilized it for simulation for those eight ASEAN countries.²

We assume that the current growth rate of agricultural investments from 2000 to 2007 in each country will continue during the outlook period (2010/12 to 2030). The growth rates of investments in land development in Vietnam and Lao PDR from 2000 to 2007 were 2.3% and 2.0%, respectively, which appear to be too high (Table 1). Instead, we applied the growth rates from 1985 to 1995 for these countries (1.0% and 1.2%, respectively) to the outlook period. The growth rates of investments in agricultural machinery & equipment in China and India from 2000 to 2007 were 8.1% and 8.4%, respectively (Table 2). We applied the growth rate from 1990 to 2007 for China (4.2%) and that from 1985 to 1995 for India (5.9%) to the outlook period.

The growth rates of investments in land development in the eight ASEAN countries ranged from -0.1% to 1.9%, and those of machinery & equipment ranged from -0.1% to 1.0%.

2. Policy scenarios

This study applied alternative scenarios to the baseline outlook. This study produces outlooks under three policy scenarios as listed in Table 3. In policy scenario 1, we hypothesize that the growth rate of investments in land development and agricultural machinery & equipment in the eight ASEAN countries will increase by 2.0% and 1.0% per annum from 2010/12 to 2030, respectively. In policy scenario 2, we also hypothesize that the growth rate of investments in land development and in agricultural machinery & equipment in Thailand will increase by 2.0% and 1.0% per annum from 2010/12 to 2030, respectively. In policy scenario 3, we also hypothesize that the growth rate of investments in land development and in agricultural machinery & equipment in Vietnam will increase by 2.0% and 1.0% per annum from 2010/12 to 2030, respectively.

Results

1. Baseline outlook

Under the baseline assumptions, world rice production and consumption are expected to increase at a rate of 1.2% per annum from 2010/12 to 2030 (Tables 4 and 5). World rice exports and imports are expected to increase at a rate of

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2 Thailand, Vietnam, Indonesia, the Philippines, Malaysia, Cambodia, Lao PDR and Myanmar.

Table 1. Growth rates of investments in land development (Baseline outlook)

| Country          | 1975-1985 | 1985-1995 | 1975-2007 | 1990-2007 | 2000-2007 | 2008-2030 (Projection) |
|------------------|-----------|-----------|-----------|-----------|-----------|------------------------|
| Thailand         | 2.8%      | 0.9%      | 1.4%      | 0.8%      | 0.9%      | 0.9%                   |
| Vietnam          | 2.9%      | 1.0%      | 2.2%      | 2.0%      | 2.3%      | 1.0%                   |
| Indonesia        | 0.7%      | -0.4%     | 1.1%      | 1.3%      | 1.9%      | 1.9%                   |
| Cambodia         | 3.0%      | 4.7%      | 2.4%      | 0.3%      | 0.3%      | 0.3%                   |
| Lao PDR          | 2.9%      | 1.2%      | 2.6%      | 3.0%      | 2.0%      | 1.2%                   |
| Myanmar          | 0.3%      | 1.1%      | 1.0%      | 1.7%      | 1.7%      | 1.7%                   |
| Malaysia         | 1.9%      | 2.4%      | 1.3%      | 0.3%      | -0.1%     | -0.1%                  |
| The Philippines  | 2.1%      | 0.1%      | 0.5%      | -0.4%     | 0.5%      | 0.5%                   |
| China            | 1.1%      | 1.1%      | 0.9%      | 0.8%      | 1.1%      | 1.1%                   |
| India            | 1.1%      | 1.2%      | 0.9%      | 0.8%      | -0.1%     | -0.1%                  |
| Japan            | -0.6%     | -0.7%     | -0.6%     | -0.6%     | -0.6%     | -0.6%                  |
| Korea            | 0.1%      | -0.7%     | -0.4%     | -0.9%     | -0.7%     | -0.7%                  |
| Italia (EU27)    | 0.0%      | 0.5%      | 1.0%      | 1.3%      | -0.3%     | -0.3%                  |
| USA              | 0.8%      | 0.3%      | 0.3%      | 0.0%      | -0.1%     | -0.1%                  |
| Bangladesh       | 1.6%      | 2.9%      | 2.0%      | 1.8%      | 1.6%      | 1.6%                   |

(The rest of the world)
1.9% per annum during the same period (Tables 6 and 7). World rice ending stocks are expected to increase at a rate of 0.3% per annum during the same period (Table 8). The international rice price (5% broken milled white rice, Thailand’s nominal price quota) was 550.8 USD/ton in 2010/12, but is expected to be 956.4 USD/ton in 2030 (Table 9). The coefficient of variation (CV) of international rice price from 2010/12 to 2030 is 0.142325.

2. Impacts of agricultural investments on the world rice market

Outlooks were made using various agricultural investment scenarios in selected countries for a comparison against the baseline outlook. These agricultural investments...
### Table 5. World rice consumption (Baseline outlook)

|                | 2010-12 | 2015    | 2020    | 2025    | 2030    | Growth rate (2010/12-2030) |
|----------------|---------|---------|---------|---------|---------|---------------------------|
| World          | 468,706 | 500,719 | 537,445 | 569,370 | 593,579 | 1.2%                      |
| Thailand       | 12,198  | 13,132  | 14,652  | 16,309  | 18,089  | 2.2%                      |
| Vietnam        | 21,085  | 22,289  | 23,866  | 25,239  | 26,406  | 1.3%                      |
| Indonesia      | 43,446  | 46,554  | 51,399  | 55,881  | 59,790  | 1.8%                      |
| Malaysia       | 2,717   | 2,853   | 2,997   | 3,074   | 3,091   | 0.7%                      |
| Cambodia       | 3,478   | 3,686   | 4,038   | 4,095   | 3,897   | 0.6%                      |
| Lao PDR        | 1,450   | 1,644   | 1,983   | 2,354   | 2,741   | 3.6%                      |
| Myanmar        | 10,167  | 10,497  | 10,934  | 11,067  | 10,931  | 0.4%                      |
| The Philippines| 12,157  | 13,458  | 15,690  | 16,628  | 16,368  | 1.7%                      |
| India          | 93,418  | 98,819  | 107,311 | 115,052 | 121,213 | 1.5%                      |
| China          | 130,595 | 141,974 | 145,576 | 146,394 | 145,251 | 0.6%                      |
| Japan          | 8,514   | 8,489   | 8,388   | 8,264   | 8,133   | -0.3%                     |
| Korea          | 4,603   | 4,622   | 4,613   | 4,625   | 4,631   | 0.03%                     |
| USA            | 3,911   | 4,044   | 4,216   | 4,335   | 4,407   | 0.7%                      |
| EU27           | 2,602   | 2,686   | 2,877   | 2,996   | 3,047   | 0.9%                      |

### Table 6. World rice exports (Baseline outlook)

|                | 2010-12 | 2015    | 2020    | 2025    | 2030    | Growth rate (2010/12-2030) |
|----------------|---------|---------|---------|---------|---------|---------------------------|
| World          | 36,626  | 41,496  | 43,123  | 45,976  | 51,689  | 1.9%                      |
| Thailand       | 8,453   | 11,877  | 11,998  | 13,706  | 16,011  | 3.6%                      |
| Vietnam        | 7,444   | 6,633   | 8,185   | 9,642   | 11,575  | 2.5%                      |
| Indonesia      | 2       | 2       | 2       | 2       | 2       | 0.4%                      |
| Malaysia       | 0       | 0       | 0       | 0       | 2       | -                        |
| Cambodia       | 878     | 868     | 814     | 1,108   | 1,805   | 4.1%                      |
| Lao PDR        | 0       | 0       | 0       | 0       | 0       | -                        |
| Myanmar        | 739     | 726     | 1,476   | 2,552   | 3,630   | 9.2%                      |
| The Philippines| 0       | 0       | 0       | 0       | 0       | -                        |
| India          | 7,179   | 10,436  | 9,778   | 8,208   | 7,555   | 0.3%                      |
| China          | 365     | 500     | 647     | 758     | 888     | 5.1%                      |
| Japan          | 173     | 200     | 200     | 200     | 200     | 0.8%                      |
| Korea          | 30      | 3       | 3       | 3       | 3       | 0.0%                      |
| USA            | 3,363   | 2,426   | 2,318   | 2,130   | 2,397   | -1.9%                     |
| EU27           | 168     | 227     | 290     | 330     | 387     | 4.7%                      |

### Table 7. World rice imports (Baseline outlook)

|                | 2010-12 | 2015    | 2020    | 2025    | 2030    | Growth rate (2010/12-2030) |
|----------------|---------|---------|---------|---------|---------|---------------------------|
| World          | 36,879  | 41,496  | 42,866  | 45,498  | 51,689  | 1.9%                      |
| Thailand       | 517     | 341     | 204     | 119     | 69      | -10.6%                    |
| Vietnam        | 583     | 549     | 542     | 559     | 570     | -0.1%                     |
| Indonesia      | 1,800   | 1,973   | 2,744   | 3,131   | 2,169   | 1.0%                      |
| Malaysia       | 1,021   | 1,195   | 1,324   | 1,427   | 1,416   | 1.8%                      |
| Cambodia       | 5       | 5       | 6       | 6       | 6       | 1.0%                      |
| Lao PDR        | 22      | 141     | 7       | 10      | 725     | 21.3%                     |
| Myanmar        | 0       | 0       | 0       | 0       | 0       | -                        |
| The Philippines| 1,543   | 2,057   | 3,187   | 3,155   | 1,746   | 0.7%                      |
| India          | 100     | 100     | 100     | 100     | 100     | 0.0%                      |
| China          | 1,656   | 4,289   | 6,862   | 3,820   | 3,343   | 4.0%                      |
| Japan          | 853     | 768     | 768     | 768     | 768     | -0.6%                     |
| Korea          | 393     | 499     | 578     | 664     | 753     | 3.7%                      |
| USA            | 612     | 606     | 603     | 603     | 602     | -0.1%                     |
| EU27           | 1,008   | 1,107   | 1,414   | 1,571   | 1,608   | 2.6%                      |
can be considered climate change adaptation measures. Under policy scenario 1, world rice production and consumption are expected to increase by 2.7%, and world rice exports and imports are expected to increase by 18.8%, compared with the baseline outlook in 2030 (Table 10). Consequently, the international rice price is expected to decrease by 19.4%, compared with the baseline outlook in 2030.

Using policy scenario 2, rice production in Thailand is expected to increase by 29.6% and its exports are expected to increase by 62.8%, compared with the baseline outlook in 2030. Accordingly, world rice production and consumption are expected to increase by 1.3%, and world rice exports and imports are expected to increase by 13.9%, compared with the baseline outlook in 2030. Consequently, the international rice price is expected to decrease by 10.2%, compared with the baseline outlook in 2030.

The results of policy scenario 3 show rice production in Vietnam is expected to increase by 9.8% and its exports are expected to increase by 32.4%, compared with the baseline outlook in 2030.

**Table 8. World rice ending stocks (Baseline outlook)**

|                | 2010-12 | 2015 | 2020 | 2025 | 2030 | Growth rate (2010-12-2030) |
|----------------|---------|------|------|------|------|---------------------------|
| World          | 158,635 | 155,420 | 157,191 | 161,989 | 166,281 | 0.3%                      |
| Thailand       | 13,000  | 12,688 | 12,797 | 13,195 | 13,530 | 0.2%                      |
| Vietnam        | 3,157   | 3,276  | 3,500  | 3,744  | 4,005  | 1.3%                      |
| Indonesia      | 5,933   | 5,839  | 5,944  | 6,173  | 6,379  | 0.4%                      |
| Malaysia       | 233     | 239    | 250    | 263    | 277    | 1.0%                      |
| Cambodia       | 178     | 147    | 129    | 124    | 116    | -2.3%                     |
| Lao PDR        | 57      | 58     | 60     | 62     | 65     | 0.7%                      |
| Myanmar        | 361     | 372    | 392    | 413    | 436    | 1.0%                      |
| The Philippines| 3,026   | 3,037  | 3,133  | 3,269  | 3,400  | 0.7%                      |
| India          | 22,833  | 19,077 | 16,974 | 16,389 | 15,505 | -2.1%                     |
| China          | 83,947  | 84,524 | 87,425 | 91,333 | 95,178 | 0.7%                      |
| Japan          | 2,562   | 2,877  | 3,204  | 3,453  | 3,647  | 2.0%                      |
| Korea          | 1,523   | 1,549  | 1,614  | 1,693  | 1,773  | 0.8%                      |
| USA            | 1,260   | 1,166  | 1,127  | 1,136  | 1,133  | -0.6%                     |
| EU27           | 470     | 475    | 493    | 516    | 539    | 0.8%                      |

**Table 9. International and domestic rice prices (Baseline outlook)**

|                          | Unit   | 2010-12 | 2022   | 2030   |
|--------------------------|--------|---------|--------|--------|
| International rice price | USD/ton| 550.8   | 834.9  | 956.4  |
| Domestic rice price, Thailand | USD/ton | 205.0 | 247.3  | 263.0  |
| Domestic rice price, Indonesia | USD/ton | 251.9 | 306.5  | 326.7  |
| Domestic rice price, Malaysia | USD/ton | 203.7 | 213.3  | 216.6  |
| Domestic rice price, Cambodia | USD/ton | 164.9 | 210.3  | 227.7  |
| Domestic rice price, Lao PDR | USD/ton | 179.8 | 211.8  | 223.4  |
| Domestic rice price, Myanmar | 2010/12=100 | 100.0  | 109.5  | 112.7  |
| Domestic rice price, The Philippines | USD/ton | 240.8 | 267.6  | 277.6  |
| Domestic rice price, India | USD/ton | 178.9 | 269.2  | 294.8  |
| Domestic rice price, China | USD/ton | 254.3 | 277.6  | 285.7  |
| Domestic rice price, South Korea | USD/ton | 1,627.5 | 1,670.8 | 1,685.2 |
| Domestic rice price, USA | USD/ton | 207.6 | 294.2  | 329.5  |
| Domestic rice price, Italy | USD/ton | 392.7 | 557.5  | 625.0  |

**Table 10. Impact on the world rice market (Scenario 1/Baseline: 2030)**

|                          | Changing rate |
|--------------------------|---------------|
| World Rice Production    | 2.7%          |
| World Rice Export        | 18.8%         |
| World Rice Consumption   | 2.7%          |
| World Rice Import        | 18.8%         |
| World Rice Ending Stocks | 5.0%          |
| International Rice Price | -19.4%        |

**Table 11. Impact on the world rice market (Scenario 2/Baseline: 2030)**

|                          | Changing rate |
|--------------------------|---------------|
| World Rice Production    | 1.3%          |
| Thailand                 | 29.6%         |
| World Rice Export        | 13.9%         |
| Thailand                 | 62.8%         |
| World Rice Consumption   | 1.3%          |
| World Rice Import        | 13.9%         |
| World Rice Ending Stocks | 2.4%          |
| International Rice Price | -10.2%        |
line outlook in 2030 (Table 12). Accordingly, world rice production and consumption are expected to increase by 0.5%, and world rice exports and imports are expected to increase by 5.2%, compared with the baseline outlook in 2030. Consequently, the international rice price is expected to decrease by 4.0%, compared with the baseline outlook in 2030.

The coefficient of variation (CV) of the international rice price from 2010/12 to 2030 is 0.142325 in the baseline outlook. As a result of policy scenarios, the CV is calculated to be 0.08188 during the simulation period (under policy scenario 1), 0.11154 (under policy scenario 2), and 0.130578 (under policy scenario 3) as shown in Fig. 5.

### Conclusion

We conducted policy simulations for alleviating climate risks to rice production systems and rice markets by utilizing a partial equilibrium model. We examined how future agricultural investments will impact the world rice market, especially the volatility of international rice prices, by factoring in future climate change. The simulation results suggest that a constant increase in agricultural investment in eight ASEAN countries will contribute to reducing international rice price volatility, by taking into account climate change. The same investment increase in Thailand and Vietnam will also contribute to reducing international rice price volatility. We conclude that a constant increase of agricultural investments in the eight ASEAN countries, especially Thailand and Vietnam, has a crucial role in stabilizing international rice prices as rice production becomes increasingly affected by climate change.

Some uncertainties remain regarding the baseline and policy scenario simulation results. The first issue is the uncertain GDP growth rates after 2016 in each country and region. The second issue is the uncertain future rice policies of the main exporters, especially Thailand and Vietnam. The third issue is that climate change projections carry large uncertainties and strongly depend on the emission scenarios, choice of climate models, and other factors. These uncertainties pose limitations for this study. This study applied specified assumptions to baseline and scenarios outlooks. We need to apply other macro assumptions and climate change projections to baseline and scenarios outlooks. Rice consumption is increasing in Africa and the Middle East, especially in countries such as Nigeria, Madagascar, Egypt, and Iran. However, the RECC model does not cover these countries due to a lack of reliable climate and agricultural investment data. We will incorporate these countries into the RECC model after collecting reli-

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**Table 12. Impact on the world rice market (Scenario 3/Baseline: 2030)**

|                                | Changing rate |
|--------------------------------|---------------|
| World Rice Production          | 0.5%          |
| Vietnam                        | 9.8%          |
| World Rice Export              | 5.2%          |
| Vietnam                        | 32.4%         |
| World Rice Consumption         | 0.5%          |
| World Rice Import              | 5.2%          |
| World Rice Ending Stocks       | 0.9%          |
| International Rice Price       | -4.0%         |

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**Fig. 5. The coefficient of variation (CV) of international rice price (2010/12-2030)**
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Rice ending stocks can depend not only on domestic rice price but also on domestic production. We will incorporate domestic production into the explanatory variable of rice ending stocks. We plan to address these issues in future studies.

References

Food and Agricultural Organization (FAO) (2011) The State of Food Security in the world, How does international policy volatility affect domestic economics and food security? Food and Agricultural Organization (FAO): FAOSTAT, FAO statistic databases. http://faostat.fao.org/
Furuya, J. and Koyama, O. (2005) Impacts of Climate Change on World Agricultural Product Markets: Estimation of Macro Yield Functions. JARQ 39(2), 121-134.
International Monetary Fund (2013) World Economic Outlook Database. http://www.imf.org/external/pubs/ft/weo/2014/01/weodata/index.aspx
Intergovernmental Panel on Climate Change (IPCC) (2013) The Physical Science Basis. Working Group I Contribution to the

Fifth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC.
Lobloll, D. B. (2007) Changes in diurnal temperature range and national cereal yields. Agricultural and Forest Meteorology. 145: 229-238.
OECD-FAO (2013) OECD-FAO Agricultural Outlook 2013-2022. OECD-FAO.
Peng, S. et al. (2004) Rice yields decline with higher night temperature from global warming. Agricultural Sciences. Vol. 101. No. 27, 9971-9975.
United Nations (2011) World Population Prospects, the 2010 Revision. http://esa.un.org/unpd/wpp/
United States Department of Agriculture (USDA): PS&D. https://apps.fas.usda.gov/psdonline/psdQuery.aspx
United States Department of Agriculture (USDA) (2013) USDA Agricultural Projections to 2022. http://www.ers.usda.gov/publications/oce-usda-agricultural-projections/oce131.aspx
Welch, J. R. et al. (2010) Rice yields in tropical/subtropical Asia exhibit large but opposing sensitivities to minimum and maximum temperatures. Sustainability Science, 107(33): 14562-14567.
## Appendix

### Table A1-1. Estimation of parameters (Yield)

|                        | Thailand t statistics | Vietnam t statistics | Indonesia t statistics | Cambodia t statistics | Lao PDR t statistics | Myanmar t statistics | Malaysia t statistics | The Philippines t statistics |
|------------------------|-----------------------|----------------------|------------------------|-----------------------|-----------------------|----------------------|------------------------|-------------------------------|
| a1. Minimum Temperature | -0.1611               | -0.3718              | -0.2674                | -0.6206              | -0.3719               | -1.0485              | -0.2526              | -0.1784                       |
| (t-1/t-2)              |                       |                      |                        |                       |                       |                      |                        |                               |
| a2. Maximum Temperature| 0.0663                | -0.0671              | -0.1350                | -0.0947              | -                    |                      |                       |                               |
| (t-1/t-2)              |                       |                      |                        |                       |                       |                      |                        |                               |
| a3. Precipitation      | 0.0218                | -0.2229              | 0.0249                 | 0.7207               | 0.0270                | -1.6721              | -0.0662              | -0.0389                      |
| (t/t-1)                |                       |                      |                        |                       |                       |                      |                        |                               |
| a4. Land development   | 0.4594                | 1.4489               | 0.2711                 | 1.1538               | 0.0067                | 0.1555               | 0.0241                | 0.5807                       |
| (t-1/t-2)              |                       |                      |                        |                       |                       |                      |                        |                               |
| a5. Agricultural       | 0.0146                | 0.9006               | 0.2081                 | 1.8007               | 0.1079                | 2.4504               | 0.4187                | 0.4784                       |
| machinery & equipment  | (t-1/t-2)             |                       |                        |                       |                       |                      |                        |                               |
| a6. Time trend         | 0.0150                | 12.7355              | 0.0258                 | 17.2002              | 0.0057                | 5.6358               | 0.0252                | 6.2837                       |
| (t-1)                  |                       |                      |                        |                       |                       |                      |                        |                               |
| Constant               | 0.3252                | 7.0356               | 0.3589                 | 5.7797               | 1.1015                | 2.2580               | -0.6342              | -2.6606                      |
|                       |                       |                      |                        |                       |                       |                      |                        |                               |
| Dummy 1                | -                    | -                    | -                      | 0.0093               | -1.5409 (1984)        | -                    | -0.0295              | -1.4860 (2001)              |
|                       |                       |                      |                        |                       |                       |                      |                        |                               |
| Dummy 2                | -                    | -                    | -                      | -0.0368              | -0.0408 (1984)        | -                    | -0.0397              | -0.3925 (1997)              |
|                       |                       |                      |                        |                       |                       |                      |                        |                               |
| Dummy 3                | -                    | -                    | -                      | 0.0078               | -5.3925 (1997)        | -                    | -                    | -                            |
|                       |                       |                      |                        |                       |                       |                      |                        |                               |
| Sample                | 1988-2008             | 195-2008             | 193-2006               | 1900-2008            | 1998-2007             | 1995-2009            | 1995-2008             | 1998-2011                     |
| R-squared             | 0.9108                | 0.9139               | 0.9108                 | 0.9404               | 0.9439                | 0.9292               | 0.9245                | 0.9106                       |
| Adjusted R-squared    | 0.8812                | 0.9688               | 0.8803                 | 0.7696               | 0.7757                | 0.9700               | 0.8364                | 0.8340                       |
| Durbin-Watson stat    | 2.0577                | 1.8365               | 1.4699                 |                       |                      |                      |                      |                               |

### Table A1-2. Estimation of parameters (Yield)

|                        | China t statistics (Year for dummy) | India t statistics (Year for dummy) | Japan t statistics (Year for dummy) | Korea t statistics (Year for dummy) | USA t statistics (Year for dummy) | EU27 t statistics (Year for dummy) | Bangladesh t statistics (The rest of the world) | t statistics |
|------------------------|-------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|------------------------------------|-------------------------------------|-----------------------------------------------|--------------|
| a1. Minimum Temperature| -0.1380                             | -0.7577                              | -0.6434                              | -0.8077                              | -0.4569                            | -0.1086                            | -0.1000                                     | -0.1278      |
| (t-1)                  |                                     |                                      |                                      |                                      |                                    |                                    |                                               |              |
| a2. Maximum Temperature| -                                   | -                                    | -                                    | 0.8039                              | 1.6315                            | 0.2544                             | 0.2711                                       | -             |
| (t-1)                  |                                     |                                      |                                      |                                      |                                    |                                    |                                               |              |
| a3. Precipitation      | 0.0052                              | 0.1053                              | 0.1234                              | 1.2655                              | -0.2091                            | -1.2291                           | -0.0859                                    | -1.0385      |
| (t-1/t-2)              |                                     |                                      |                                      |                                      |                                    |                                    |                                               |              |
| a4. Land development   | 0.4846                             | 1.3065                              | 0.6718                              | 0.6689                              | 0.2264                            | 0.5599                            | 1.9611                                    | 0.6775       |
| (t-1/t-2)              |                                     |                                      |                                      |                                      |                                    |                                    |                                               |              |
| a5. Agricultural       | 0.0662                             | 0.5367                              | 0.2873                              | 1.0359                              | 0.2144                            | 0.5699                            | 1.3004                                    | 2.4631       |
| machinery & equipment  | (t-1/t-2)                           |                                     |                                      |                                      |                                    |                                    |                                               |              |
| a6. Time trend         | 0.1596                             | 2.2152                              | 0.0109                              | 6.3151                              | 0.1307                            | 2.3489                            | 0.8143                                    | 2.9045       |
| (t-1)                  |                                     |                                      |                                      |                                      |                                    |                                    |                                               |              |
| Constant               | 1.2290                             | 4.7471                              | 0.3272                              | 1.1488                              | 1.3853                            | 6.7998                            | -1.2256                                    | -1.1828      |
|                       |                                     |                                      |                                      |                                      |                                    |                                    |                                               |              |
| Dummy 1                | 0.0417                             | 1.6380                              | (1998)                              | -0.3106                            | -8.3535 (1993)                    | -0.0690                           | -2.0021                                    | (2007)       |
|                       |                                     |                                      |                                      |                                    |                                    |                                    |                                               |              |
| Dummy 2                | -                                  | -                                  | -                                  | -0.0974                            | -2.7154 (2003)                    | -                                  | -                              | -1.0468 (2000) |
|                       |                                     |                                      |                                      |                                    |                                    |                                    |                                               |              |
| Dummy 3                | -                                  | -                                  | -                                  | -                                  | -                                  | -                                  | -                              | -1.245 (2004) |
|                       |                                     |                                      |                                      |                                    |                                    |                                    |                                               |              |
| Sample                | 1990-2008                          | 1968-2008                          | 1990-2008                          | 1990-2008                          | 2000-2009                        | 1976-2008                        | 195-2009                    | 1998-2008                                      |
| R-squared             | 0.8310                             | 0.8303                              | 0.9148                              | 0.9388                              | 0.9342                            | 0.9342                            | 0.7087                        | 0.8705                                  |
| Adjusted R-squared    | 0.7215                             | 0.7576                              | 0.8060                              | 0.7245                              | 0.9100                            | 0.5340                            | 0.9712                        |                                      |
| Durbin-Watson stat    | 1.6660                             | 1.9774                              | 2.0726                              | 1.6634                              | 1.7806                            | 1.4137                            |                                      |                  |
### Table A2.1. Estimation of parameters (Planted Area)

|                  | Thailand | t statistics | Vietnam (Year for dummy) | t statistics | Indonesia | t statistics | Cambodia | t statistics | Laos (Year for dummy) | t statistics | Myanmar | t statistics | Malaysia | t statistics | The Philippines | t statistics |
|------------------|----------|--------------|---------------------------|--------------|-----------|--------------|----------|--------------|------------------------|--------------|----------|--------------|----------|--------------|----------------|-------------|
| a7, Domestic rice price (t-1) | 0.0119 | 0.5399 | 0.0131 | 0.3278 | 0.0513 | 1.7849 | 0.1234 | 1.0936 | 0.0142 | 0.1661 | 0.0528 | 1.7499 | 0.0156 | 1.0936 | 0.0113 | 0.0273 |
| a8, Domestic wheat price (t-1) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| a9, Precipitation (t-1) | -0.1071 | -2.6265 | 0.0225 | 0.0410 | 0.0747 | 4.4689 | 0.0737 | -0.4043 | 0.0572 | 1.4174 | -0.0020 | -0.0246 | 0.0538 | 1.6562 | 0.0291 | 0.6665 |
| a10, Land Development (t-1:2) | 0.8361 | 1.0316 | 0.0247 | 1.0581 | 0.0699 | 1.2660 | 0.4878 | 0.1271 | 0.4357 | 0.9555 | 0.1581 | 3.5235 | 0.1475 | 0.6486 | 0.0008 | 0.1796 |
| a11, Time trend (t-1) | 0.0066 | 0.3116 | 0.4658 | 27.3775 | 0.0040 | 3.5503 | 0.2512 | 5.2993 | -0.0441 | -1.0065 | 0.0245 | 13.2558 | 0.0567 | 2.4343 | 0.5094 | 11.2071 |
| Constant | 9.4150 | 82.159 | 1.5616 | 64.589 | 9.1610 | 108.96 | 6.5050 | 10.647 | 10.6998 | 75.816 | 14.934 | 90.736 | 6.1984 | 50.752 | 6.4106 | 58.72 |
| Dummy 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dummy 2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dummy 3 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Sample | 1989-2011 | 1996-2011 | 1991-2010 | 1992-2007 | 1995-2006 | 1999-2008 | 2000-2009 | 2001-2010 | 1985-2011 | 1988-2011 | 1985-2011 | 1988-2011 |
| R-squared | 0.8772 | 0.8576 | 0.9198 | 0.7873 | 0.8680 | 0.9641 | 0.6943 | 0.9541 | 0.6943 | 0.9541 | 0.6943 | 0.9541 |
| Adjusted R-squared | 0.8539 | 0.9176 | 0.7873 | 0.8680 | 0.9641 | 0.6943 | 0.9541 | 0.6943 | 0.9541 | 0.6943 | 0.9541 | 0.6943 |
| Durbin-Watson stat | 2.3143 | 1.7557 | 1.6663 | 2.0455 | 1.8120 | 1.4480 | 2.3386 |

### Table A2.2. Estimation of parameters (Planted Area)

|                  | China | t statistics (Year for dummy) | India | t statistics (Year for dummy) | Japan | t statistics (Year for dummy) | Korea | t statistics (Year for dummy) | USA | t statistics (Year for dummy) | EU27 | t statistics (Year for dummy) | Bangladesh (The rest of the world) | t statistics |
|------------------|-------|-------------------------------|-------|-------------------------------|-------|-------------------------------|-------|-------------------------------|------|-------------------------------|------|-------------------------------|-----------------------------|-------------|
| a7, Domestic rice price (t-1) | 0.0577 | 2.7739 | 0.0780 | 2.9637 | 0.1139 | 1.6432 | 0.0428 | 1.1259 | 0.1406 | 2.3120 | 0.0674 | 5.5356 | 0.0246 | 1.3504 |
| a8, Domestic wheat price (t-1) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| a9, Precipitation (t-1) | 0.0013 | 0.0241 | 0.0322 | 0.6852 | -0.0374 | -0.6515 | -0.0234 | -1.1267 | -0.1297 | -1.5262 | 0.0469 | 1.2877 | -0.0232 | -0.9629 |
| a10, Land Development (t-1:2) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| a11, Time trend (t-1) | -0.0078 | -2.9243 | 0.0008 | 0.7961 | -0.1592 | -3.9888 | -0.0125 | -17.0489 | 0.0198 | 10.5436 | -0.0089 | -0.8593 | 0.0081 | 9.4538 |
| Constant | 10.123 | 101.03 | 9.9797 | 50.790 | 6.9958 | 10.619 | 6.7901 | 24.348 | 8.3078 | 226.62 | 11.882 | 145.95 | 8.9877 | 88.517 |
| Dummy 1 | 0.0450 | 1.8314 | 0.0697 | -3.3116 | 0.1900 | 1.1910 | 0.0341 | 2.0476 | 0.2417 | -3.1107 | 0.4384 | 0.1581 | -0.0020 | -2.8315 | 0.0790 | - |
| Dummy 2 | -0.0911 | -3.2807 | 0.0320 | 1.4068 | 0.0000 | -0.0063 | 0.0241 | 2.0109 | 0.0511 | 2.0783 | 0.0112 | -0.0451 | -0.0020 | -2.8315 | 0.0790 | - |
| Dummy 3 | 0.0332 | 1.2192 | 0.0452 | 2.0016 | 0.0042 | -0.0063 | -0.0020 | -3.1107 | 0.0511 | 2.0783 | 0.0112 | -0.0451 | -0.0020 | -2.8315 | 0.0790 | - |
| Sample | 1991-2010 | 1974-2004 | 1995-2010 | 1995-2010 | 1985-2011 | 1985-2011 | 1992-2011 | 1992-2011 | 1999-2011 | 1999-2011 |
| R-squared | 0.8539 | 0.8886 | 0.9310 | 0.9719 | 0.8710 | 0.8297 | 0.8610 |
| Adjusted R-squared | 0.8539 | 0.8886 | 0.9310 | 0.9719 | 0.8710 | 0.8297 | 0.8610 |
| Durbin-Watson stat | 1.4328 | 1.7080 | 1.8165 | 2.0813 | 1.8003 | 1.5918 | 1.5345 |
### Table A3. Milling rates

| Country | Milling rate |
|---------|--------------|
| Thailand | 0.6600 |
| Viet Nam | 0.6251 |
| Indonesia | 0.6332 |
| Cambodia | 0.6403 |
| Lao PDR | 0.6309 |
| Myanmar | 0.6401 |
| Malaysia | 0.6499 |
| The Philippines | 0.6307 |
| China | 0.6999 |
| India | 0.6668 |
| Japan | 0.7281 |
| Korea | 0.7441 |
| USA | 0.6915 |
| EU27 | 0.6936 |
| Bangladesh | 0.6401 |

### Table A4-1. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Thailand     | t-statistics | 0.0070 | -1.0770 |
| Vietnam      | t-statistics | 0.0119 | 0.5508 |
| Indonesia    | t-statistics | 0.0785 | 2.6335 |
| Cambodia     | t-statistics | 0.3433 | 3.7847 |
| Lao PDR      | t-statistics | 0.0594 | 0.5818 |
| Myanmar      | t-statistics | 0.1414 | 6.0049 |
| Malaysia     | t-statistics | 0.0951 | 0.8481 |
| The Philippines | t-statistics | 0.7148 | 0.9874 |

### Table A4-2. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6499 | 2.0565 |

### Table A4-3. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| China        | t-statistics | 0.0513 | 0.9434 |
| India        | t-statistics | 0.0636 | 0.2292 |
| Japan        | t-statistics | -0.1326 | -0.8858 |
| Korea        | t-statistics | -0.1002 | -3.0231 |
| USA          | t-statistics | 0.1655 | 1.7185 |
| EU27         | t-statistics | 0.0741 | 1.0361 |
| The Philippines | t-statistics | 0.8771 | 3.7631 |

### Table A4-4. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6401 | 2.0565 |

### Table A4-5. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| China        | t-statistics | 0.0513 | 0.9434 |
| India        | t-statistics | 0.0636 | 0.2292 |
| Japan        | t-statistics | -0.1326 | -0.8858 |
| Korea        | t-statistics | -0.1002 | -3.0231 |
| USA          | t-statistics | 0.1655 | 1.7185 |
| EU27         | t-statistics | 0.0741 | 1.0361 |
| The Philippines | t-statistics | 0.8771 | 3.7631 |

### Table A4-6. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6401 | 2.0565 |

### Table A4-7. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| China        | t-statistics | 0.0513 | 0.9434 |
| India        | t-statistics | 0.0636 | 0.2292 |
| Japan        | t-statistics | -0.1326 | -0.8858 |
| Korea        | t-statistics | -0.1002 | -3.0231 |
| USA          | t-statistics | 0.1655 | 1.7185 |
| EU27         | t-statistics | 0.0741 | 1.0361 |
| The Philippines | t-statistics | 0.8771 | 3.7631 |

### Table A4-8. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6401 | 2.0565 |

### Table A4-9. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| China        | t-statistics | 0.0513 | 0.9434 |
| India        | t-statistics | 0.0636 | 0.2292 |
| Japan        | t-statistics | -0.1326 | -0.8858 |
| Korea        | t-statistics | -0.1002 | -3.0231 |
| USA          | t-statistics | 0.1655 | 1.7185 |
| EU27         | t-statistics | 0.0741 | 1.0361 |
| The Philippines | t-statistics | 0.8771 | 3.7631 |

### Table A4-10. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6401 | 2.0565 |

### Table A4-11. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| China        | t-statistics | 0.0513 | 0.9434 |
| India        | t-statistics | 0.0636 | 0.2292 |
| Japan        | t-statistics | -0.1326 | -0.8858 |
| Korea        | t-statistics | -0.1002 | -3.0231 |
| USA          | t-statistics | 0.1655 | 1.7185 |
| EU27         | t-statistics | 0.0741 | 1.0361 |
| The Philippines | t-statistics | 0.8771 | 3.7631 |

### Table A4-12. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6401 | 2.0565 |

### Table A4-13. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| China        | t-statistics | 0.0513 | 0.9434 |
| India        | t-statistics | 0.0636 | 0.2292 |
| Japan        | t-statistics | -0.1326 | -0.8858 |
| Korea        | t-statistics | -0.1002 | -3.0231 |
| USA          | t-statistics | 0.1655 | 1.7185 |
| EU27         | t-statistics | 0.0741 | 1.0361 |
| The Philippines | t-statistics | 0.8771 | 3.7631 |

### Table A4-14. Estimation of parameters (Per Capita Consumption)

| Country      | Parameter | Estimate | t-statistics |
|--------------|-----------|----------|--------------|
| Bangladesh   | t-statistics | 0.6401 | 2.0565 |
### Table A5. Estimation of parameters (Imports)

|                | Thailand | t statistics | Vietnam | t statistics (Year for dummy) | Cambodia | t statistics (Year for dummy) | USA | t statistics |
|----------------|----------|--------------|---------|-------------------------------|----------|-------------------------------|-----|--------------|
| a17, International Rice Price (t/t-1) | -1.6886  | -0.4651      | -0.1934 | -2.2069                       | -0.9879  | -3.1612                       | -0.0647 | -0.7593      |
| a18, Domestic Production (t/t-1)    | -1.1475  | -0.0451      | -0.1265 | -2.8750                       | 1.1747   | 5.9048 (2006)                 | 3.0756 | 2.7117 (1997) |
| a19, Domestic Rice Price (t/t-1)    | -0.3350  | -0.0841      | 1.2123  | 5.3627                        | 1.2143   | 1.5921                        | 3.1087  | 11.2972      |
| a20, Time Trend (t/t-1)             | 3.7137   | 3.7672       | 1.5759  | 16.4130                       | 1.0078   | 3.4920                        | 0.0696  | 12.9809      |
| Constant                    | -0.7775  | 0.4686       | 1.1233  | 3.7627                        | 1.2143   | 1.5921                        | 3.1087  | 11.2972      |
| Dummy 1                     | -        | -            | 0.1670  | 5.9048 (2006)                 | -1.8724  | -5.3617 (1996)               | -      | -            |
| Dummy 2                     | -        | -            | -0.2768 | -8.2282 (2009)               | -0.6415  | -1.7531 (2009)               | -      | -            |
| Dummy 3                     | -        | -            | -       | -                             | 1.8703   | 5.1046 (2004)                | -      | -            |
| Sample                      | 2005-2012|              | 2003-2010|                               | 1991-2006|                               | 1991-2010|              |
| R-squared                   | 0.8752   |              | 0.9692  |                               | 0.9335   |                               | 0.9344  |              |
| Adjusted R-squared          | 0.7504   |              | 0.9867  |                               | 0.8892   |                               | 0.9221  |              |
| Durbin-Watson stat          | 1.8936   |              | 2.2773  |                               | 1.6027   |                               | 1.6884  |              |

### Table A6. Estimation of parameters (Exports)

|                | China | t statistics (Year for dummy) | EU27 | t statistics (Year for dummy) |
|----------------|-------|-------------------------------|------|-------------------------------|
| a21, International Rice Price (t/t-1) | -1.6886 | -0.4651                       | 1.5213 | 2.7334                       |
| a22, Domestic Production (t/t-1)   | -1.1475 | -0.0451                       | 0.8788 | 0.1211                       |
| a23, Domestic Rice Price (t/t-1)   | -0.3350 | -0.0841                       | -     | -                             |
| a24, Time Trend (t/t-1)             | 3.7137  | 3.7672                        | 1.5759 | 16.4130                       |
| Constant                    | -0.7775 | 0.4686                        | 1.1233 | 3.7627                        |
| Dummy 1                     | -       | -                             | 0.1670 | 5.9048 (2006)                 |
| Dummy 2                     | -       | -                             | -0.2768 | -8.2282 (2009)               |
| Dummy 3                     | -       | -                             | -       | -                             |
| Sample                      | 1995-2005|                               | 1991-2006|                               |
| R-squared                   | 0.9190  |                               | 0.9335   |                               |
| Adjusted R-squared          | 0.7849  |                               | 0.8892   |                               |
| Durbin-Watson stat          | 1.7263  |                               | 1.6027   |                               |

### Table A7-1. Estimation of parameters (Ending Stocks)

|                | Thailand | t statistics | Vietnam | t statistics (Year for dummy) | Indonesia | t statistics (Year for dummy) | Cambodia | t statistics (Year for dummy) | LAO PDR | t statistics (Year for dummy) | Myanmar | t statistics (Year for dummy) | Malaysia | t statistics (Year for dummy) | The Philippines | t statistics (Year for dummy) |
|----------------|----------|--------------|---------|-------------------------------|-----------|-------------------------------|----------|-------------------------------|---------|-------------------------------|----------|-------------------------------|----------|-------------------------------|------------------|-------------------------------|
| a25, Domestic rice price (t/t-1) | -0.6304  | -0.0223      | -0.3582 | -0.3452                       | -1.6599   | -1.9302                       | -0.0892  | -0.3290                       | -0.0582 | -0.2847                       | -0.4235  | -1.637                        | -0.5792  | -1.249                        |
| a26, Time Trend (t/t-1)            | 1.0461   | 0.9772       | 0.7560  | 0.9535                        | -0.1847   | 0.7944                        | 0.5706   | 0.4942                        | 8.2391  | 1.2148                        | 11.1136  | 6.697                        | 7.8814  | 1.5990                        |
| Constant                  | 3.9436   | 1.6430       | 3.5462  | 2.8534                        | 8.1256    | 7.6643                        | 0.0529   | 0.4042                        | 12.8305 | 13.6315                      | 11.5650  | 4.2570                       | 19.9873  | 3.4846                        |
| Dummy 1                   | -        | -             | -0.6992 | -3.1066 (1995)               | -0.3341   | -0.9144 (2004)               | 0.0747   | 0.3122 (2007)               | 0.2262  | -1.5801 (1999)               | 3.5385   | 1.3543 (2001)               | 1.5113  | 4.663 (1995)                 |
| Dummy 2                   | -        | -             | 0.1578  | 0.396 (1997)                 | -0.4890   | -2.5066 (2003)               | -        | -0.0927                       | -3.5456 | 0.0770                        | 4.5121   | 0.0460                       | -1.5949 (1998)  | -1.0068                       |
| Dummy 3                   | -        | -             | -       | -                             | -        | -                             | -        | -0.6530                       | -2.8101 | 0.6443                        | -0.5689  | -2.5169 (1999)              | -0.6562 (2010) |                |
| Sample                    | 1995-2011|               | 1995-2011|                               | 1999-2011|                               | 2005-2011|                               | 1990-2010|                               | 2002-2011| 1985-2011                    | 1993-2010| 1990-2010                    |
| R-squared                 | 0.8819   |              | 0.9412  | 0.7034                        | 0.9583    | 0.9339                        | 0.8963   | 0.7769                        | 0.9284  | 0.8950                        |
| Adjusted R-squared        | 0.8547   |              | 0.9145  | 0.5668                        | 0.9666    | 0.9091                        | 0.9034   | 0.7769                        | 0.9284  | 0.8950                        |
| Durbin-Watson stat        | 1.7862   |              | 1.8915  | 0.0210                        | 1.9088    | 1.7918                        | 1.8707   | 1.4289                        | 2.0751  |                |
Table A7-2. Estimation of parameters (Ending Stocks)

| Country      | t statistics (Year for dummy) | t statistics (Year for dummy) | t statistics (Year for dummy) | t statistics (Year for dummy) | t statistics (Year for dummy) | EU27 | t statistics (Year for dummy) | Bangladesh | t statistics (Year for dummy) |
|--------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|------|-------------------------------|------------|-------------------------------|
| a25, Domestic rice price (t/t-1) | -0.6124 | -2.4058 | -0.0779 | -2.7813 | -2.0823 | -2.8179 | -1.2966 | -3.7565 | -0.6549 | -2.3590 | -0.1281 | -1.4628 | -0.0144 | -0.0240 |
| a26, Time Trend (t/t-1) | -1.1123 | -0.8464 | 1.1715 | 4.3277 | 2.3637 | 7.4218 | 0.9245 | 4.4672 | -1.2793 | -6.3793 | 0.1299 | 6.8302 | 0.5250 | 1.9448 |
| Dummy 1      | -0.2704 | -1.5177 | 0.5520 | 2.1534 | 2.2659 | 3.8279 | 0.5887 | 2.7632 | -0.1181 | -0.4649 | -0.1345 | -2.3475 | -2.0149 | -2.3553 |
| Dummy 2      | - - | 0.6302 | 2.6234 | (2001) | 1.8143 | 2.8601 | (2003) | - | 0.2546 | 1.3023 | (2001) | 0.1323 | 2.5677 | (2005) | -0.9985 |
| Dummy 3      | - - | -0.496 | -1.6543 | (2005) | - | - | - | - | - | - | - | - | 0.6334 | 1.4023 | (2010) |
| Sample       | 1995-2011 | 1996-2011 | 1991-2011 | 1995-2011 | 1991-2011 | 1995-2011 | 1991-2011 | 1991-2011 | 1991-2011 | 1991-2011 | 1991-2011 | 1991-2011 | 1991-2011 | 1991-2011 |
| R-squared    | 0.8707 | 0.7866 | 0.8780 | 0.7278 | 0.5084 | 0.7281 | 0.3929 | 1.4164 | 0.1110 | 0.8433 | 0.2911 | 4.5701 |
| Adjusted R-squared | 0.8276 | 0.6444 | 0.8257 | 0.6441 | 0.8495 | 0.6441 | 0.8495 | 0.6441 | 0.8495 | 0.8249 | 0.5669 |
| Durbin-Watson stat | 1.3271 | 1.6683 | 1.4540 | | | | | | | | | | | |

Table A8-1. Estimation of parameters (Price Transmission)

| Country      | t statistics (Year for dummy) | t statistics (Year for dummy) | t statistics (Year for dummy) | Lao PDR | t statistics (Year for dummy) | Malaysia | t statistics (Year for dummy) | The Philippines | t statistics (Year for dummy) |
|--------------|-------------------------------|-------------------------------|-------------------------------|---------|-------------------------------|-----------|-------------------------------|-----------------|-------------------------------|
| a27, International Rice Price (t/t-1) | 0.4513 | 3.6687 | 0.4714 | 1.9679 | 0.5851 | 2.5157 | 0.3929 | 1.4164 | 0.1110 | 0.8433 | 0.2911 | 4.5701 |
| a28, Time Trend (t/t-1) | 0.1081 | 14.6742 | 0.0668 | 1.1774 | -0.0614 | -1.1024 | -0.3474 | -4.9017 | 0.0637 | 1.8553 | 0.0273 | 5.6230 |
| Dummy 1      | 3.8474 | 62.5078 | 5.0545 | 42.2685 | 4.9607 | 40.3529 | 5.3025 | 41.8154 | 5.0151 | 69.1149 | 0.5072 | 1.8611 |
| Dummy 2      | - - | -0.6222 | -2.7267 | (2001) | - - | -0.4360 | -2.4035 | (1991) | - - | - - | - - | - - |
| Dummy 3      | - - | 0.3401 | 2.3377 | (2010) | - - | 0.3937 | 2.9461 | (1998) | - - | - - | - - | - - |
| Sample       | 2000-2010 | 1991-2010 | 1991-2007 | 1991-2007 | 0.7517 | 0.9361 | 0.6988 | 0.9330 | 0.9227 |
| R-squared    | 0.9005 | 0.6530 | 0.6027 | 0.0859 | 0.5912 | 0.5669 |
| Adjusted R-squared | 0.9080 | 1.4621 | 1.6179 | 1.3126 | 1.5412 | 1.9866 |
| Durbin-Watson stat | 2.0829 | 1.4621 | 1.6179 | 1.3126 | 1.5412 | 1.9866 |

Table A8-2. Estimation of parameters (Price Transmission)

| Country      | t statistics (Year for dummy) | t statistics (Year for dummy) | t statistics (Year for dummy) | USA | t statistics (Year for dummy) | EU27 | t statistics (Year for dummy) |
|--------------|-------------------------------|-------------------------------|-------------------------------|------|-------------------------------|------|-------------------------------|
| a27, International Rice Price (t/t-1) | 0.2112 | 0.7995 | 0.9819 | 3.5492 | 0.0631 | 0.3977 | 0.8376 | 4.3356 | 0.8423 | 2.3282 |
| a28, Time Trend (t/t-1) | 0.3610 | 4.9854 | 0.0147 | 0.2156 | 0.1881 | 4.4513 | -0.0137 | -0.2921 | -0.3049 | -3.3535 |
| Dummy 1      | 4.5854 | 27.2061 | 4.9687 | 35.9738 | 6.9394 | 69.7888 | 2.7992 | 29.4166 | 6.3002 | 34.9585 |
| Dummy 2      | - - | - - | - - | - - | - - | - - | - - | - - | - - | - - |
| Dummy 3      | - - | - - | - - | - - | - - | 0.5425 | 5.6099 | (2008) | -0.4194 | -1.5210 | (2002) |
| Sample       | 1992-2010 | 1991-2007 | 1992-2010 | 1991-2010 | 1991-2010 | 1991-2010 | 1991-2010 | 1991-2010 | 1991-2010 |
| R-squared    | 0.7747 | 0.6134 | 0.7661 | 0.7764 | 0.6462 | 1.3787 |
| Adjusted R-squared | 0.6880 | 0.5242 | 0.6761 | 0.7764 | 0.6462 | 1.3787 |
| Durbin-Watson stat | 1.8276 | 1.6663 | 2.0443 | 1.4387 | 1.4387 | 1.4387 |
### Table A9. Standard deviation of climate data

| Minimum temperature (Unit: Degrees C) | Source | 1961-1990 (Historical) | 1990-2010 (Historical) | 2010-2030 (Projection: Exogenous Variable) |
|---------------------------------------|--------|------------------------|------------------------|-------------------------------------------|
| Thailand                              |        | 0.3023                 | 0.2686                 | 0.3160                                    |
| Viet Nam                              |        | 0.3048                 | 0.2972                 | 0.2756                                    |
| Indonesia                             |        | 0.4175                 | 0.1866                 | 0.2139                                    |
| Malaysia                              |        | 0.2998                 | 0.1891                 | 0.1978                                    |
| Cambodia                              |        | 0.2980                 | 0.2743                 | 0.2502                                    |
| Lao PDR                               |        | 0.3358                 | 0.3217                 | 0.3062                                    |
| Myanmar                               |        | 0.3107                 | 0.3579                 | 0.4281                                    |
| The Philippines                       |        | 0.3162                 | 0.2841                 | 0.2268                                    |
| Bangladesh (The rest of world)        |        | 0.3908                 | 0.4287                 | 0.4562                                    |
| India                                 |        | 0.3306                 | 0.2462                 | 0.2909                                    |
| China                                 |        | 0.3393                 | 0.3984                 | 0.4068                                    |
| Japan                                 |        | 0.4825                 | 0.3699                 | 0.6292                                    |
| South Korea                           |        | 0.5218                 | 0.4937                 | 0.4980                                    |
| USA                                   |        | 0.4754                 | 0.5012                 | 0.5153                                    |
| Italy (EU27)                          |        | 0.3297                 | 0.4155                 | 0.4809                                    |
| Maximum temperature (Unit: Degrees C) |        | 0.3194                 | 0.4151                 | 0.6696                                    |
| Thailand                              |        | 0.2810                 | 0.3457                 | 0.5141                                    |
| Viet Nam                              |        | 0.4377                 | 0.2223                 | 0.2268                                    |
| Indonesia                             |        | 0.2631                 | 0.1907                 | 0.1779                                    |
| Malaysia                              |        | 0.2996                 | 0.3123                 | 0.5095                                    |
| Cambodia                              |        | 0.3152                 | 0.4404                 | 0.6812                                    |
| Lao PDR                               |        | 0.3360                 | 0.3360                 | 0.5518                                    |
| Myanmar                               |        | 0.4429                 | 0.3474                 | 0.2740                                    |
| The Philippines                       |        | 0.3226                 | 0.4352                 | 0.5882                                    |
| Bangladesh (The rest of world)        |        | 0.2932                 | 0.2694                 | 0.4550                                    |
| India                                 |        | 0.4405                 | 0.5046                 | 0.6706                                    |
| China                                 |        | 0.4657                 | 0.4414                 | 0.5486                                    |
| Japan                                 |        | 0.5685                 | 0.4980                 | 0.5281                                    |
| South Korea                           |        | 0.5184                 | 0.6092                 | 0.9436                                    |
| USA                                   |        | 0.4032                 | 0.3987                 | 0.6428                                    |
| Italy (EU27)                          |        |                       |                       |                                           |
| Precipitation (Unit: mm)              |        |                       |                       |                                           |
| Thailand                              |        | 114.3                 | 134.1                  | 198.0                                     |
| Viet Nam                              |        | 169.5                 | 165.8                  | 169.2                                     |
| Indonesia                             |        | 452.5                 | 465.5                  | 225.2                                     |
| Malaysia                              |        | 248.8                 | 369.3                  | 145.2                                     |
| Cambodia                              |        | 173.8                 | 230.2                  | 215.6                                     |
| Lao PDR                               |        | 166.4                 | 181.9                  | 213.8                                     |
| Myanmar                               |        | 218.4                 | 128.8                  | 145.0                                     |
| The Philippines                       |        | 383.0                 | 344.0                  | 213.1                                     |
| Bangladesh (The rest of world)        |        | 293.2                 | 256.8                  | 227.5                                     |
| India                                 |        | 102.4                 | 113.1                  | 144.7                                     |
| China                                 |        | 161.1                 | 123.8                  | 162.8                                     |
| Japan                                 |        | 165.5                 | 183.2                  | 228.8                                     |
| South Korea                           |        | 213.8                 | 265.2                  | 121.6                                     |
| USA                                   |        | 184.9                 | 186.4                  | 165.8                                     |
| Italy (EU27)                          |        | 97.6                  | 93.8                   | 86.4                                      |
Table A10. Exogenous variables

| Per capita GDP growth rate | Unit                      | 2010-12  | 2022  | 2030  |
|----------------------------|---------------------------|----------|-------|-------|
| Thailand                   | USD (2005 base)           | 3,205    | 5,255 | 5,255 |
| Vietnam                    | USD (2005 base)           | 868      | 1,531 | 1,531 |
| Indonesia                  | USD (2005 base)           | 1,632    | 2,697 | 2,697 |
| Malaysia                   | USD (2005 base)           | 6,260    | 8,673 | 8,673 |
| Cambodia                   | USD (2005 base)           | 620      | 1,206 | 1,206 |
| Lao PDR                    | USD (2005 base)           | 667      | 1,196 | 1,196 |
| Myanmar                    | USD (2005 base)           | 1,016    | 1,709 | 1,709 |
| The Philippines            | USD (2005 base)           | 1,341    | 1,842 | 1,842 |
| Bangladesh                 | USD (2005 base)           | 542      | 861   | 861   |
| China                      | USD (2005 base)           | 1,117    | 2,180 | 2,180 |
| Japan                      | USD (2005 base)           | 3,123    | 6,898 | 6,898 |
| South Korea                | USD (2005 base)           | 36,389   | 41,761| 41,761|
| USA                        | USD (2005 base)           | 42,669   | 52,310| 52,310|
| EU27                       | USD (2005 base)           | 34,144   | 41,621| 41,621|

| Population                 | Unit                      | 2010-12  | 2022  | 2030  |
|----------------------------|---------------------------|----------|-------|-------|
| Thailand                   | thousand                  | 69,473   | 72,409| 73,321|
| Viet Nam                   | thousand                  | 87,767   | 97,547| 101,483|
| Indonesia                  | thousand                  | 242,273  | 266,281| 279,659|
| Malaysia                   | thousand                  | 28,864   | 33,866| 37,266|
| Cambodia                   | thousand                  | 14,313   | 16,211| 17,363|
| Lao PDR                    | thousand                  | 6,268    | 7,199 | 7,754 |
| Myanmar                    | thousand                  | 48,351   | 52,290| 54,331|
| The Philippines            | thousand                  | 94,893   | 113,080| 126,321|
| Bangladesh                 | thousand                  | 150,617  | 170,432| 181,863|
| India                      | thousand                  | 1,241,335| 1,415,729| 1,523,482|
| China                      | thousand                  | 1,347,017| 1,390,778| 1,393,076|
| Japan                      | thousand                  | 126,443  | 123,990| 120,218|
| South Korea                | thousand                  | 48,371   | 49,978| 50,335|
| USA                        | thousand                  | 313,084  | 342,164| 361,680|
| EU27                       | thousand                  | 515,000  | 627,782| 679,798|

| Domestic rice price, Japan | USD/ton | OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013) | 2010-12  | 2022  |
|----------------------------|---------|--------------------------------------------------------|----------|-------|
|                            |         | 199.1                                                   | 184.7    | 184.7 |

| Rice export, Japan         | 1,000 ton | OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013) | 2010-12  | 2022  |
|----------------------------|-----------|--------------------------------------------------------|----------|-------|
|                            |           | 173.0                                                   | 200.0    | 200.0 |

| Rice import, Japan         | 1,000 ton | OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013) | 2010-12  | 2022  |
|----------------------------|-----------|--------------------------------------------------------|----------|-------|
|                            |           | 853.0                                                   | 768.0    | 768.0 |

| International wheat price  | USD/ton   | OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013) | 2010-12  | 2022  |
|----------------------------|-----------|--------------------------------------------------------|----------|-------|
|                            |           | 313                                                    | 274      | 274   |

| International corn price   | USD/ton   | OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013) | 2010-12  | 2022  |
|----------------------------|-----------|--------------------------------------------------------|----------|-------|
|                            |           | 285                                                    | 241      | 241   |

Note: The international wheat price is for No. 2 hard red winter wheat (ordinary protein), USA f.o.b. Gulf ports. International corn prices are for No. 2 yellow corn, USA f.o.b. Gulf ports.