JARQ 50 (3), 267 - 284 (2016) http://www.jircas.affrc.go.jp

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

Tatsuji KOIZUMI[1]* and Hideki KANAMARU

Climate, Energy and Tenure Division, Food and Agriculture Organization of the United Nations (FAO)
(Viale delle Terme di Caracalla, 00153, Rome, Italy)

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.

Discipline: Agricultural economics
Additional key words: partial equilibrium model, policy scenarios, land development, agricultural machinery and equipment, rice market

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.
Present address:
[1] Policy Research Institute of Japan's Ministry of Agriculture, Forestry and Fisheries. (3-1-1 Kasumigaseki Chiyoda-ku, Tokyo 100-0013 Japan)
*Corresponding author: e-mail tatsuji_koizumi410@maff.go.jp
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:

$$\ln (Y_{t,c}/ Y_{t-1, c}) = a1 \ln (Tmin_{t, c}/ Tmin_{t-1,c}) + a2 \ln (Tmax_{t, c}/ Tmax_{t-1,c}) + a3 \ln (PRC_{t, c}/PRC_{t-1,c}) + a4 \ln (LD_{t-1, c}/ LD_{t-2,c}) + a5 \ln (AME_{t-1, c}/ AME_{t-2,c}) + a6 \ln (T_t/ T_{t-1}) \quad (1)$$

where, Y is paddy rice yield, $Tmin$ is minimum temperature, $Tmax$ is maximum temperature, PRC is precipitation, LD denotes investments in land development, AME denotes investments in agricultural machinery/equipment, T is time trend, t is time, c are countries/region, and $a1$-$a6$ 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:

$$\ln (APW_{t ,c}/ APW_{t-1,c}) = a7 \ln (RP_{t,c}/RP_{t-1,c}) + a8 \ln (WP_{t,c}/ WP_{t-1,c}) + a9 \ln (PRC_{t,c}/ PRC_{t-1,c}) + a10 \ln (LD_{t-1,c}/ LD_{t-2,c}) + a11 \ln (T_t/ T_{t-1}) \quad (2)$$

where, APW is the planted area of rice, RP is the domestic rice price, WP is the domestic wheat price, $a7$ is the own domestic price elasticity of rice, $a8$ is the substitute price elasticity, and $a9$-11are 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.

$$AHW_{t,c} = APW_{t,c} - ABD_{t, c} \quad (3)$$

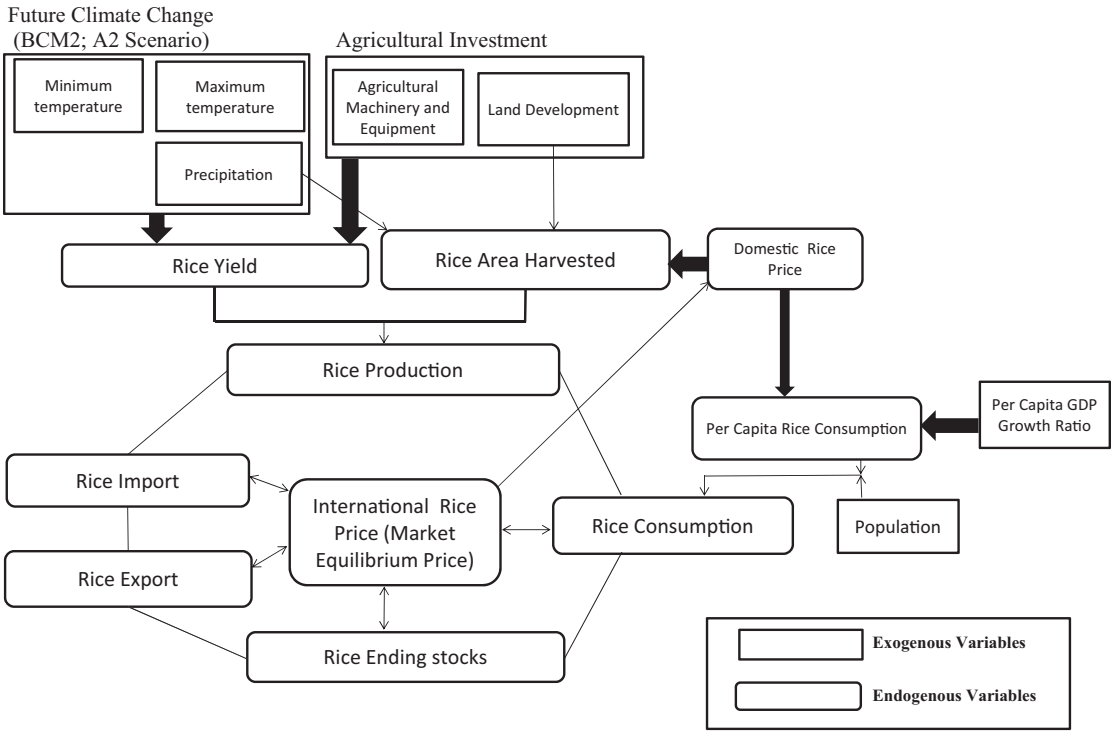

Fig. 1. Structure of the RECC model in the case of Thailand

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.

$$QPRP_{t,c} = AHW_{t,c} * Y_{t,c} \quad (4)$$

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.

$$QPR_{t,c} = QPRP_{t,c} * MIL_{t,c} \quad (5)$$

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.

$$\begin{aligned}\ln (PQCR_{t,c} / PQCR_{t-1,c}) = {} & a12 \ln (PCGDP_{t,c}/PCGDP_{t-1,c}) + \\ & a13 \ln (RP_{t,c}/RP_{t-1,c}) + \\ & a14 \ln (WP_{t,c}/ WP_{t-1,c}) + \\ & a15 \ln (CGP_{t,c}/CGP_{t-1,c}) + \\ & a16 \ln (T_t / T_{t-1}) \end{aligned} \quad (6)$$

$$QCR_{t,c} = PQCR_{t,c} * POP_{t,c} \quad (7)$$

where, *PQCR* is the per capita consumption of rice, *PCGDP* is per capita GDP, *CGP* is the domestic corn price, *QCR* is rice consumption, *POP* is population, $a12$ is income elasticity, $a13$ is the own domestic price elasticity of rice, $a14$ and $a15$ are substitute price elasticity, and $a16$ 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:

$$\begin{aligned}\ln (IMR_{t,c} / IMR_{t-1,c}) = {} & a17 \ln (IRP_{t,c} / IRP_{t-1,c}) + \\ & a18 \ln (QPR_{t,c}/QPR_{t-1,c}) + a19 \ln (RP_{t,c} /RP_{t-1,c}) \\ & + a20 \ln (T_t / T_{t-1}) \end{aligned} \quad (8)$$

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

where, *IMR* is rice imports, *IRP* is the international rice price, *EXR* denotes rice exports and *ESR* the ending stocks of rice, and $a17$-$a20$ are parameters. Table A5 lists the estimated parameters. For net rice importing countries, rice exports 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:

$$\begin{aligned}\ln (EXR_{t,c} / EXR_{t-1,c}) = {} & a21 \ln (IRP_{t,c} / IRP_{t-1,c}) + \\ & a22 \ln (QPR_{t,c}/QPR_{t-1,c}) + \\ & a23 \ln (RP_{t,c} /RP_{t-1,c}) + \\ & a24 \ln (T_t / T_{t-1}) \end{aligned} \quad (10)$$

$$\begin{aligned}IMR_{t,c} = {} & - QPR_{t,c} + QCR_{t,c} + EXR_{t,c} + \\ & (ESR_{t,c} - ESR_{t-1,c}) \end{aligned} \quad (11)$$

where, $a21$-$a24$ are parameters. Table A6 lists the estimated parameters. Rice ending stocks depend on the domestic rice price and time trend. The domestic rice price depends on the international rice price and time trend as follows:

$$\begin{aligned}\ln (ESR_{t,c} / ESR_{t-1,c}) = {} & a25 \ln (DP_{t,c} / DP_{t-1,c}) + \\ & a26 \ln (T_t / T_{t-1}) \end{aligned} \quad (12)$$

$$\begin{aligned}\ln (RP_{t,c}/RP_{t-1,c}) = {} & a27 \ln (IRP_{t,c} / IRP_{t-1,c}) + \\ & a28 \ln (T_t / T_{t-1}) \end{aligned} \quad (13)$$

where, $a25$-28 are parameters. Tables A7-1, A7-2, A8-1, and A8-2 list the estimated parameters. The model determines the production, consumption, imports, and ending stocks for each simulation year. The rice market clearing price is obtained from the following equilibrium conditions by using the Gauss-Seidel algorithm. Note that 5% broken milled white rice (Thailand's nominal price quota) refers to the international rice market clearing price.

$$\Sigma \ IMR_{t,c} = \Sigma \ EXR_{t,c} \quad (14)$$

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 Ecija 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 PS&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 countries[1] 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

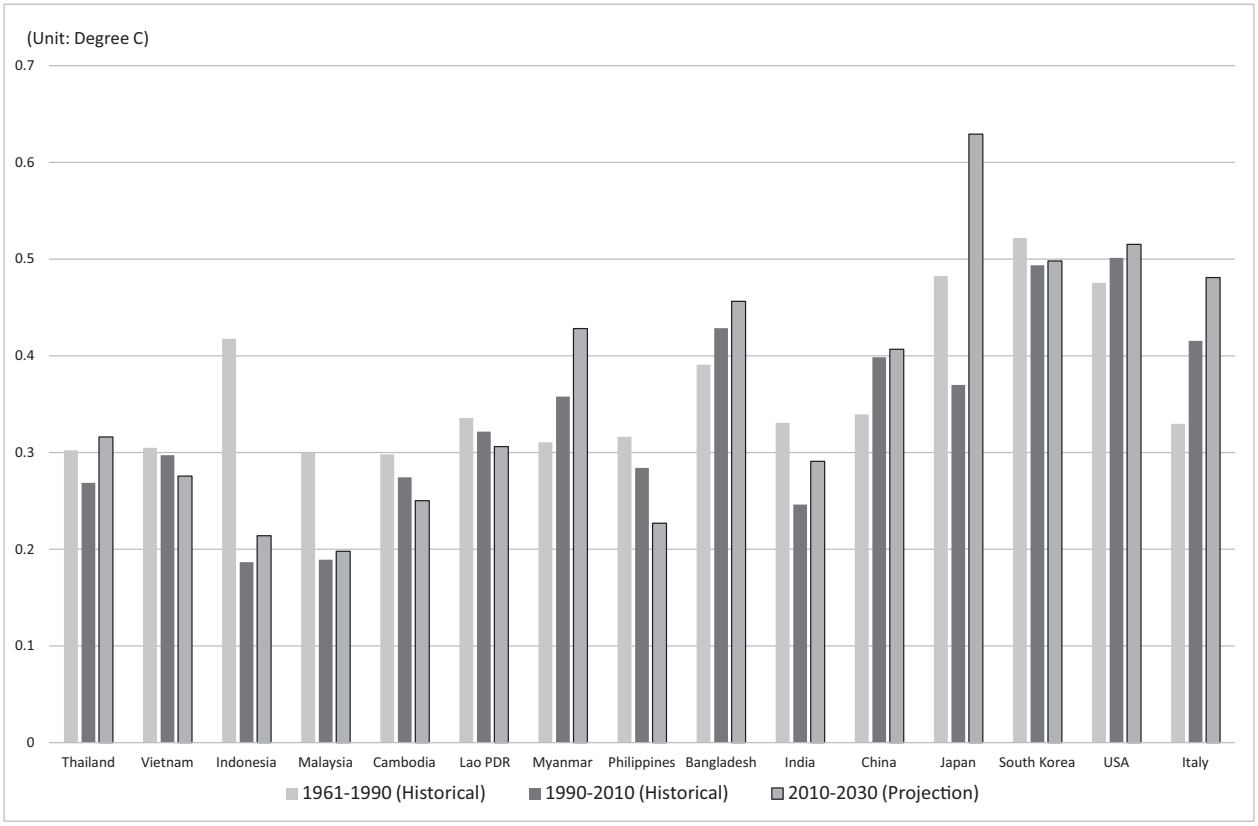

Fig. 2. Standard deviation of annual minimum temperature

[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)).

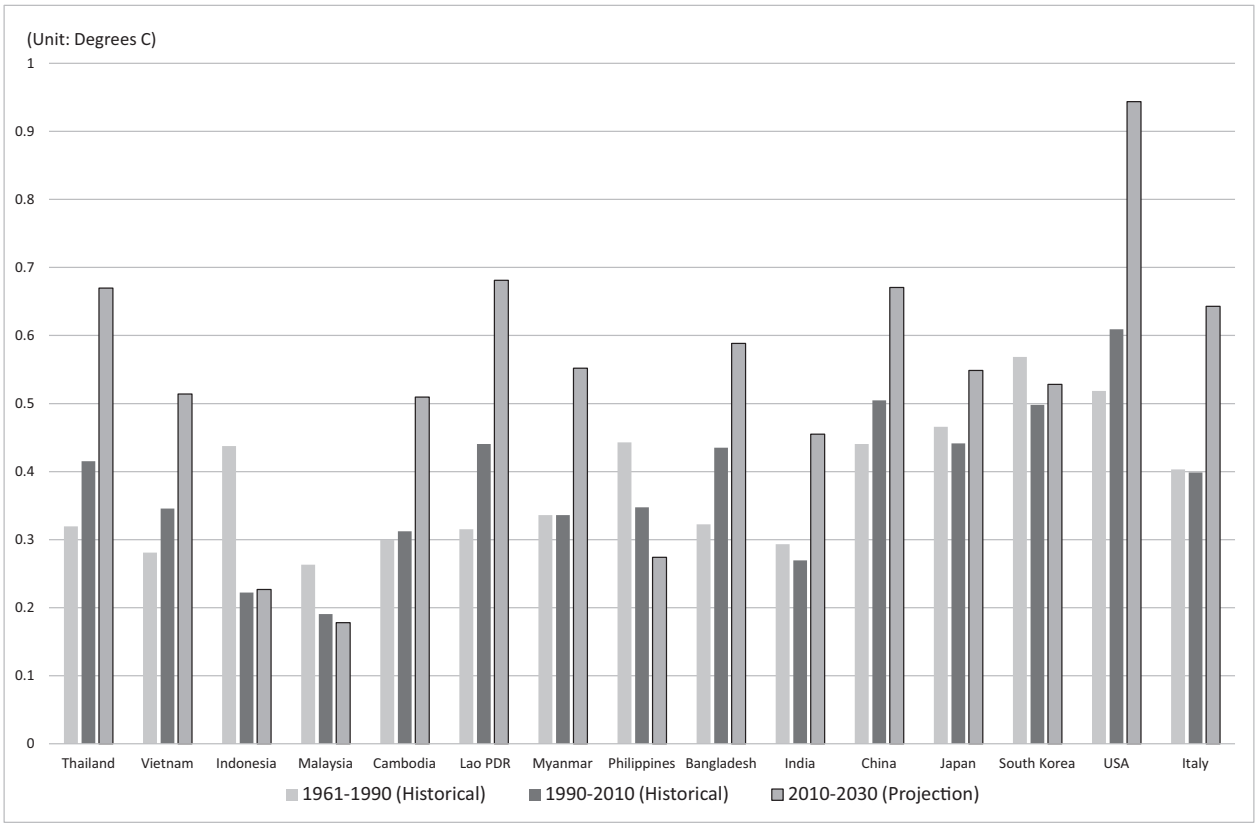

Fig. 3. Standard deviation of annual maximum temperature

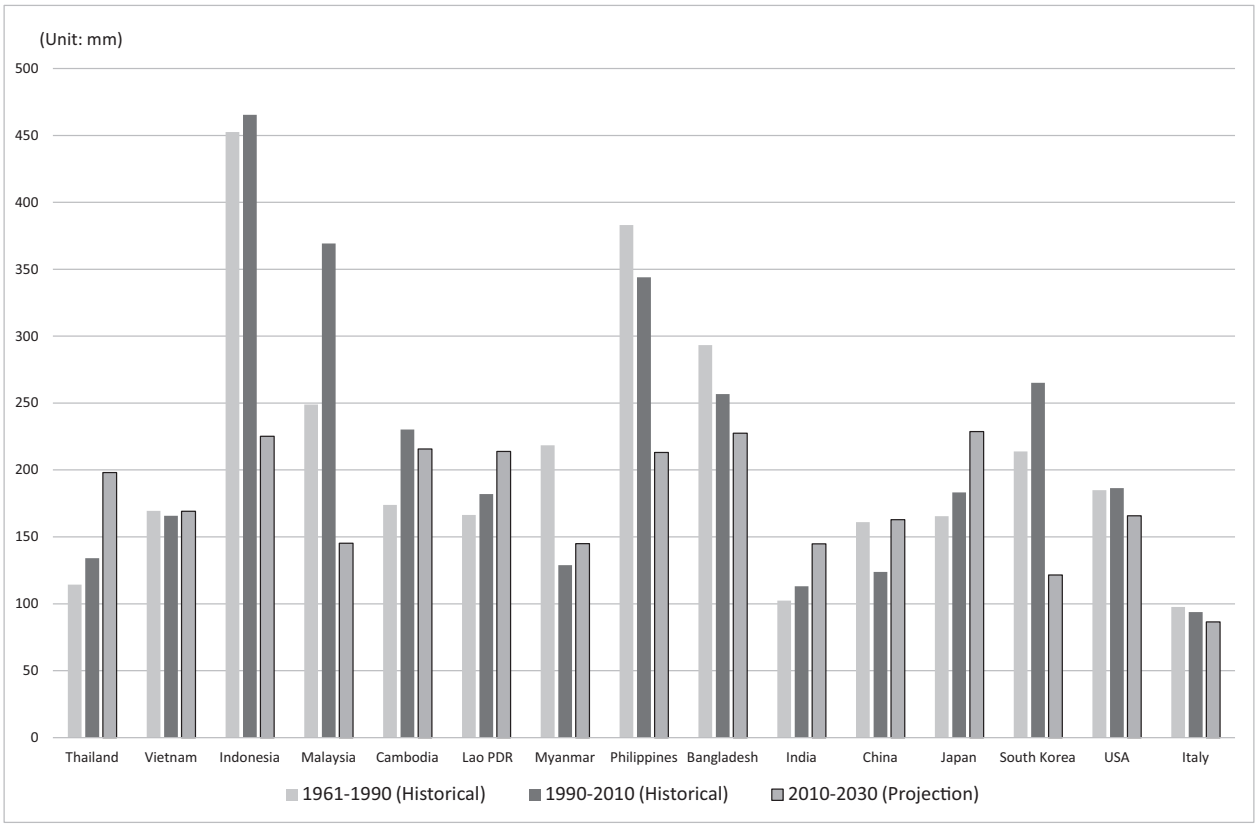

Fig. 4. Standard deviation of annual precipitation

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

	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 (The rest of the world)	1.6%	2.9%	2.0%	1.8%	1.6%	1.6%

to the model. 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

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

Table 2. Growth rates of investments in agricultural machinery & equipment (Baseline outlook)

	1975-1985	1985-1995	1975-2007	1990-2007	2000-2007	2008-2030 (Projection)
Thailand	5.5%	5.4%	3.5%	2.2%	-0.1%	-0.1%
Vietnam	9.0%	19.1%	9.6%	13.1%	-0.1%	-0.1%
Indonesia	8.0%	12.4%	6.4%	4.5%	-0.2%	-0.2%
Cambodia	1.1%	2.0%	2.7%	3.8%	5.0%	0.0%
Lao PDR	3.5%	2.6%	2.7%	2.2%	2.2%	0.0%
Myanmar	2.8%	1.4%	2.6%	2.2%	1.0%	1.0%
Malaysia	2.8%	1.4%	2.6%	2.2%	1.0%	1.0%
The Philippines	0.2%	2.6%	1.0%	0.8%	0.5%	0.5%
China	7.0%	-0.8%	4.4%	4.2%	8.1%	4.2%
India	7.2%	5.9%	6.6%	6.2%	8.4%	5.9%
Japan	1.1%	-0.1%	-2.6%	-5.3%	-10.3%	-10.3%
Korea	14.3%	19.2%	11.9%	7.5%	2.3%	2.3%
Italia (EU27)	4.0%	2.1%	1.8%	0.2%	-0.8%	-0.8%
USA	-0.7%	-0.3%	-0.4%	-0.2%	-0.7%	-0.7%
Bangladesh (The rest of the world)	2.8%	0.9%	1.3%	0.3%	0.4%	0.4%

Table 3. Policy scenarios

	Countries	Growth rate of agricultural investment during the projection period (2010-2030)	
		land development	machinery & equipment
Policy scenario 1	ASEAN 8 countries	2.0% annum	1.0 % annum
Policy scenario 2	Thailand	2.0% annum	1.0 % annum
Policy scenario 3	Vietnam	2.0% annum	1.0 % annum

Table 4. World rice production (Baseline outlook)

(1,000 ton)

	2010-12	2015	2020	2025	2030	Growth rate (2010/12-2030)
World	481,059	504,929	540,971	572,935	596,222	1.2%
Thailand	24,084	25,431	26,896	30,148	34,113	2.0%
Vietnam	28,012	29,515	32,640	35,489	38,601	1.8%
Indonesia	42,248	44,628	48,687	52,771	57,612	1.7%
Malaysia	1,683	1,660	1,676	1,649	1,678	-0.02%
Cambodia	4,367	4,558	4,854	5,205	5,702	1.5%
Lao PDR	1,423	1,503	1,719	1,865	2,017	2.0%
Myanmar	10,670	11,227	12,414	13,623	14,565	1.7%
The Philippines	10,613	11,427	12,524	13,492	14,633	1.8%
India	101,030	109,237	116,886	122,931	128,154	1.3%
China	137,990	138,930	140,009	143,918	143,185	0.2%
Japan	7,749	8,064	7,922	8,211	7,850	0.1%
Korea	4,175	4,141	4,053	3,978	3,893	-0.4%
USA	6,594	7,078	7,131	7,059	7,385	0.6%
EU27	1,731	1,811	1,757	1,760	1,829	0.3%

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)

(1,000 ton)

	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)

(1,000 ton)

	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	0	-
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	3	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)

(1,000 ton)

	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%

Table 8. World rice ending stocks (Baseline outlook)

(1,000 ton)

	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

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 (Table 11). 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 base-

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.

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%

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-

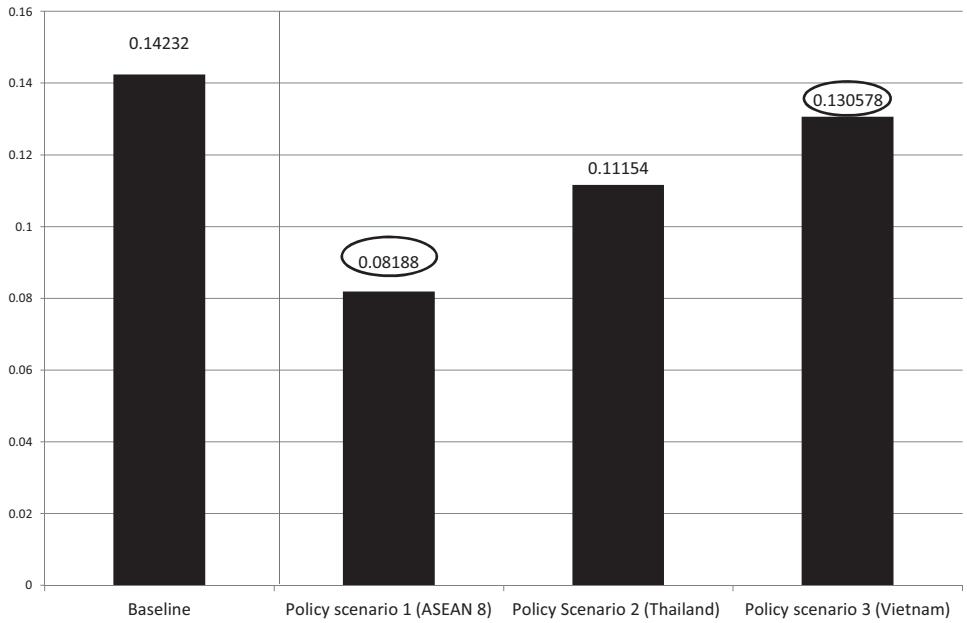

Fig. 5. The coefficient of variation (CV) of international rice price (2010/12-2030)

able data for them. 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.

Loblell, 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 (Year for dummy)*	Cambodia	*t statistics*	Lao PDR	*t statistics (Year for dummy)*	Myanmar	*t statistics*	Malaysia	*t statistics*	The Philippines	*t statistics (Year for dummy)*
a1, Minimum Temparature (t/t-1)	-0.1611	*-0.1718*	-0.2674	*-0.6206*	-0.3719	*-1.0485*	-0.2526	*-0.1784*	-0.0259	*-0.0359*	-0.2400	*-0.4758*	-0.8424	*-0.3904*	-0.7096	*-0.8673*
a2, Maximum Temparature (t/t-1)	0.0693	*-0.0671*	-0.1350	*-0.3047*	-	-	-	-	-	-	-0.0725	*-0.1288*	-0.3020	*-0.0831*	-	-
a3, Precipitation(t/t-1)	-0.0218	*-0.2229*	0.0289	*0.7307*	-0.0270	*-1.6725*	-0.0062	*-0.0389*	0.1295	*1.6327*	0.0205	*0.0421*	-0.0266	*-0.2432*	0.0623	*0.8020*
a4, Land development (t-1/t-2)	0.4594	*1.4489*	0.2711	*1.1838*	0.0087	*0.1535*	0.0261	*0.5887*	0.5315	*1.1279*	0.0951	*0.1223*	0.0140	*0.1954*	0.33715	*1.4237*
a5, Agricultural machinery & equipment (t-1/t-2)	0.0146	*8.9606*	0.2081	*1.8007*	0.1697	*2.4506*	0.4187	*0.4794*	0.2590	2.6562	0.3043	*1.1227*	0.2564	*0.7861*	0.4976	*1.3860*
a6, Time trend (t/t-1)	0.0150	*12.7535*	0.0258	*17.2082*	0.0057	*5.6356*	0.0212	*6.2037*	0.7106	*1.4014*	0.9747	*12.2059*	0.0140	*6.2300*	1.0178	*8.0467*
Constant	0.3252	*5.0536*	0.3959	*5.7797*	1.1805	*2.2560*	-0.4342	*-2.6300*	-1.2070	*-0.7144*	6.8175	*23.40*	0.5900	*6.2314*	-2.6250	*-5.4871*
Dummy 1	-	-	-	-	-0.0393	*-1.5409 (1984)*	-	-	-0.0295	*-1.4860 (2001)*	-	-	-	-	0.0597	*0.0597 (2005)*
Dummy 2	-	-	-	-	-0.1368	*-4.0408 (1986)*	-	-	-	-	-	-	-	-	-	-
Dummy 3	-	-	-	-	-0.0738	-3.3925 (1997)	-	-	-	-	-	-	-	-	-	-
Sample	1988-2008		1995-2008		1983-2006		1990-2008		1999-2007		1995-2009		1995-2008		1998-2011	
R-squared	0.9168		0.9939		0.9308		0.8464		0.9439		0.9829		0.9245		0.9106	
Adjusted R-squared	0.8812		0.9868		0.8863		0.7696		0.7757		0.9700		0.8364		0.8340	
Durbin-Watson stat	2.0577		1.8865		1.4689		1.3536		2.1034		2.0357		1.4852		1.8483	

Table A1-2. Estimation of parameters (Yield)

	China	*t statistics (Year for dummy)*	India	*t statistics*	Japan	*t statistics (Year for dummy)*	Korea	*t statistics (Year for dummy)*	USA	*t statistics*	EU27	*t statistics (Year for dummy)*	Bangladesh (The rest of the world)	*t statistics*
a1, Minimum Temparature (t/t-1)	-0.1380	*-0.7577*	-0.6434	*-0.8077*	-0.4569	*-0.1006*	-0.0100	*-0.0209*	-0.1278	*-0.9947*	-0.4367	*-1.0953*	-0.2877	*-0.5931*
a2, Maximum Temparature (t/t-1)	-	-	-	-	0.8039	*1.6115*	0.2544	*0.2711*	-	-	1.2670	*1.4944*	0.0388	*0.0547*
a3, Precipitation (t/t-1)	0.0052	*0.1035*	0.1234	*1.2655*	-0.2091	*-1.2291*	-0.0859	*-1.0385*	0.0481	*1.0809*	0.0666	*0.6695*	-0.0005	*-0.0125*
a4, Land development (t-1/t-2)	0.4846	*1.3065*	0.6718	*0.6689*	0.2264	*0.5599*	1.9611	*0.6775*	0.2223	*0.4925*	0.8113	*1.3166*	0.8072	*2.4469*
a5, Agricultural machinery & equipment (t-1/t-2)	0.0662	*0.5367*	0.2873	*1.0359*	0.2144	*0.5699*	1.3004	*2.4631*	0.0131	*0.5961*	0.0035	*1.7065*	0.0320	*1.8099*
a6, Time trend (t/t-1)	0.1596	*2.2152*	0.0109	*6.3151*	0.1307	*2.3498*	0.8143	*2.9805*	0.0113	*13.2772*	0.0066	*1.9922*	0.0309	*22.6376*
Constant	1.2290	*4.7451*	0.3272	*1.1488*	1.3853	*6.7998*	-1.2256	*-1.1828*	1.4347	*41.7235*	10.8084	*88.3382*	-0.1208	*-1.7390*
Dummy 1	0.0417	*1.6530 (1998)*	-	-	-0.3106	*-8.3565 (1993)*	-0.0960	*-2.0821 (2007)*	-	-	0.0836	*1.8739 (1999)*	-	-
Dummy 2	-	-	-	-	-0.0974	*-2.7154 (2003)*	-	-	-	-	-0.1046	*-2.3988 (2000)*	-	-
Dummy 3	-	-	-	-	-	-	-	-	-	-	0.1245	*2.3286 (2004)*	-	-
Sample	1990-2008		1988-2008		1990-2008		2000-2009		1976-2008		1985-2009		1983-2008	
R-squared	0.8310		0.8303		0.9148		0.9388		0.9342		0.7087		0.9793	
Adjusted R-squared	0.7235		0.7576		0.8606		0.7245		0.9190		0.5340		0.9712	
Durbin-Watson stat	1.6660		1.9774		2.0736		1.6634		1.7806		1.9137		1.7780	

Table A2-1. Estimation of parameters (Planted Area)

	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*	Malaysia	*t statistics (Year for dummy)*	The Philippines	*t statistics (Year for dummy)*
a7, Domestic rice price (t/t-1)	0.0119	*0.5599*	0.0131	*0.5278*	0.0313	*1.7849*	0.1234	*1.0936*	0.0162	*0.1661*	0.0528	*1.7489*	0.0156	*1.0336*	0.0013	*0.0273*
a8, Domestic wheat price (t/t-1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a9, Precipitation(t/t-1)	-0.1671	*-2.8625*	0.0025	*0.0430*	0.0747	*4.4869*	-0.0737	*-0.4043*	0.0672	*1.4374*	-0.0020	*-0.0246*	0.0388	*1.6562*	0.0291	*0.6865*
a10, Land Development (t-1/t-2)	0.8361	*1.0718*	0.0247	*1.0381*	0.1699	*1.2660*	0.4878	*0.1271*	0.4357	*0.9555*	0.1581	*3.5285*	0.1475	*0.6486*	0.0008	*0.1796*
a11, Time trend (t/t-1)	0.0066	*3.7168*	0.4658	*27.3773*	0.0040	*3.5503*	0.2512	*5.2991*	-0.0441	*-1.0863*	0.0245	*15.2536*	0.0567	*2.3433*	0.5094	*11.2071*
Constant	9.0150	*82.158*	8.5612	*64.883*	9.1613	*108.86*	6.5003	*10.847*	10.6998	*73.918*	14.934	*90.738*	6.1984	*50.732*	6.4100	*38.72*
Dummy 1	-	-	0.0532	*1.7841 (1999)*	0.0304	*1.3115 (1997)*	0.0858	*1.3115 (1997)*	-0.0635	*-1.4930 (2002)*	-	-	-0.0573	*-3.6221 (1989)*	-0.0926	*-2.5024 (1992)*
Dummy 2	-	-	-	-	-0.0313	*-2.4402 (2004)*	-	-	-	-	-	-	0.0146	*0.9525 (1990)*	-0.0900	*-2.4980 (1997)*
Dummy 3	-	-	-	-	-	-	-	-	-	-	-	-	-0.0362	*-0.0362 (1998)*	-	-
Sample	1989-2011		1990-2011		1991-2010		1993-2007		1995-2001		1988-2011		1985-2011		1988-2011	
R-squared	0.8772		0.9876		0.9198		0.7873		0.8680		0.9641		0.8253		0.9283	
Adjusted R-squared	0.8411		0.9826		0.8476		0.6277		0.7030		0.9541		0.6983		0.8970	
Durbin-Watson stat	2.3143		1.7557		1.6063		2.0455		1.8120		1.4849		2.3386		1.5706	

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/t-1)	0.0577	*2.7739*	0.0780	*2.9657*	0.1139	*1.6432*	0.0428	*1.1259*	0.1406	*2.3120*	0.0674	*5.3356*	0.0246	*1.3504*
a8, Domestic wheat price (t/t-1)	-	-	-0.0230	*-0.9719*	-	-	-	-	-	-	-	-	-	
a9, Precipitation (t/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/t-2)	-		0.7178	*1.8989*	0.8651	*0.2321*	1.5069	*3.4576*	0.9254	*0.5816*	-	-	0.5198	*2.4578*
a11, Time trend (t/t-1)	-0.0078	*-2.6924*	0.0008	*0.7961*	-0.1592	*-3.9898*	-0.0135	*-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 (1999)*	-0.0697	*-3.1316 (1982)*	0.0429	*1.1910 (2006)*	0.0341	*2.4076 (2002)*	-0.2417	*-3.1107 (2001)*	-0.0790	*-2.8315 (2008)*	-	-
Dummy 2	-0.0911	*-3.2807 (2003)*	0.0320	*1.4605 (1991)*	-	-	-	-	-0.1481	*-2.010 (2007)*	0.0511	*2.0785 (2010)*	-	-
Dummy 3	0.0332	*1.2192 (2010)*	0.0452	*2.0016 (2002)*	-	-	-	-	-	-	-	-	-	-
Sample	1991-2010		1974-2004		1995-2010		1995-2010		1985-2011		1992-2011		1990-2011	
R-squared	0.8539		0.8886		0.9310		0.9719		0.8710		0.8297		0.9007	
Adjusted R-squared	0.7865		0.8144		0.8964		0.9531		0.8235		0.7445		0.8610	
Durbin-Watson stat	1.4328		1.7080		1.8165		2.0813		1.8003		1.5918		1.5345	

Table A3. Milling rates

	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)

	Thailand	*t statistics (Year for dummy)*	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*
a12, Income; Per capita GDP growth ratio (t/t-1)	-0.0170	*-1.0770*	0.0119	*0.5508*	0.0785	*2.6335*	0.3433	*3.7947*	0.0504	*0.5818*	0.1414	*6.0049*	0.0951	*0.8481*	0.7148	*0.9874*
a13, Domestic rice price (t/t-1)	-0.0298	*-2.7657*	-0.0109	*-0.2740*	-0.1123	*-3.1545*	-0.2270	*-3.3403*	-0.0985	*-1.5732*	-0.1520	*-2.6412*	-0.1302	*-2.3770*	-0.4855	*-3.7923*
a14, Domestic wheat price (t/t-1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a15, Domestic corn price (t/t-1)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3618	*2.0365*
a16, Time Trend (t/t-1)	0.0088	*1.3793*	0.1697	*12.4887*	-0.0718	*-4.3262*	-0.1437	*-2.0198*	0.2285	*7.7660*	-0.1502	*-2.5272*	0.2698	*4.9074*	-0.0833	*0.3572*
Constant	5.2453	*76.9165*	4.8726	*137.2728*	5.3014	*101.6247*	4.7586	*21.6290*	4.6770	*60.4873*	3.6894	*3.2830*	3.6456	*22.0433*	4.7349	*17.1008*
Dummy 1	0.0163	*2.6596 (2006)*	0.0652	*2.0478 (2001)*	0.0364	*2.0973 (1999)*	-0.0502	*-1.5398 (1996)*	0.1235	*2.4196 (1992)*	-0.1097	*-2.8983 (1991)*	-0.0573	*-1.6480 (2005)*	-	-
Dummy 2	-	-	-	-	-0.0092	*-0.5589 (2005)*	-	-	-	-	-0.0802	*-2.1167 (1997)*	-0.0805	*-2.31 1(2006)*	-	-
Dummy 3	-	-	-	-	-0.0184	*-1.1942 (2006)*	-	-	-	-	-0.1163	*-3.1164 (1998)*	-	-	-	-
Sample	1995-2008		1988-2011		1991-2011		1995-2007		1991-2011		1987-2004		1999-2011		1990-2010	
R-squared	0.9202		0.9217		0.8679		0.8603		0.8311		0.9536		0.8094		0.7420	
Adjusted R-squared	0.8848		0.9052		0.7887		0.7904		0.7889		0.9284		0.6732		0.6775	
Durbin-Watson stat	1.9195		1.5682		1.7872		2.0918		2.2753		1.5782		1.5315		1.7356	

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

	China	*t statistics*	India	*t statistics (Year for dummy)*	Japan	*t statistics*	Korea	*t statistics (Year for dummy)*	USA	*t statistics*	EU27	*t statistics (Year for dummy)*	Bangladesh (The rest of the world)	*t statistics*
a12, Income; Per capita GDP growth ratio (t/t-1)	0.0513	*0.9434*	0.0636	*0.2292*	-0.1326	*-0.8658*	-0.1002	*-3.0231*	0.1655	*1.7195*	0.0741	*1.0361*	0.8771	*3.7631*
a13, Domestic rice price (t/t-1)	-0.0577	*-2.2564*	-0.0986	*-1.1158*	-0.0043	*-0.0362*	-0.0267	*-0.5174*	-0.0238	*-1.0067*	-0.0896	*-1.7142*	-0.3109	*-2.3652*
a14, Domestic wheat price (t/t-1)	0.0312	*0.5062*	0.0269	*0.8647*	-	-	-	-	-	-	-	-	0.1553	
a15, Domestic corn price (t/t-1)	-	-	-	-	-	-	-	-	-	-	-	-	-	
a16, Time Trend (t/t-1)	0.0190	*1.0693*	-0.3158	*-3.2427*	-0.0995	*-2.8779*	-0.0488	*-3.1951*	0.0112	*0.4271*	0.0055	*0.1188*	-0.0837	*-1.6550*
Constant	4.9878	*31.6253*	3.5210	*8.1826*	5.8896	*6.5052*	5.9545	*14.8265*	0.9183	*1.0033*	4.8307	*69.4742*	1.8287	*1.6938*
Dummy 1	-	-	-0.0740	*-2.4692 (2000)*	-	-	-0.1053	*-3.7062 (2003)*	-	-	-0.1332	*-3.1099 (1993)*	-	-
Dummy 2	-	-	0.0784	*2.8640 (2001)*	-	-	-	-	-	-	0.0545	*1.3567 (1994)*	-	-
Dummy 3	-	-	-	-	-	-	-	-	-	-	-0.0934	*-2.4145 (1996)*	-	-
Sample	1999-2009		1998-2008		1994-2010		1991-2010		1991-2010		1991-2011		1991-2007	
R-squared	0.8580		0.8847		0.7727		0.9187		0.8232		0.9016		0.8294	
Adjusted R-squared	0.7634		0.7117		0.7202		0.8971		0.7416		0.8594		0.7725	
Durbin-Watson stat	1.7324		2.1513		1.7407		1.8935		2.6557		2.0975		1.6324	

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	*-0.7393*
a18, Domestic Production (t/t-1)	-1.1475	*-0.0451*	-	-	-	-	-	-
a19, Domestic Rice Price (t/t-1)	-	-	-0.3350	*-0.0841*	-	-	-	-
a20, Time Trend (t/t-1)	3.7137	*3.7672*	1.5759	*16.4310*	1.0078	*3.4920*	0.0696	*12.9809*
Constant	-0.7775	*-0.4688*	1.1233	*3.7627*	1.2143	*1.5921*	4.9583	*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		0.9962		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)	1.5213	*2.7334*	0.0800	*1.4763*
a22, Domestic Production (t/t-1)	0.8788	*0.1211*	-	-
a23, Domestic Rice Price (t/t-1)	-	-	-	-
a24, Time Trend (t/t-1)	5.7516	*3.0756*	0.3975	*5.8972*
Constant	-16.2178	*-2.4703*	12.2302	*63.0068*
Dummy 1	1.1747	*2.7117 (1997)*	-0.1137	*-1.5052 (2001)*
Dummy 2	-1.9834	*-3.7932 (2003)*	0.1518	*1.8927 (2005)*
Dummy 3	-	-	-	-
Sample	1995-2005		1995-2010	
R-squared	0.9190		0.8234	
Adjusted R-squared	0.7840		0.7592	
Durbin-Watson stat	1.7263		2.0373	

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)*	Myammar	*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	*-1.6350*	-0.0223	*-0.1582*	-0.5472	*-1.8599*	-1.9302	*-3.0892*	-0.3290	*-0.0582*	-0.0754	*-0.2847*	-0.4235	*-1.4237*	-0.5792	*-1.2489*
a26, Time Trend (t/t-1)	1.0141	*0.9772*	0.7360	*0.9035*	-0.1847	*-0.3804*	0.7944	*39.9757*	0.5106	*8.2891*	1.2148	*11.1356*	0.6597	*7.8814*	1.5990	*11.5130*
Constant	3.9436	*1.6430*	3.5462	*2.8354*	8.1256	*7.6643*	3.7187	*135.0530*	3.0259	*30.4042*	13.3615	*11.3560*	4.2570	*19.8673*	3.4548	*8.6784*
Dummy 1	-	-	-0.6892	*-3.1086 (1995)*	-0.3343	*-1.9144 (2004)*	0.1074	*3.1122 (2007)*	-0.2262	*-1.3801 (1999)*	0.5585	*3.3543 (2003)*	1.5113	*4.4633 (1985)*	-0.5869	*-2.5169 (1999)*
Dummy 2	-	-	0.1578	*0.8396 (1997)*	-0.4890	*-2.9686 (2005)*	-	-	-0.6927	*-3.3465 (2007)*	0.6770	*4.5121 (2007)*	-0.4660	*-1.5994 (1988)*	-1.0068	*-5.1662 (2010)*
Dummy 3	-	-	-	-	-	-	-	-	-	-	-	-	-0.6530	*-2.4110 (2003)*	-	-
Sample	1995-2011		1995-2011		1999-2011		2005-2011		1999-2010		2002-2011		1985-2011		1993-2010	
R-squared	0.8819		0.9412		0.7934		0.9983		0.9339		0.9463		0.8284		0.9259	
Adjusted R-squared	0.8547		0.9145		0.5868		0.9966		0.9091		0.9034		0.7769		0.8950	
Durbin-Watson stat	1.7862		1.8915		2.0120		1.9008		1.7918		1.3076		1.4299		2.0751	

Table A7-2. Estimation of parameters (Ending Stocks)

	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 (Year for dummy)*
a25, Domestic rice price (t/t-1)	-0.6124	*-2.4058*	-1.0779	*-2.7815*	-2.0823	*-2.8179*	-1.2966	*-3.7565*	-0.6549	*-2.5590*	-0.1281	*-1.4620*	-0.0144	*-0.0240*
a26, Time Trend (t/t-1)	-1.1123	*-6.8448*	1.1715	*4.3277*	2.3637	*7.4218*	0.9245	*4.4672*	-1.2793	*-6.3793*	0.1299	*6.8302*	0.5250	*1.9848*
Constant	14.2413	*30.2544*	6.1207	*7.6998*	0.7094	*0.8012*	4.0626	*6.8410*	14.6763	*25.0781*	6.7345	*181.2164*	4.7401	*6.7569*
Dummy 1	-0.2704	*-1.5177 (2006)*	0.5520	*2.1154 (2000)*	2.2659	*3.8279 (1995)*	0.5887	*2.7632 (2001)*	-0.1181	*-0.5449 (1995)*	-0.1345	*-2.3475 (2001)*	-1.0419	*-2.3333 (2004)*
Dummy 2	-	-	0.6502	*2.6234 (2001)*	1.8143	*2.8601 (2003)*	-	-	0.2546	*1.5023 (2001)*	0.1323	*2.3677 (2005)*	-0.9985	*-2.1623 (2005)*
Dummy 3	-	-	-0.4096	*-1.6543 (2005)*	-	-	-	-	-	-	-	-	0.6334	*1.4023 (2010)*
Sample	1995-2011		1996-2011		1991-2011		1985-2011		1995-2011		1999-2013		1991-2011	
R-squared	0.8707		0.7866		0.8780		0.7278		0.8896		0.8874		0.6968	
Adjusted R-squared	0.8276		0.6444		0.8257		0.6441		0.8495		0.8249		0.5669	
Durbin-Watson stat	1.3271		1.6683		1.4540		1.8226		1.4924		1.9742		2.2230	

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

	Thailand	*t statistics*	Indonesia	*t statistics (Year for dummy)*	Cambodia	*t statistics*	Lao PDR	*t statistics (Year for dummy)*	Malaysia	*t statistics*	The Philippines	*t statistics*
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	*0.6833*	0.2511	*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	*1.8153*	0.0273	*5.6230*
Constant	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 1	-	-	-0.6222	*-2.7287 (2001)*	-	-	-0.4360	*-2.4035 (1991)*	-	-	-	-
Dummy 2	-	-	-0.5135	*1.7565 (2008)*	-	-	0.3618	*2.7330 (1996)*	-	-	-	-
Dummy 3	-	-	0.3401	*2.3377 (2010)*	-	-	0.3937	*2.9461 (1998)*	-	-	-	-
Sample	2000-2010		1991-2010		1991-2007		1991-2002		1991-2010		1996-2011	
R-squared	0.9692		0.7808		0.7517		0.9361		0.6988		0.9330	
Adjusted R-squared	0.9605		0.6530		0.6027		0.0859		0.5912		0.9227	
Durbin-Watson stat	2.0829		1.4621		1.6179		1.3126		1.5412		1.9066	

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

	China	*t statistics*	India	*t statistics*	Korea	*t statistics*	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)	0.36103	*4.9854*	0.0147	*0.2156*	0.1881	*4.4313*	-0.0137	*-0.2921*	-0.3049	*-3.3335*
Constant	4.5854	*27.2061*	4.9687	*35.9738*	6.9394	*69.7888*	2.7992	*29.4366*	6.3002	*34.9595*
Dummy 1	-	-	-	-	-	-	-0.4937	*-3.3920 (2001)*	0.5015	*1.8423 (1996)*
Dummy 2	-	-	-	-	-	-	-0.4852	*-3.3161 (2002)*	-0.4703	*-1.7165 (2001)*
Dummy 3	-	-	-	-	-	-	0.5425	*3.6099 (2008)*	-0.4194	*-1.5210 (2002)*
Sample	1992-2010		1991-2007		1992-2010		1991-2010		1991-2010	
R-squared	0.7747		0.6134		0.7661		0.8553		0.7919	
Adjusted R-squared	0.6880		0.5242		0.6761		0.7764		0.6462	
Durbin-Watson stat	1.8276		1.6663		2.0443		1.4387		1.3787	

Table A9. Standard deviation of climate data

		Source	1961-1990 (Historical)	1990-2010 (Historical)	2010-2030 (Projection: Exogenous Variable)
Minimum tempetature (Unit: Degrees C)					
	Thailand	Historical data: CRU TS 3.2 (University of East Anglia) , Projection data: BCM2 (Bergen Climate Model Version 2), Global Climate Model under A2 greenhouse gas emission scenario	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)					
	Thailand	Historical data: CRU TS 3.2 (University of East Anglia) , Projection data: BCM2 (Bergen Climate Model Version 2), Global Climate Model under A2 greenhouse gas emission scenario	0.3194	0.4151	0.6696
	Viet Nam		0.2810	0.3457	0.5141
	Indonesia		0.4377	0.2223	0.2268
	Malaysia		0.2631	0.1907	0.1779
	Cambodia		0.2996	0.3123	0.5095
	Lao PDR		0.3152	0.4404	0.6812
	Myanmar		0.3360	0.3360	0.5518
	The Philippines		0.4429	0.3474	0.2740
	Bangladesh (The rest of world)		0.3226	0.4352	0.5882
	India		0.2932	0.2694	0.4550
	China		0.4405	0.5046	0.6706
	Japan		0.4657	0.4414	0.5486
	South Korea		0.5685	0.4980	0.5281
	USA		0.5184	0.6092	0.9436
	Italy (EU27)		0.4032	0.3987	0.6428
Precipitation (Unit: mm)					
	Thailand	Historical data: CRU TS 3.2 (University of East Anglia) , Projection data: BCM2 (Bergen Climate Model Version 2), Global Climate Model under A2 greenhouse gas emission scenario	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

	Unit	Source	2010-12	2022	2030
Per capita GDP growth rate					
Thailand	USD (2005 base)	2010-12 data; World Economic Outlook 2013 (IMF). Projection data: USDA Agricultural Projections to 2022 (USDA 2013)	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)	2010-12 data; World Economic Outlook 2013 (IMF). Projection data: OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013)	542	861	861
India	USD (2005 base)		1,117	2,180	2,180
China	USD (2005 base)		3,123	6,898	6,898
Japan	USD (2005 base)		36,389	41,761	41,761
South Korea	USD (2005 base)		21,562	31,321	31,321
USA	USD (2005 base)		42,669	52,310	52,310
EU27	USD (2005 base)		34,144	41,621	41,621
Population					
Thailand	thousand	World Population Prospects, the 2010 Revision (United Nations, Department of Economics and Social Affairs)	69,473	72,409	73,321
Viet Nam	thousand		88,767	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		6,286	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)	199.1	184.7	184.7
Rice export, Japan	1,000 ton	OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013)	173.0	200.0	200.0
Rice import, Japan	1,000 ton	OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013)	853.0	768.0	768.0
International wheat price	USD/t	OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013)	313	274	274
International corn price	USD/t	OECD-FAO Agricultural Outlook 2013-2022 (OECD-FAO 2013)	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.