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REVIEW

The Contribution of Agricultural Investments to Food Loss and the World Rice Market in Asian Countries

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Abstract

This study examines the role of agricultural investment growth in food loss, and international rice price using a partial equilibrium model. The developed Rice Economy Climate Change (RECC) model covers rice markets in 24 countries and regions. The purpose of this study is to conduct simulations on how agricultural investment for agricultural machinery and equipment can impact the food loss rate of rice and the world rice market. The result of this study concluded that an increase in agricultural machinery and equipment investment in the eight ASEAN countries, Bangladesh, Sri Lanka and Nepal would contribute to increasing not only the rice yield but also to reducing the food loss rate of rice, as rice consuming continues to grow and its production becomes increasingly affected by climate change. This study suggests that reducing the food loss rate of rice can contribute to coping with growing global rice consumption without increasing rice production. Consequently, policy makers should promote constant agricultural machinery and equipment investment not only to increase agricultural productivity, but also to reduce the food loss of rice.

Discipline: Agricultural economics
Additional key words: agricultural machinery and equipment, ASEAN, South Asia, partial equilibrium model, climate change adaptation

Introduction

The Food and Agriculture Organization of the United Nations (FAO) (2011) has estimated food losses occurring along the entire food chain, assessed the magnitude thereof, and reported that roughly one-third of food produced for human consumption, amounting to about 1.3 billion t, is lost or wasted globally every year (FAO 2011). These food losses and waste[1] can have a serious impact on world food security and the environment. The FAO's study pointed out that food is lost mostly during the early and middle stages of the food supply chain: during agricultural production, postharvest handling, and storage in developing countries. This study adopts the use of *food losses* defined by the High Level Panel of Experts (HLPE) on food security and nutrition as "food appropriate for human consumption being discarded or left to spoil at the consumer level" (HLPE 2014).

The FAO has estimated that most of the food losses and waste in developing countries occurs during agricultural production, postharvest handling, and during storage, while most of the food losses and waste in developed countries occurs during the distribution and consumption phases.[2] This study defines the ratio of the amount of food loss in rice divided by that of production as the *food loss rate* of rice. The food loss rate of rice-producing countries has been estimated as follows: 7.5% in Thailand, 9.2% in Vietnam, 15.0% in Cambodia, 7.9% in Indonesia, and 6.0% in Lao PDR in 2010 (Table 1).

Rutten (2013) conducted economic analysis for

[1] This refers to a decrease at all stages of the food chain from harvest to consumption in mass, of food that was originally intended for human consumption, regardless of the cause (HLPE 2014).

[2] For more information, please refer to Koizumi (2016).

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food losses and waste. The HLPE (2014) analyzed food losses and waste from a triple perspective, and advocated that national and international research and development organizations should increase investment in technological innovations at postharvest to effectively reduce food losses and waste. Koizumi and Kanamaru (2016) conducted policy simulations for alleviating climate risks to rice production systems and rice markets, by utilizing a partial equilibrium model. Koizumi (2016) examined how agricultural investment can impact food losses and the world rice market. This study develops the studies of these authors, and incorporates other main rice exporting and importing countries into the partial equilibrium model developed by Koizumi and Kanamaru (2016). The purpose of this study is to conduct simulations for agricultural investment relative to affecting the food loss rate of rice and the world rice market, by utilizing a developed partial equilibrium model.

Examining the impact of agricultural investment on food loss and rice yield

The food loss rate of rice in the Philippines decreased from 3.4% in 1980 to 1.0% in 2011 (Table 1). The Japan International Cooperation Agency (JICA) and other international organizations promoted efforts to increase agricultural equipment, such as drying facilities and storage facilities, and thus contributed to reducing the food loss of rice in the Philippines. After the 1990s, an increase in modern storage facilities also helped to reduce the food loss of rice in this country (Koizumi 2016). The relationship between the food loss rate of rice and the changing rate of agricultural machinery and equipment has an inverse correlation (Koizumi 2016). FAO (1970) identified the factors affecting food value and the deterioration of grains in tropical and subtropical areas. FAO (2011) pointed out that a lack of proper storage facilities is the major cause of postharvest losses. Liu (2013) considered that storage is the most important cause of postharvest losses for all types of food in China. The HLPE (2014) has pointed out that agricultural investment is an effective method of reducing food losses. It also identified such causes as poor harvesting techniques at harvest and the initial handling stage, a lack of proper storage facilities for shelf-stable foods such as grains, resulting in losses from pest damage, and fungal infection at the storage stage. Consequently, it is considered that agricultural investment, such as in increasing storage facilities and developing agricultural machinery, can contribute to reducing the food loss rate of rice.

Kumar (1992) examined the relationship between agricultural investment and rice yield in India. FAO (2003) and Liu (2014) pointed out that agricultural investment played a crucial factor in increasing agricultural productivity in developing countries. Consequently, it is considered that increasing agricultural investment can contribute to increasing agricultural yield, when assuming constant labor input.

FAO (2011), BCFN (2012), and Lipinski et.al (2013) pointed out that relatively low food prices were an important cause of food losses in supply and food waste in demand. The relationship between the food loss rates of rice and rice price is an inverse correlation (Koizumi 2016). Thus, this study hypothesizes that increasing storage facilities and developing agricultural machinery can contribute to reducing the food loss rate of rice. This study estimates parameters derived from time-series analysis between the food loss rate of rice and agricultural investment in the ASEAN countries and other main rice-producing countries by using the Ordinary Least Squares (OLS) method. It also hypothesizes that increasing agricultural investment

Table 1. Food loss rates of rice in major rice-producing countries

	1961	1980	1990	2000	2010	2011
Thailand	5.6%	5.6%	5.9%	7.5%	7.4%	7.5%
Vietnam	9.6%	9.9%	9.7%	9.1%	9.3%	9.2%
Cambodia	9.0%	9.0%	10.0%	10.1%	15.0%	15.0%
Indonesia	7.1%	6.8%	7.9%	7.9%	7.7%	7.9%
Lao PDR	5.0%	5.0%	5.0%	5.0%	6.0%	6.0%
Philippines	3.3%	3.4%	1.4%	1.5%	1.0%	1.0%
Malaysia	3.0%	3.0%	3.0%	3.0%	7.5%	7.7%
Myanmar	3.0%	3.0%	3.5%	4.0%	5.9%	5.1%
Bangladesh	3.0%	3.0%	3.0%	5.0%	5.0%	5.0%
Sri Lanka	1.8%	3.5%	6.0%	6.0%	6.0%	5.9%
Nepal	11.1%	11.1%	12.0%	11.3%	11.4%	11.4%
Pakistan	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%

Source: Calculated by FAO (2011) and FAO.

can contribute to increasing rice yield. This study also estimates parameters derived from time-series analysis between yield and agricultural investment by OLS. The study covers the endogenous variable for the food loss rate of rice, depending on agricultural investment and domestic rice prices in the ASEAN countries and other main rice-producing countries. This study is the first to evaluate how agricultural machinery and equipment investment can affect the food loss rate of rice and the world rice market in ASEAN and South Asian countries.

Method and data

1. Method

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 the world food market. The Rice Economy Climate Change (RECC) model is a partial equilibrium (PE) model developed by Koizumi and Kanamaru (2016). The PE model can analyze the agricultural sector in more detail than the Computable General Equilibrium (CGE) model. In the RECC model, the yield is decided by minimum temperature, maximum temperature, precipitation, agricultural investment and other factors. The planted area is decided by crop prices, precipitation, agricultural investment and other factors. These equation structures are unique and different from those in previous studies. The RECC model has an advantage in being able to analyze how agricultural investment will impact the world rice market under climate change.

The RECC model originally covered the rice markets in 15 countries and regions (Thailand, Vietnam, Indonesia, Malaysia, the Philippines, Cambodia, Lao PDR, Myanmar, China, Japan, South Korea, India, USA, EU28, and the rest of the world). Rice consumption is increasing in Africa and the Middle East. However, the original RECC model did not cover the countries in those regions. This study develops the RECC model and incorporates nine countries (Bangladesh, Sri Lanka, Nepal, Pakistan, Brazil, Côte d'Ivoire, Egypt, Madagascar, and Nigeria) into the RECC model. Each country's market consists of production (yield and planted area), consumption, exports, imports, ending stock, and food loss rate of rice up to the year 2035. This study defines planted area as being equal to the area harvested. The RECC model covers equations for projecting the rice yield and planted area affected by climate change (Fig. 1). We applied an Error Correction Model (ECM) to this study to evaluate the long-term equilibrium relationships among economic variables. As for the equations and parameters used for paddy rice yield, planted area, paddy rice production, milled rice production, per capita consumption, exports, imports, ending stocks and domestic prices, please refer to Koizumi and Kanamaru (2016).[3] The food loss rate of rice depends on the domestic rice price, a possible lack of agricultural machinery and equipment, and technical change as follows:

$$\ln (LOR_{t,c}/LOR_{t-1,c}) = a29 \ln (RP_{t-1,c}/RP_{t-2,c}) + a30 \ln (AME_{t-1,c}/AME_{t-2,c}) + a31 \ln (T_t/T_{t-1}) \quad (1)$$

where, LOR is the food loss rate of rice, RP is the domestic rice price, AME denotes investments in agricultural machinery and equipment, T is time trend, and $a29$-$a31$ are parameters. Tables 2 and 3 list these estimated parameters. Parameters such as $a29$ and $a30$ are negative in the eight ASEAN and in South Asian countries. Consequently, providing more agricultural machinery and equipment, and raising the domestic rice price can contribute to reducing the food loss rate of rice. The model determines the production, consumption, imports, food loss rate, 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.

$$\Sigma \; IMR_{t,c} = \Sigma \; EXR_{t,c} \quad (2)$$

where, IMR denotes rice imports and EXR denotes rice exports. Historical annual minimum and maximum temperatures and precipitation data are derived from CRU TS. 3.2 (University of East Anglia). The values for all grids that cover the entire territory are spatially averaged for the 24 covered countries and regions. Historical planted area, yield, production, per capita consumption, imports, exports, and ending stock data of rice are derived from PS&D (USDA). These producer prices[4] are derived from FAOSTAT (FAO), and the data are used for regression in time-series analysis.

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[3] Tables A2 to A8 list the parameters for the newly incorporated countries from a1 to a28. The results of unit root tests (ADF test, Dickey-Fuller test and PP test) confirmed that the time-series data of dependent variables and explanatory variables used in this study are nonstationary series. As for the detailed test results, please refer to Koizumi (2016).

[4] This study defines the rice producer price as the domestic rice price, and the wheat and corn producer prices as domestic wheat and corn prices.

2. 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 and maximum temperatures and precipitation) in each country and region are exogenous variables to the model. All climate variables for both the baseline outlook and policy scenario come from climate change projections by the Model for Interdisciplinary Research on Climate

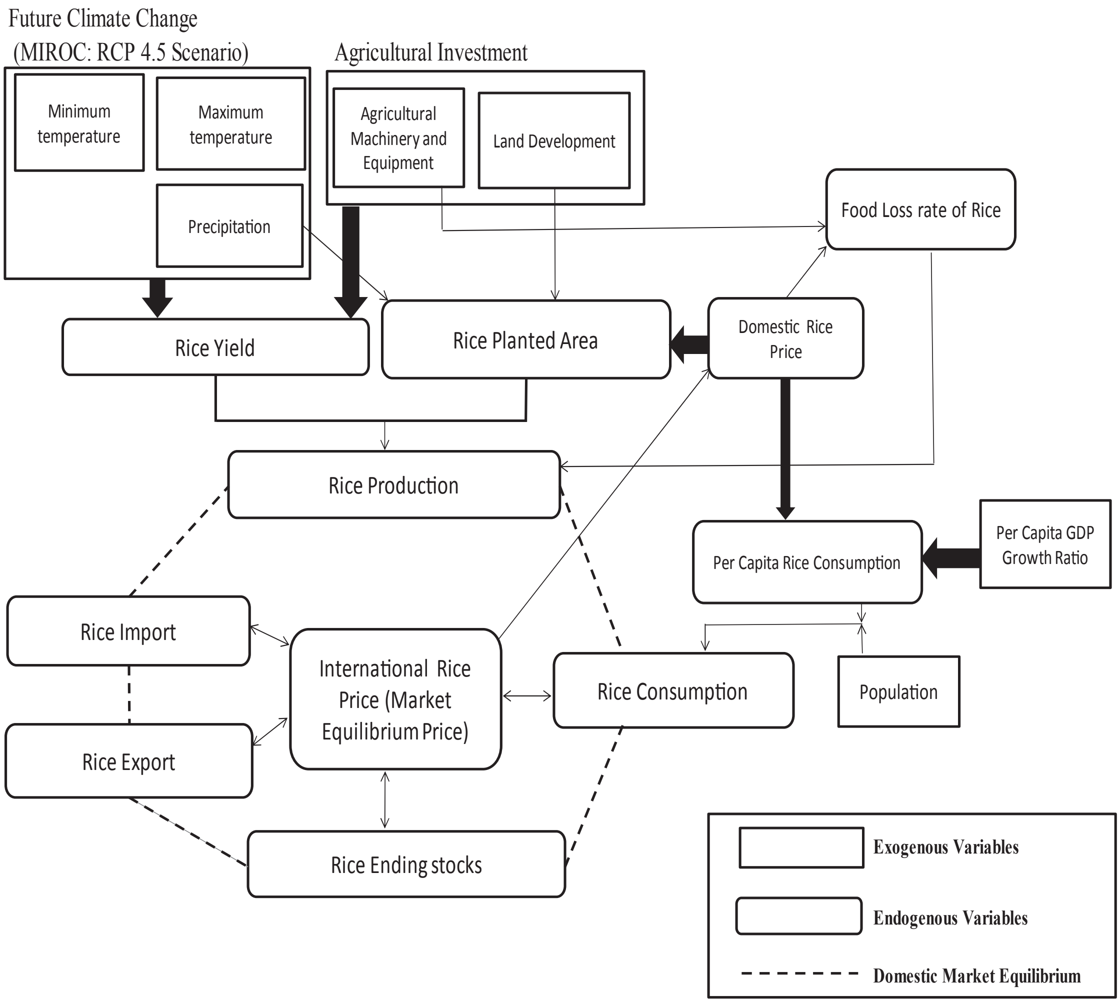

Fig. 1. Structures of the RECC model in the case of Thailand

Table 2. Estimation of parameters (food loss rate of rice: 1)

	Thailand	*t statistics (Year for dummy)*	Vietnam	*t statistics (Year for dummy)*	Cambodia	*t statistics (Year for dummy)*	Indonesia	*t statistics (Year for dummy)*	Lao PDR	*t statistics (Year for dummy)*	Phillipines	*t statistics (Year for dummy)*
a29, Domestic rice price	-0.1119	*-1.2627*	-0.0418	*-1.1518*	-	-	-0.0545	*-2.6615*	-0.0397	*-0.6704*	-0.0961	*-1.0202*
a30, Agricultural machinery and equipment (t-1/t-2)	-1.8737	*-5.1695*	-0.2870	*-1.9956*	-1.3892	*-0.7507*	-0.2171	*-4.6732*	-2.9241	*-0.4850*	-0.9688	*-0.9144*
a31, Time trend	0.4134	*8.9504*	0.0760	*1.6656*	1.4081	*3.0107*	0.0138	*1.3876*	0.3887	*6.1852*	-0.0184	*-0.3797*
Constant	-3.7209	*-28.3605*	-2.5556	*-18.9431*	-5.9598	*-4.6712*	-2.5409	*-94.5794*	-3.8060	*-14.5572*	-4.1218	*-30.6782*
Dummy 1	-0.1023	*-2.5149 (1999)*	-0.0411	*-1.9338 (1997)*	-0.2721	*-1.8178 (2002)*	-0.0457	*-2.9978 (1991)*	0.0489	*1.6342 (2001)*	0.1146	*0.1146 (1996)*
Dummy 2	-0.1671	*-0.1672 (2000)*	-0.0690	*-2.5815 (2007)*	-0.3312	*-2.1281 (2003)*	0.0867	*5.0413 (1993)*	-	-	-0.1839	*-3.4978 (1998)*
Dummy 3	-0.0906	*-0.0906 (2007)*	-	-	-	-	0.0534	*3.8983 (1996)*	-	-	-0.3497	*-4.7374 (2007)*
Sample	1993-2007		1995-2007		1997-2007		1990-2007		1996-2007		1990-2007	
R-Square	0.9779		0.8942		0.9030		0.9121		0.9298		0.8836	
Adjusted R-squared	0.9612		0.8186		0.7576		0.8339		0.8897		0.8202	
Durbin-Watson stat	2.0525		2.2653		1.1567		1.4503		2.2014		2.2721	

Table 3. Estimation of parameters (food loss rate of rice: 2)

	Malyasia	t statistics (Year for dummy)	Myanmar	t statistics (Year for dummy)	Bangladesh	t statistics (Year for dummy)	Sri Lanka	t statistics (Year for dummy)	Nepal	t statistics (Year for dummy)
a29, Domestic rice price	-	-	-	-	-0.0808	-0.5989	-0.2026	-2.6877	-0.0212	-1.3212
a30, Agricultural machinery and equipment (t-1/t-2)	-0.7242	-0.4725	-0.6563	-1.6179	-1.1963	-0.5394	-0.8794	-2.3305	-0.2738	-1.7755
a31, Time trend	0.1069	0.8548	0.5717	3.3411	0.0847	5.2174	0.0233	3.6353	0.0050	1.1863
Constant	-3.6252	-10.2488	-4.7270	-10.0152	12.1181	14.4871	-3.0836	-24.0181	-2.1461	-14.2107
Dummy 1	0.6682	3.5556 (2005)	-0.1321	-1.6709 (2003)	-0.2009	-0.2008 (1998)	0.2254	4.5963 (1996)	-0.0605	-4.7280 (1982)
Dummy 2	0.6840	3.6236 (2006)	0.1259	1.4997 (2006)	0.3649	0.3649 (2000)	0.1654	0.1655 (1992)	0.0455	3.7205 (1991)
Dummy 3	-	-	-	-	0.2432	1.6015 (2001)	-	-	0.0393	2.9574 (2007)
Sample	1986-2007		1996-2007		1993-2010		1984-2007		1982-2007	
R-Square	0.7812		0.9062		0.9516		0.8376		0.8155	
Adjusted R-squared	-0.7128		0.8281		0.9253		0.7924		0.7572	
Durbin-Watson stat	2.0013		2.2151		1.5935		1.9952		1.6076	

(MIROC), a global climate model under the RCP 4.5 scenario.[5] Spatially averaged[6] climate variables for each country are computed the same way as the historical climate data used for regression. The standard deviations of minimum and maximum temperatures in the newly incorporated countries[7] were projected to increase during the decades of 1990-2010 and 2010-2035.[8] The standard deviations of precipitation in these countries are projected to increase during the same periods[7].

Population data for all countries were taken from the 2015 Revision (medium variant) of World Population Prospects, United Nations (2015). Per capita real GDP was also treated as an exogenous variable, and GDP growth rate assumptions were based on World Economic Outlook 2016 (IMF 2016). These GDP growth rates are available up to the year 2021. This study assumes the growth rate of per capita GDP from 2022 to 2035 is applied at the average rate from 2018 to 2021 in all the countries and regions. Tables A9-1 and A9-2 list the exogenous variables for per capita GDP growth rate, population, international wheat and corn prices, and others. These prices are derived from OECD-FAO Agricultural Outlook 2016-2025 (OECD-FAO 2016). This study also assumes that current agricultural policies will continue in all countries throughout the outlook period. Following generally adopted procedures, this study assumes that historical rates of technological innovation will continue. The model does not take into account any new agricultural trade agreements. This study focuses on agricultural investment for storage facilities and agricultural machinery in developing countries. FAOSTAT data for agricultural machinery and equipment covers both storage facilities and agricultural machinery. Agricultural investments (land development, agricultural machinery and equipment) are exogenous variables to the model when assuming constant labor input during the outlook period. This study assumes a constant head rice yield in all countries and regions during the outlook period.

This study assumes that these agricultural investments will be used mainly for rice production in the eight ASEAN countries,[9] as well as Sri Lanka, Bangladesh, and Nepal. Consequently, this study utilized these agricultural investments for simulation for those eight ASEAN countries, Sri Lanka, Bangladesh, and Nepal. This study assumes that the current growth rate of agricultural investments from 2000 to 2007 in the 24 covered countries and regions will continue during the outlook period (2013/15 to 2035)[10] (Tables 4 and 5). The growth rate of agricultural machinery and equipment in Sri Lanka from 2000 to 2007 was 1.4% (Table 5). This study applied the growth rate from 1990 to 2000 for Sri Lanka (0.8%) to the outlook period.

[5] Four Representative Concentration Pathways (RCPs) were selected and defined by their total radiative forcing pathway and level in 2100. RCP4.5 is descripted stabilization without an overshot pathway to 4.5 W/m^2 at stabilization after 2100 (IPCC).

[6] The values for all grids are the same as historical minimum and maximum temperatures and precipitation.

[7] Iran is considered to represent the “rest of the world.” Italy is considered to represent the EU28.

[8] Please refer to Table A1.

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

[10] 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. 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 rate of agricultural machinery & equipment in Cambodia from 2000 to 2007 was 5.0%, which appears to be too high. Instead, we applied the growth rate from 1980 to 1990 for this country (2.1%) to the outlook period.

3. Four Scenarios

This study applied alternative scenarios to the baseline outlook. The study produces outlooks under the four scenarios listed in Table 6. In Scenario 1, this study hypothesizes that the growth rate of agricultural machinery and equipment in Thailand, Vietnam, Indonesia, the Philippines, and Malaysia will increase by 2.0% per annum, and that in Cambodia, Lao PDR, and Myanmar will increase by 4.0% per annum from 2013/15 to 2035, respectively. In these countries, poor agricultural production, postharvest handling, and storage are the main factors responsible for food losses. Consequently, reducing the amount of the food loss rate of rice can add to production in the same year and countries in the model.

Increasing agricultural machinery and equipment contributes to both increasing the rice yield and reducing the food loss rate of rice under Scenario 1. This study needs to extract the impact of the food loss rate of rice from Scenario 1. Consequently, in Scenario 2, this study hypothesizes that the growth rate of agricultural machinery and equipment in Scenario 1 will only apply to the food loss rate of rice, not rice yield. In this scenario, the growth rate of agricultural machinery and equipment in the yield equation is applied to the baseline outlook assumption. In Scenario 3, this study hypothesizes that the growth rate of investments in agricultural machinery and equipment and land development in Bangladesh, Sri Lanka, and Nepal will increase by 3.0% and 0.0% per annum from 2013/15 to 2035, respectively. In Scenario 4, this study also hypothesizes that the growth rate of investments in Scenario 3 will only apply to the food loss rate of rice, not the rice yield in Bangladesh, Sri Lanka, and Nepal. These agricultural machinery and equipment investments covering storage facilities and agricultural machinery can be considered as climate change adaptation measures.

Table 4. Growth rates of land development (baseline outlook)

	1980-1990 (Historical)	1990-2000 (Historical)	2000-2007 (Historical)	2013/15-2035 (Projection)
Thailand	1.7%	0.7%	0.9%	0.9%
Vietnam	2.5%	2.0%	2.3%	1.0%
Indonesia	1.0%	1.0%	1.9%	1.9%
Cambodia	6.5%	0.3%	0.3%	0.3%
Lao PDR	0.7%	3.9%	2.0%	1.2%
Myanmar	0.1%	2.0%	1.7%	1.7%
Malaysia	3.3%	0.7%	-0.1%	-0.1%
Philippines	1.4%	-1.1%	0.5%	0.5%
Bangladesh	3.3%	1.9%	1.6%	1.6%
Sri Lanka	0.9%	0.7%	0.4%	0.4%
Nepal	3.8%	1.1%	0.3%	0.3%
Pakistan	0.7%	1.2%	0.8%	0.8%

Note: Historical data are derived from FAO.

Table 5. Growth rates of agricultural machinery and equipment (baseline outlook)

	1980-1990 (Historical)	1990-2000 (Historical)	2000-2007 (Historical)	2005-07 (Historical)	2013/15-2035 (Projection)
Thailand	4.9%	4.0%	-0.1%	-0.3%	-0.1%
Vietnam	1.5%	24.8%	-0.1%	-0.2%	-0.1%
Indonesia	12.0%	8.4%	-0.2%	0.0%	-0.2%
Cambodia	2.1%	3.3%	5.0%	2.8%	2.1%
Lao PDR	2.9%	2.4%	2.2%	2.5%	2.2%
Myanmar	3.0%	3.2%	1.0%	2.2%	1.0%
Malaysia	3.0%	3.2%	1.0%	2.2%	1.0%
Philippines	1.1%	1.0%	0.5%	0.7%	0.5%
Bangladesh	2.1%	0.2%	0.4%	0.0%	0.4%
Sri Lanka	-1.1%	0.8%	1.4%	0.1%	0.8%
Nepal	2.8%	2.4%	2.9%	1.8%	1.8%
Pakistan	7.9%	2.1%	0.7%	0.4%	0.7%

Note: Historical data are derived from FAO.

Results

Under the baseline assumptions, world rice production and consumption are expected to increase at a rate of 1.7% per annum from 2013/15 to 2035 (Table 7). World rice exports are expected to increase at a rate of 3.2% per

Table 6. Scenarios

	Countries	Growth rates of investments in agricultural investment (2013/15～2035)		Coverage
		Agricultural machinery and equipment	Land development	
Scenario 1	Thailand, Vietnam, Indonesia, Philippines and Malaysia	2.0%	Apply for baseline projection	Apply for yield and food loss rate of rice
	Cambodia, Lao PDR and Myanmar	4.0%	Apply for baseline projection	
Scenario 2	Thailand, Vietnam, Indonesia, Philippines and Malaysia	2.0%	Apply for baseline projection	Apply for rice yield
	Cambodia, Lao PDR and Myanmar	4.0%	Apply for baseline projection	
Scenario 3	Bangladesh, Sri Lanka and Nepal	3.0%	0.0%	Apply for yield and food loss rate of rice
Scenario 4	Bangladesh, Sri Lanka and Nepal	3.0%	0.0%	Apply for food loss rate of rice

Table 7. World rice production and consumption (baseline outlook)

（Unit: 1,000 t)

	World Rice Production			World Rice Consumption		
	2013-15	2035	Growth rate per annum (2013/15-2035)	2013-15	2035	Growth rate per annum (2013/15-2035)
World	475,988	665,187	1.7%	473,664	665,074	1.7%
Thailand	18,337	26,908	1.9%	10,700	12,749	0.9%
Vietnam	27,942	46,830	2.6%	21,933	29,877	1.6%
Indonesia	36,020	44,947	1.1%	38,300	56,671	2.0%
Malaysia	1,785	1,777	0.0%	2,758	3,407	1.1%
Cambodia	4,592	6,245	1.5%	3,622	4,967	1.6%
Lao PDR	1,817	2,566	1.7%	1,838	3,474	3.2%
Myanmar	12,252	17,521	1.8%	10,517	13,250	1.2%
Philippines	11,708	17,577	2.1%	13,083	34,908	5.0%
Bangladesh	34,463	54,428	2.3%	35,067	78,122	4.1%
Nepal	3,187	5,850	3.1%	3,709	9,345	4.7%
Pakistan	6,799	12,271	3.0%	2,567	3,816	2.0%
Sri Lanka	2,997	4,153	1.6%	3,073	5,137	2.6%
India	105,209	155,929	2.0%	97,070	130,046	1.5%
China	144,287	153,588	0.3%	144,000	155,615	0.4%
Japan	7,811	5,384	-1.8%	8,527	8,456	0.0%
Korea	4,266	4,239	0.0%	4,331	4,442	0.1%
USA	6,443	8,362	1.3%	4,044	4,812	0.9%
EU28	1,985	1,567	-1.2%	3,350	2,959	-0.6%
Brazil	7,963	9,492	0.9%	7,875	11,216	1.8%
Cote d'Ivoire	1,459	2,657	3.0%	2,500	5,046	3.6%
Egypt	4,427	7,853	2.9%	3,983	6,442	2.4%
Nigeria	2,772	4,355	2.3%	5,417	10,059	3.1%
Madagascar	2,413	3,566	2.0%	2,733	4,244	2.2%
Rest of the world	25,054	67,122	5.1%	42,667	66,013	2.2%

Note: 1. Data for 2013/15 were actually derived from USDA-FAS, and data for 2035 are projections.

2. Actual data are calculated by exportable domestic market balance.

3. The growth rates per annum for world rice exports and imports are different because 2013/15 data are actual data.

annum, and world rice imports are expected to increase at a rate of 3.6% per annum during the same period (Table 8). World rice ending stocks are expected to decrease at a rate of 0.1% per annum during the same period. The international rice price (5% broken milled white rice, Thailand's nominal price quota) was 441.8 USD/t in 2013/15, but is expected to be 1,014 USD/t in 2035.

Under Scenario 1, the food loss rate of rice in all eight ASEAN countries is expected to be reduced as compared with the baseline outlook from 2016 to 2035 average, because an increase in agricultural machinery and equipment can contribute to reducing the food loss rate of rice (Table 9). Rice yield is expected to increase as compared with the baseline outlook period (Table 9). World rice production is expected to increase by 0.8%, rice consumption by 0.7%, and world rice exports and imports by 1.9%, compared with the baseline outlook period (Table 9). Consequently, the international rice price is expected to decrease by 10.1%, compared with the baseline outlook period. Using Scenario 2, the food loss rate of rice in all eight ASEAN countries is expected to be reduced, compared with the baseline outlook period (Table 10).[11] World rice production and consumption are expected to increase by 0.1%, and world rice exports and imports by 0.3%, compared with the baseline outlook period. Consequently, the international rice price is expected to decrease by 1.0%, compared with the baseline outlook period.

The results of Scenario 3 show that the food loss rates of rice in Bangladesh, Sri Lanka, and Nepal are expected to be reduced as agricultural machinery and equipment that will help reduce the food loss rate of rice, and rice yields in those countries are expected to be increased, compared with the baseline outlook period (Table 11). Accordingly, world rice production and consumption are expected to increase by 0.2%, and world rice exports and imports by 1.2% (Table 11). Consequently, the international rice price is expected to decrease by 2.4%, compared with the baseline outlook period. The results of Scenario 4 show that the food loss rates of rice in

Table 8. World rice exports and imports (baseline outlook)

(Unit: 1,000 t)

	World Rice Production			World Rice Consumption		
	2013-15	2035	Growth rate per annum (2013/15-2035)	2013-15	2035	Growth rate per annum (2013/15-2035)
World	42,616	80,324	3.2%	39,524	80,328	3.6%
Thailand	10,183	14,126	1.6%	300	23	-12.1%
Vietnam	6,444	16,614	4.8%	367	319	-0.7%
Indonesia	0	2	-	1,358	11,740	11.4%
Malaysia	53	0	-	1,020	1,636	2.4%
Cambodia	1,017	1,264	1.1%	13	18	1.5%
Lao PDR	51	0	-	152	911	9.4%
Myanmar	1,691	4,263	4.7%	16	0	-
Philippines	0	0	-	1,533	17,344	12.9%
Bangladesh	10	10	0.0%	749	23,720	18.9%
Nepal	0	0	-	522	3,495	10.0%
Pakistan	4,083	8,484	3.7%	27	27	0.0%
Sri Lanka	5	0	-	306	977	6.0%
India	10,786	26,040	4.5%	0	100	-
China	329	1,255	6.9%	4,500	3,700	-1.0%
Japan	69	200	5.5%	664	768	0.7%
Korea	2	3	2.0%	416	219	-3.2%
USA	3,128	2,823	-0.5%	760	735	-0.2%
EU28	258	897	6.4%	1,662	2,299	1.6%
Brazil	783	0	-	591	1,730	5.5%
Cote d'Ivoire	57	0	-	1,117	2,384	3.9%
Egypt	350	1,435	7.3%	49	28	-2.8%
Nigeria	0	0	-	2,567	5,707	4.1%
Madagascar	0	0	-	320	678	3.8%
Rest of the world	3,317	2,908	-0.7%	20,515	1,770	-11.5%

Note: 1. Data for 2013/15 were actually derived from USDA-FAS, and data fir 2035 are projections.

2. Actual data are calculated by exportable domestic market balance.

3. The growth rates per annum for world rice exports and imports are different because 2013/15 data are actual data.

Table 9. Impacts on world rice markets, yields and food loss rates of rice in major rice-producing countries (Scenario 1/Baseline: 2016-2035 average)

	Changing rate		Changing rate (Unit:%)
Food loss rate (Unit: Point)		World rice production	0.8
Thailand	-0.6	Thailand	0.8
Vietnam	-0.6	Vietnam	4.6
Cambodia	-2.2	Indonesia	3.8
Indonesia	-0.3	Malaysia	3.2
Lao PDR	-1.9	Cambodia	18.1
Philippines	-0.1	Lao PDR	12.7
Malaysia	-0.6	Myanmar	10.3
Myanmar	-0.7	World rice consumption	0.7
Yield (Unit: %)		World rice export	1.9
Thailand	0.3	Thailand	1.2
Vietnam	5.0	Vietnam	15.5
Cambodia	13.8	Cambodia	50.7
Indonesia	4.0	Myanmar	48.5
Lao PDR	11.5	World rice import	1.9
Philippines	8.3	Indonesia	-16.2
Malaysia	2.8	Malaysia	-3.5
Myanmar	10.1	Lao PDR	-45.9
		Philippines	-11
		International rice price	-10.1

Table 10. Impacts on world rice markets and food loss rates of rice in major rice-producing countries (Scenario 2/Baseline: 2016-2035 average)

	Changing rate
Food loss rate (Unit: Point)	
Thailand	-0.6
Vietnam	-0.6
Cambodia	-2.2
Indonesia	-0.3
Lao PDR	-2.0
Philippines	-0.1
Malaysia	-0.6
Myanmar	-0.7
World Rice Market (Unit: %)	
World Rice Production	0.1
World Rice Demand	0.1
World Rice Import	0.3
World Rice Export	0.3
International Rice Price	-1.0

Table 11. Impacts on world rice markets, yields and food loss rates of rice in major rice-producing countries (Scenario 3 /Baseline: 2016-2035 average)

	Changing rate		Changing rate (Unit: %)
Food loss rate（Unit: Point）		World rice production	0.2
Bangladesh	-1.0	Bangladesh	1.8
Sri Lanka	-1.0	Sri Lanka	3.3
Nepal	-0.3	Nepal	16.2
Yield（Unit: %）		World rice consumption	0.2
Bangladesh	0.9	World rice import	-1.2
Sri Lanka	2.5	Bangladesh	-5
Nepal	3.7	Sri Lanka	-17.2
		Nepal	-56.2
		World rice export	-1.2
		International rice price	-2.4

Table 12. Impacts on world rice markets and food loss rates of rice in major rice-producing countries (Scenario 4 / Baseline: 2016-2035 average)

	Changing rate (Unit: Point)		Changing rate (Unit: %)
Food loss rate		World rice production	0.1
Bangladesh	-1.0	Bangladesh	1
Sri Lanka	-1.0	Sri Lanka	3.3
Nepal	-0.4	Nepal	12.1
		World rice consumption	0.1
		World rice import	-0.8
		Bangladesh	-2.4
		Sri Lanka	-17.5
		Nepal	-45.6
		World rice export	-0.8
		International rice price	-1.6

Bangladesh, Sri Lanka, and Nepal are expected to be reduced, compared with the baseline outlook from 2016 to 2035 average (Table 12).[12] As a result of reducing the food loss rates in these countries, world rice production and consumption are expected to increase by 0.1%, and world rice exports and imports are expected to decrease by 0.8% (Table 12). Consequently, the international rice price is expected to decrease by 1.6%, compared with the baseline outlook period.

Conclusion

The purpose of this study is to conduct simulations of how agricultural machinery and equipment investment covering storage facilities and agricultural machinery can impact the food loss rate of rice and the world rice market, by factoring in future climate change. Agricultural prices will increase as a result of demand growth when the supply is constant. The price increase can contribute to less food loss, as farmers and food processors/manufacturers try to reduce food loss to maximize their profits. On the other hand, when they increase storage facilities and harvesting machineries to reduce food loss, agricultural production will increase. As a result, agricultural prices will decrease when the demand is constant.

The simulation results suggest that a constant increase in agricultural machinery and equipment in the eight ASEAN countries will contribute to increasing rice yield, reducing the food loss rates of rice, and lowering international rice prices. The same investment increase in Bangladesh, Sri Lanka, and Nepal will also contribute to increasing rice yield, reducing the food loss rates of rice, and lowering international rice prices. The absolute value of the changing rate between baseline and scenario in Bangladesh, Sri Lanka, and Nepal was lower than those in the eight ASEAN countries. This study suggests that reducing the food loss rate of rice can contribute to coping with growing global rice consumption without increasing rice production. This study concludes that an increase in agricultural machinery and equipment investment in the eight ASEAN countries, Bangladesh, Sri Lanka, and Nepal would contribute to increasing not only rice yield but also reducing the food loss rate of rice, as rice consumption is growing and its production becomes increasingly affected by climate change. Consequently, policy makers should promote constant agricultural machinery and equipment investment not only to increase agricultural productivity but also to reduce the food loss of rice. This study examined the relationship between agricultural investment and the food loss rate of rice by utilizing estimated parameters. However, the author recognizes that this theoretical relationship is not good enough to be proved by this study. This analysis is the future direction of this study. This study applied specified climate change and macro assumptions to baseline and scenario outlooks. It needs to apply other climate change projections and macro assumptions to baseline and scenario projections as a future direction of study.

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Appendix

Table A1. Standard deviation of annual minimum and maximum temperature, and precipitation

	1980-1989 (Historical)	1990-1999 (Historical)	2000-2009 (Historical)	2014-2035 (Projection)
Minimum temp SD (Unit: Degrees C)				
Bangladesh	0.3062	0.3689	0.3221	0.5095
Sri Lanka	0.1958	0.2913	0.1433	0.5375
Nepal	0.2971	0.4750	0.1618	0.4839
Pakistan	0.2926	0.3781	0.2581	0.4390
Brazil	0.3348	0.2550	0.2393	0.7237
Cote d'Ivore	0.2302	0.2095	0.2408	0.4950
Egypt	0.2401	0.3917	0.2762	0.3753
Madagascar	0.4047	0.1974	0.1253	0.4081
Nigeria	0.3229	0.3109	0.3191	0.5311
Iran (Rest of the world)	0.5096	0.5474	0.2880	0.3850
Maximum temp SD (Unit: Degrees C)				
Bangladesh	0.2960	0.3720	0.3558	0.7175
Sri Lanka	0.2169	0.2270	0.1365	0.5791
Nepal	0.3539	0.4995	0.2974	0.5583
Pakistan	0.3320	0.4690	0.2791	0.6504
Brazil	0.3305	0.2698	0.2289	0.9514
Cote d'Ivore	0.1640	0.3182	0.1872	0.5427
Egypt	0.2879	0.3795	0.3197	0.5009
Madagascar	0.3841	0.1916	0.1381	0.4889
Nigeria	0.5403	0.3003	0.2402	0.5697
Iran (Rest of the world)	0.4842	0.7994	0.2551	0.7104
Precipitation (Unit: mm)				
Bangladesh	27.6214	23.5835	14.3066	41.4363
Sri Lanka	12.7729	12.5757	15.8752	41.0110
Nepal	13.1560	12.3685	9.9463	13.9828
Pakistan	7.5795	4.3688	3.2683	5.0552
Brazil	6.5906	6.9630	5.8853	10.9658
Cote d'Ivore	9.0298	7.4089	5.7243	7.5479
Egypt	21.9210	0.3936	0.2107	1.0848
Madagascar	0.2446	10.3299	6.6497	14.0392
Nigeria	2.1671	4.3871	7.0685	6.0274
Iran (Rest of the world)	3.0430	2.1956	2.1392	4.1529

Note: Historical data are derived from CRU TS 3.2 (CRU), Projection data are derived from MIROC RCP 4.5.

Table A2. Estimation of parameters (yield)

	Bangladesh	t statistics	Sri Lanka	t statistics (Year for dummy)	Nepal	t statistics (Year for dummy)	Pakistan	t statistics	Brazil	t statistics (Year for dummy)
a1, Minimum Temperature (t/t-1)	-0.2895	-1.5931	-0.5434	-0.9612	-0.1258	-0.4399	-0.5382	-0.9098	-0.3800	-0.7332
a2, Maximum Temperature (t/t-1)	0.0378	0.8572	1.0402	0.7604	-	-	1.5596	1.1855	1.3700	1.2208
a3, Precipitation(t/t-1)	-0.0045	-0.8562	-0.0624	-1.1695	0.0369	0.6462	0.0409	1.5639	0.1392	1.6684
a4, Land development (t-1/t-2)	0.8226	2.4469	1.2968	2.9147	1.1633	1.0694	-	-	-	-
a5, Agricultural machinery and equipment (t-1/t-2)	0.0312	1.8099	0.1590	0.6412	0.1274	1.0522	-	-	-	-
a6, Time trend (t/t-1)	0.0321	22.6376	0.1071	8.0967	0.2940	6.0741	0.2835	7.6170	0.0384	45.9159
Constant	-0.1221	-1.7390	0.9814	26.0454	0.0598	0.3833	0.2175	1.9840	0.3405	26.3056
Dummy 1	-	-	0.0968	2.4589 (1985)	-0.1258	-3.3033 (1992)	-0.0593	-1.1045 (1989)	-0.0525	-1.5813 (2002)
Dummy 2	-	-	0.0891	2.3358(1999)	-0.1161	-0.1161 (1994)	-0.0978	-2.2400 (2001)	-0.0792	-2.3188 (2004)
Dummy 3	-	-	-0.0876	-2.4216(2003)	-0.0802	-0.0802 (2006)	-	-	-	-
Sample	1982-2008		1983-2008		1991-2009		1988-2007		1980-2006	
R-squared	0.9793		0.8127		0.9309		0.9198		0.9916	
Adjusted R-squared	0.9712		0.7294		0.8869		0.8829		0.9890	
Durbin-Watson stat	1.7780		1.3695		1.3049		1.8484		1.8852	
	Cote d'Ivoire	t statistics (Year for dummy)	Egypt	t statistics	Madagascar	t statistics (Year for dummy)	Nigeria	t statistics (Year for dummy)	Iran	t statistics
a1, Minimum Temperature (t/t-1)	-1.8508	-1.3461	-1.1702	-1.7861	-1.0698	-1.2008	-0.3265	-1.6008	-0.3068	-0.8123
a2, Maximum Temperature (t/t-1)	-	-	-	-	-	-	-	-	-	-
a3, Precipitation(t/t-1)	0.5558	0.8382	0.1192	1.8489	0.0734	1.2360	0.1399	1.6618	0.0395	0.8182
a4, Land development (t-1/t-2)	0.8157	1.7558	0.1247	0.4864	0.8966	1.5576	0.3061	0.8511	1.3539	3.1555
a5, Agricultural machinery and equipment (t-1/t-2)	-	-	-	-	-	-	-	-	-	-
a6, Time trend (t/t-1)	0.0081	4.1779	0.0210		0.0268	10.0796	0.1427	6.4339	-0.1904	-2.7579
Constant	1.2172	28.3578	1.7579	42.6056	0.2631	4.3961	0.9932	17.6096	2.0008	9.5923
Dummy 1	-0.2178	-3.9529 (1988)	0.0118	0.3213(1991)	0.1308	2.0478(1992)	-0.2218	-3.3451(1988)	-0.2591	-0.2591(2000)
Dummy 2	0.1436	2.6308(1998)	-	-	-0.1237	-2.0786(2002)	-0.1291	-1.9749(2000)	-0.1217	-0.1216(2001)
Dummy 3	0.1681	3.1182(2003)	-	-	-	-	0.1113	1.6882(2003)	0.0858	0.0857(2002)
Sample	1986-2009		1990-2007		1989-2009		1982-2007		1996-2009	
R-squared	0.8478		0.9563		0.8981		0.8148		0.9464	
Adjusted R-squared	0.7499		0.9324		0.8544		0.7427		0.8607	
Durbin-Watson stat	1.5365		1.4704		1.0523		2.2215		2.8521	

Table A3. Estimation of parameters (planted area)

	Bangladesh	t statistics	Sri Lanka	t statistics (Year for dummy)	Nepal	t statistics (Year for dummy)	Pakistan	t statistics (Year for dummy)	Brazil	t statistics (Year for dummy)
a7, Domestic rice price(t/t-1)	0.0246	1.3504	0.0514	0.9422	0.2645	2.6265	0.1559	3.5838	0.1427	1.2498
a8, Domestic wheat price (t/t-1)	-	-	-	-	-0.1521	-1.4341	-0.1822	-4.1504	-0.1073	-0.8513
a9, Precipitation(t/t-1)	-0.0232	-0.9629	-0.0283	-0.4271	0.0957	1.0264	-0.0134	-0.6549	0.1151	0.4348
a10, Land Development (t-1/t-2)	0.5198	2.4578	1.8619	3.1837	1.2111	0.6716	0.9083	1.7275	0.4419	0.3178
a11, Time trend (t/t-1)	0.0081	9.4538	0.0094	7.1627	0.0181	4.3702	0.0142	14.9359	-0.0275	-12.0981
Constant	8.9877	88.517	6.4262	245.907	0.5660	6.0965	7.4658	46.929	8.7230	160.8212
Dummy 1	-	-	0.0991	2.0478(1992)	-0.1462	-1.9713(1994)	0.0655	2.0478(1992)	0.1688	1.7264(1986)
Dummy 2	-	-	-0.2389	-2.0786(2002)	-	-	-0.0808	-2.0786(2002)	-0.2161	-2.3003(1997)
Dummy 3	-	-	-	-	-	-	-	-	0.1909	2.1733(2004)
Sample	1990-2011		1985-2009		1981-2007		1985-2009		1983-2009	
R-squared	0.9007		0.8659		0.8384		0.9492		0.9184	
Adjusted R-squared	0.8610		0.8212		0.7899		0.9282		0.8822	
Durbin-Watson stat	1.5345		1.9467		1.5981		1.9864		1.7848	
	Cote d'Ivoire	t statistics (Year for dummy)	Egypt	t statistics (Year for dummy)	Madagascar	t statistics (Year for dummy)	Nigeria	t statistics (Year for dummy)	Iran	t statistics
a7, Domestic rice price(t/t-1)	0.5149	3.2817	0.2819	2.0266	0.0344	2.6478	0.3018	1.3060	0.1993	1.9932
a8, Domestic wheat price (t/t-1)	-	-	-0.0907	-0.8014	-	-	-0.4452	-1.8701	-0.1242	-1.2310
a9, Precipitation(t/t-1)	0.5149	3.2817	0.0388	1.8207	0.0081	1.9062	0.0739	0.8721	0.0618	0.9527
a10, Land Development (t-1/t-2)	0.4055	0.4126	0.6774	1.2648	0.2844	2.2661	-	-	-	-
a11, Time trend (t/t-1)	0.0253	4.8272	0.0174	5.2923	0.0031	6.4808	0.0637	13.1115	0.0092	3.9047
Constant	6.0180	73.0371	6.0186	83.190	7.0391	73.251	6.3303	77.2388	6.2087	14.4719
Dummy 1	-0.2949	-2.1982(1992)	-0.1187	-1.7197(1998)	-0.0480	-3.9696(1995)	-0.3222	-1.9655(1986)	-	-
Dummy 2	0.1123	0.9862(2000)	0.1317	1.8797(2000)	0.0201	1.6172(2007)	0.5097	3.0888(1989)	-	-
Dummy 3	-	-	-	-	-	-	0.3726	2.2553(1992)	-	-
Sample	1992-2011		1990-2008		1985-2008		1982-2007		1993-2014	
R-squared	0.8400		0.8821		0.8778		0.9340		0.7812	
Adjusted R-squared	0.7662		0.8071		0.8243		0.9029		0.7128	
Durbin-Watson stat	1.0988		1.5835		2.0126		1.4619		1.8795	

Table A4. Head rice yield

Countries/Region	Head rice yield
Bangladesh	0.6667
Brazil	0.6800
Cote d'Ivoire	0.6499
Egypt	0.6900
Madagascar	0.6400
Nepal	0.6659
Nigeria	0.6300
Pakistan	0.6666
Sri Lanka	0.6800
Iran	0.6600

Table A5. Estimation of parameters (per capita consumption)

	Bangladesh	*t statistics*	Sri Lanka	*t statistics (Year for dummy)*	Nepal	*t statistics (Year for dummy)*	Pakistan	*t statistics (Year for dummy)*	Brazil	*t statistics (Year for dummy)*
a12, Income; Per capita GDP growth ratio (t/t-1)	0.8771	3.7631	0.3438	1.3912	0.4806	1.7502	-0.4644	-1.7543	0.0498	1.3541
a13, Domestic rice price(t/t-1)	-0.3109	-2.3652	-0.0296	-0.4150	-0.0436	-0.4257	-0.1280	-1.3365	-0.0353	-1.0637
a14, Domestic wheat price(t/t-1)	0.1553	1.2524	-	-	0.0912	0.9047	0.3298	3.8525	0.0433	1.3070
a15, Domestic corn price(t/t-1)	-	-	-	-	-	-	-	-	-	-
a16, Time Trend (t/t-1)	-0.0837	-1.6550	0.0121	6.4505	0.0424	1.6351	-0.0179	-8.1941	-0.0109	-15.2721
Constant	1.8287	1.6938	4.4328	10.4971	4.5764	62.4788	3.3024	62.2916	4.0549	23.4561
Dummy 1	-	-	0.0663	1.0771(1991)	-0.1726	-1.9120(1994)	-0.3318	-4.4949(2005)	0.0788	2.8409(2004)
Dummy 2	-	-	0.1076	1.5877(2012)	0.1970	2.1375(2013)	-	-	-0.0360	-1.2740(2012)
Dummy 3	-	-	-	-	0.1622	1.7358(2014)	-	-	-	-
Sample	1991-2007		1990-2014		1982-2015		1992-2015		1990-2015	
R-squared	0.8294		0.8048		0.6446		0.8715		0.9361	
Adjusted R-squared	0.7725		0.7377		0.5458		0.8358		0.9159	
Durbin-Watson stat	1.6324		1.2520		1.4290		1.9644		1.3054	

	Cote d'Ivoire	*t statistics (Year for dummy)*	Egypt	*t statistics (Year for dummy)*	Madagascar	*t statistics (Year for dummy)*	Nigeria	*t statistics (Year for dummy)*	Iran	*t statistics*
a12, Income; Per capita GDP growth ratio (t/t-1)	0.1422	0.8409	0.1441	2.1030	0.1661	1.4862	0.0940	1.2441	0.1798	2.4357
a13, Domestic rice price(t/t-1)	-0.2719	-2.4183	-0.0649	-0.9673	-0.3643	-1.8991	-0.2237	-1.7319	-0.0729	-1.6723
a14, Domestic wheat price(t/t-1)	-	-	0.1829	2.7452	-	-	-	-	0.0099	0.5549
a15, Domestic corn price(t/t-1)	-	-	-	-	0.3229	1.9749	-	-	-	-
a16, Time Trend (t/t-1)	0.0286	12.5960	0.0065	3.9710	0.0020	0.8736	0.0177	6.4560	0.0815	6.0920
Constant	3.5485	67.7962	3.6079	89.1119	4.7748	90.3534	2.8198	43.4425	3.4619	87.9157
Dummy 1	0.4105	3.7665(1987)	-0.1770	-2.8921(1990)	-0.1319	-1.8796(1998)	-0.2219	-1.7753(1995)	-0.0782	-2.2232(1989)
Dummy 2	0.4229	3.8087(1989)	0.0713	1.2216(2000)	0.0840	1.0819 (2009)	0.2193	1.7279 (2011)	-0.1129	-2.9081(1990)
Dummy 3	-0.3009	-2.5579(2009)	-	-	0.0253	0.3661(1991)	-	-	-0.1272	-3.3979(1993)
Sample	1985-2015		1990-2015		1990-2014		1988-2015		1985-2014	
R-squared	0.8701		0.7810		0.7217		0.7494		0.8252	
Adjusted R-squared	0.8376		0.7118		0.5229		0.6924		0.7586	
Durbin-Watson stat	1.5696		1.4964		1.5534		1.4162		1.0671	

Table A6. Estimation of parameters (imports and exports)

	Pakistan	t statistics (Year for dummy)	Brazil	t statistics (Year for dummy)	Egypt	t statistics (Year for dummy)
a17, International Rice Price (t/t-1)	-0.7243	-3.6139	-0.1741	-0.4411	-0.9412	-1.0740
a18, Domestic Production (t/t-1)	-	-	-	-	-	-
a19, Domestic Rice Price (t/t-1)	-	-	-	-	-	-
a20, Time Trend (t/t-1)	0.0126	0.6856	0.0148	1.7444	-0.0807	-1.0583
Constant	2.9514	2.5184	6.1180	31.6449	5.8840	2.4916
Dummy 1	0.1999	3.7460 (2011)	-2.3283	-4.9250 (1985)	2.5670	3.9946 (2011)
Dummy 2	-0.5523	-3.3441 (2015)	0.9372	1.9679 (1986)	-0.9174	-1.3572 (2009)
Dummy 3	-	-	-2.4739	-4.3686 (1987)	-	-
Sample	2009-2015		1981-2015		2005-2014	
R-squared	0.8757		0.7670		0.7900	
Adjusted R-squared	0.6270		0.7174		0.6220	
Durbin-Watson stat	2.3334		1.3392		2.9558	

	Cote d'Ivoire	t statistics	Sri Lanka	t statistics (Year for dummy)
a21, International Rice Price (t/t-1)	0.7009	1.0088	2.2529	0.9912
a22, Domestic Production (t/t-1)	-	-	-	-
a23, Domestic Rice Price (t/t-1)	-	-	-	-
a24, Time Trend (t/t-1)	0.1297	3.1628	-0.1388	-1.2787
Constant	-0.8584	-0.6437	6.9470	1.9519
Dummy 1	-	-	-0.8770	-1.4151 (2013)
Dummy 2	-	-	-	-
Dummy 3	-	-	-	-
Sample	2009-2014		2009-2015	
R-squared	0.7821		0.6738	
Adjusted R-squared	0.6368		0.5600	
Durbin-Watson stat	2.8939		2.3148	

Table A7. Estimation of parameters (ending stocks)

	Bangladesh	t statistics	Sri Lanka	t statistics (Year for dummy)	Pakistan	t statistics (Year for dummy)	Brazil	t statistics (Year for dummy)
a25, Domestic rice price (t/t-1)	-0.0144	-0.5600	-1.8580	-4.3159	-0.4062	-0.5527	-	-
a26, Time Trend (t/t-1)	0.5250	1.9848	-1.1642	-4.7895	-0.1320	-5.9962	-0.0419	-4.8749
Constant	4.7401	6.7569	8.6343	12.0721	8.5315	-5.9962	7.8438	36.7638
Dummy 1	-1.0419	-2.3333 (2004)	-2.5592	-5.9416 (2003)	-1.3262	-5.1162 (1997)	-1.0183	-3.4053 (1997)
Dummy 2	-0.9985	-2.1623 (2005)	-	-	0.8233	3.1163 (1999)	-0.7617	-2.5523 (2001)
Dummy 3	0.6334	1.4023 (2010)	-	-	0.6221	2.3029 (2000)	-	-
Sample	1991-2011		1988-2010		1991-2002		1991-2014	
R-squared	0.6968		0.8246		0.9279		0.6761	
Adjusted R-squared	0.5669		0.7970		0.8677		0.6079	
Durbin-Watson stat	2.2230		1.4210		1.7043		1.7795	

	Cote d'Ivoire	t statistics (Year for dummy)	Egtpyt	t statistics (Year for dummy)	Nigeria	t statistics (Year for dummy)	Iran	t statistics (Year for dummy)
a25, Domestic rice price (t/t-1)	-1.4438	-4.0195	-0.3098	-0.7544	-0.3970	-0.8418	-0.2235	-1.0281
a26, Time Trend (t/t-1)	0.0423	3.4587	0.0344	2.2891	0.0577	3.8520	-0.0810	-10.5420
Constant	4.2723	13.1543	5.3096	12.7176	4.7780	12.1932	9.1703	45.6125
Dummy 1	-1.4602	-4.1126 (2009)	0.6777	1.7417 (2001)	1.1476	2.5061 (2002)	-0.3876	-1.7985 (2009)
Dummy 2	-	-	-1.6111	-4.2162 (2010)	-1.7887	-3.8154 (2009)	0.3448	1.5926 (2012)
Dummy 3	-	-	0.6932	1.7513 (2000)	-0.8049	-1.6630 (1994)	-	-
Sample	1995-2015		1996-2015		1993-2015		1995-2015	
R-squared	0.6840		0.6872		0.7046		0.8865	
Adjusted R-squared	0.6282		0.5428		0.6177		0.8581	
Durbin-Watson stat	1.5110		2.5219		1.3216		1.9046	

Table A8. Estimation of parameters (price transmission)

	Bangladesh	*t statistics*	Sri Lanka	*t statistics (Year for dummy)*	Nepal	*t statistics (Year for dummy)*	Pakistan	*t statistics (Year for dummy)*	Brazil	*t statistics (Year for dummy)*
a27, International Rice Price (t/t-1)	0.5289	*4.4997*	0.5521	*9.8835*	0.4834	*7.1712*	0.1191	*0.8735*	0.6619	*7.1606*
a28, Time Trend (t/t-1)	0.0018	*0.8935*	0.0026	*0.8295*	0.0225	*5.8378*	-0.0040	*-0.9369*	0.0654	*1.5435*
Constant	2.5119	*4.8664*	2.5568	*10.4359*	2.5683	*8.3285*	4.5963	*7.3077*	2.0814	*5.0939*
Dummy 1	0.2139	*1.5269 (1995)*	-0.2789	-3.2815 (2006)	-0.2707	-2.6377 (2000)	-0.1766	-2.6787 (2001)	-0.3119	-2.0532 (2000)
Dummy 2	0.3384	*2.4745 (2004)*	0.4285	*5.0320 (2008)*	-	-	0.0646	0.7577 (2002)	0.2804	1.7559 (2004)
Dummy 3	0.3678	*2.2613 (2004)*	-	-	-	-	0.0960	1.9985 (1997)	0.4223	2.7799 (2008)
Sample	1991-2014		1991-2004		1992-2014		1991-2002		1991-2014	
R-squared	0.7510		0.9229		0.9175		0.8886		0.8531	
Adjusted R-squared	0.6421		0.9066		0.9045		0.7957		0.8123	
Durbin-Watson stat	1.2613		2.0536		1.3945		1.4196		2.3241	

	Cote d'Ivoire	*t statistics (Year for dummy)*	Egypt	*t statistics (Year for dummy)*	Madagascar	*t statistics (Year for dummy)*	Nigeria	*t statistics (Year for dummy)*
a27, International Rice Price (t/t-1)	0.6541	*5.0923*	0.5865	*8.5863*	0.3879	*4.5566*	0.5436	*2.6301*
a28, Time Trend (t/t-1)	0.033548	*4.3992*	0.0106	*2.6788*	0.0251	*4.7060*	-0.0546	*-5.0621*
Constant	2.1130	*3.6950*	2.4499	*8.3339*	3.1669	*8.3499*	4.3570	*4.7761*
Dummy 1	0.3608	1.8511 (1993)	-0.3087	-3.0783 (1992)	0.4791	3.6819 (1993)	0.8024	2.8002 (1998)
Dummy 2	-0.3389	-1.8181 (1999)	-0.3097	-3.0536 (2009)	0.3502	2.7292 (1994)	-0.7551	-2.6476 (1999)
Dummy 3	-0.3660	-1.9641 (2001)	-	-	0.4126	3.2642 (2007)	-0.6360	-2.2304 (2000)
Sample	1991-2011		1992-2014		1991-2011		1991-2013	
R-squared	0.8620		0.9238		0.8675		0.7936	
Adjusted R-squared	0.8160		0.9069		0.8234		0.7162	
Durbin-Watson stat	1.8326		1.8136		2.3589		1.3034	

Table A9-1. Exogenous variables (per capita GDP growth rate)

	Average growth rate (2016-2035)
Thailand	2.7%
Vietnam	6.5%
Indonesia	3.6%
Malaysia	7.1%
Cambodia	7.0%
Lao PDR	8.0%
Myanmar	8.6%
Philippines	7.9%
India	7.7%
China	8.1%
Japan	1.1%
Korea	5.2%
USA	3.6%
EU27	1.8%
Bangladesh	6.5%
Sri Lanka	6.9%
Nepal	6.0%
Pakistan	5.4%
Brazil	1.6%
Madagascar	1.4%
Egypt	4.4%
Cote d'Ivoire	6.1%
Nigeria	0.9%
Iran (Rest of the world)	4.8%

Table A9-2. Exogenous variables (population and prices)

	Unit	2013/15	2020	2025	2030	2035
Thailand	1,000	67,712	68,581	68,637	68,250	67,442
Vietnam	1,000	92,417	98,157	102,093	105,220	107,773
Indonesia	1,000	254,429	271,857	284,505	295,482	304,847
Malaysia	1,000	29,899	32,374	34,334	36,107	37,618
Cambodia	1,000	15,328	16,809	17,944	18,991	19,988
Lao PDR	1,000	6,690	7,398	7,966	8,489	8,973
Myanmar	1,000	53,439	56,242	58,373	60,242	61,752
Philippines	1,000	99,137	108,436	116,151	123,575	130,556
India	1,000	1,295,280	1,388,859	1,461,625	1,527,658	1,585,350
China	1,000	1,369,333	1,402,848	1,414,872	1,415,545	1,408,316
Japan	1,000	126,784	125,039	122,840	120,127	117,063
Korea	1,000	50,072	51,251	51,982	52,519	52,715
USA	1,000	319,453	333,546	345,085	355,765	365,266
EU27	1,000	502,084	505,150	507,889	509,237	509,282
Bangladesh	1,000	159,077	170,467	179,063	186,460	192,500
Sri Lanka	1,000	20,619	21,157	21,417	21,536	21,546
Nepal	1,000	28,174	30,184	31,754	33,104	34,187
Pakistan	1,000	185,054	208,437	227,182	244,916	262,127
Brazil	1,000	206,062	215,997	222,976	228,663	233,006
Madagascar	1,000	23,577	27,799	31,728	35,960	40,450
Egypt	1,000	89,567	100,518	108,939	117,102	125,589
Cote d'Ivoire	1,000	22,160	25,566	28,717	32,143	35,857
Nigeria	1,000	177,498	206,831	233,558	262,599	293,965
International wheat price	USD/ton	271	217	237	237	237
International corn price	USD/ton	181	170	170	187	187