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Effects of Climate Change on Supply and Demand of Rice in Cambodia

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The objective of the study is to measure impacts of climate change on rice price and demand of rice in Cambodia under moderate emission scenario and high emission scenario, using supply and demand model of rice. The results show that yields of both wet and dry season rice and per capita consumption of rice under moderate emission scenario are higher than that under extreme climate change scenario, while rice price has the opposite trend. It can be concluded that climate change would affect marginalized groups of people in Cambodia. A well-established rice policy is necessary in Cambodia.

Key words: Representative Concentration Pathways (RCPs), Shared Socio-economic Pathways (SSPs), Rice price

1. Introduction

Many studies have shown that climate change affects crop yields. It has been found that yields decrease when temperature increases (Matthew et al., 1997). Parry et al. (2004) concluded that climate change leads to increases in crop yields in the countries in high and middle altitudes (mostly developed countries), but it decreases the yields in low altitude areas (developing countries). This means that Cambodia, one of developing countries, is among the countries where crop yields suffer from the changing climate.

Cambodia is among the top ten net rice exporters in the world ranked as number 6th after Thailand, Vietnam, India, Pakistan and Brazil respectively in 2011. However, Preechajarn (2006) mentioned it doesn't mean enough food is available for all Cambodians. Chronic child malnutrition, low body mass index and micronutrient deficiency especially for women are the problems to this country. Moreover, the poverty rate is high, accounted for up to 20.5% in 2013 (World Bank), which is the high rate comparing to the neighboring countries in Southeast Asia. As reported by World Bank, Cambodia's per capita GDP in 2009 is only 492 USD, the lowest rate comparing to neighboring countries, Laos, Vietnam and Thailand. With this low GDP, there's a huge gap between the high-income and low-income people. (Ministry of Planning, 2006) Meanwhile, the price of rice in Cambodia has been increasing, which mainly affects the marginalized groups of people. Maltsoğlu et al. (2010) indicated that rice prices in Cambodia have constantly increased between year 2000 and 2009. According to Preechajarn (2006), rice, which is the main staple food in Cambodia, contributes to the highest share of daily calorie intake, accounting for 70%. Thus, the increase in price of rice can affect food

security of some households in Cambodia. They also mentioned that although the increase in rice price seems to benefit the Cambodian people in general because households can be both consumers and producers, those without land ownership, accounting for about 4%, would suffer from the soaring rice price. They further emphasized that if the price increases by 10%, the welfare of landless poor household is lost at around 1.1%.

There have been quite a number of studies on effects of climate change on agricultural sectors over the world, but not many have focused on such a vulnerable country as Cambodia where a large number of people of more than 80% is highly dependent on the favor of climate for agricultural activities. (Trading Economics, 2014) In this regard, this study was conducted as an aid in climate change-related studies in Cambodian context.

This study aims to predict the effects of climate change on rice price and supply and demand of rice in Cambodia under RCP 4.5 and RCP 8.5 climate change scenarios incorporating socio-economic scenarios, SSP1 and SSP3 respectively.

2. Data and Methodology

In this paper, climate change is defined as changes in temperature, rainfall and solar radiation over a period of time. A supply and demand model of rice was employed to find out the equilibrium price of supply and demand of rice under climate change. First, functions of yields of wet and dry season rice, areas of wet and dry season rice, export of rice, stock change of rice and per capita consumption of rice were estimated using 2SLS (Two-Stage Least Square) method to eliminate endogeneity problem. Then, the system analysis was conducted to simulate the response of rice price to climate change in the next 20 years from the historical data, which is in the year 2030. The data of input prices such as fertilizer price and wage is not incorporated into the model because they are not available during the observation years. Furthermore, the data is short, so if input prices are included in yield functions, it will make the estimation difficult due to

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too many variables. In addition, yield functions include trend, which already covers the effects of plant breeding and the effects of fertilizers.

There are two important categories of variables in simultaneous equation models: endogenous and exogenous variables. Endogenous variables are defined as variables determined by economic model, while exogenous variables are determined from outside.

Furuya et al. (2008) used a supply and demand model of an agricultural product in their research to estimate the response of rice price under the changing water cycle in Cambodia. The factors used for calculating supply side are production, stock change and import functions. Production is dependent on yield and area, while demand side is influenced by population and GDP.

(1) Model

Assuming one of the factors affecting crop yield is climatic condition, yield functions were modeled incorporating climatic variables, including temperature, rainfall and solar radiation. In Cambodia, rice cropping is done mainly two times: in wet season from May to October and in dry season from November to April. Due to the small number of observations, climatic variable in one month is selected based on the flowering time of rice before harvesting. The flowering time of rice is September for wet season and March for dry season, so the climatic variable incorporated into the model was selected accordingly. Rain doesn't significantly affect yield of dry season rice because dry season rice cultivation is usually done based on the availability of irrigation rather than rainfall. Yield functions of wet season rice and dry season rice can be written as following.

Yield functions of wet season rice:

$$YW_t = a_{YW} + b_{YW1} \log T + b_{YW2} TEMP_{SEPT_t} + b_{YW3} RAIN_{SEPT_t} + b_{YW4} SOLAR_{SEPT_t} \quad (1)$$

Yield functions of dry season rice:

$$YD_t = a_{YD} + b_{YD1} \log T + b_{YD2} TEMP_{MARCH_t} + b_{YD3} SOLAR_{MARCH_t} \quad (2)$$

where YW_t is yield of wet season rice; T is time trend; $TEMP_{SEPT_t}$, $RAIN_{SEPT_t}$ and $SOLAR_{SEPT_t}$ are temperature, rainfall and solar radiation in September at time t respectively; $TEMP_{MARCH_t}$, $SOLAR_{MARCH_t}$ are temperature and solar radiation in March at time t respectively.

Lagged rainfall affects planted area of rice in wet season, so was included into the function of area of wet season rice. In addition, assuming adaptive expectation model, area functions of wet and dry season rice were modeled as follows:

Area functions of wet season rice:

$$AW_t = a_{AD} + b_{AW1} AW_{t-1} + b_{AW2} RFP_{t-1} / (CPI_{t-1} / 100) + b_{AW3} RAIN_{9_{t-1}} \quad (3)$$

Area functions of dry season rice:

$$AD_t = a_{AD} + b_{AD1} \log T + b_{AD2} AD_{t-1} + b_{AD3} RFP_{t-1} / (CPI_{t-1} / 100) \quad (4)$$

where AW_t and AW_{t-1} are planted area of wet season rice at time t and a year before respectively; AD_t and AD_{t-1} : planted area of dry season rice at time t and a year before accordingly. RFP_t and RFP_{t-1} are rice farm price at time t and one year before time t ; $RAIN_{9_{t-1}}$ is rainfall in September a year before time t ; CPI_{t-1} represents consumer price index a year before time t .

Identity of paddy production of wet season rice:

$$QW_t = YW_t AW_t \quad (5)$$

Identity of paddy production of dry season rice:

$$QD_t = YD_t AD_t \quad (6)$$

Total productions of rice (paddy and milled) are identities in the model, derived from the following equations.

Identity of total production of rice (paddy equivalent):

$$QT_t = QW_t + QD_t \quad (7)$$

Identity of production of rice (milled equivalent):

$$Q_t = 0.667 QT_t \quad (8)$$

where QW_t and QD_t are production of wet and dry season rice respectively; QT_t and Q_t are the total paddy production of rice and total milled rice at time t respectively.

Cambodia became a net rice exporter after 2003, so the export function can be estimated as following.

Export functions of rice:

$$EXP_t = a_{EXP} + b_{EXP1} Q_t + b_{EXP2} (WP_t * EXR_t) / (CPI_t / 100) + b_{EXP3} (RFP_t / (CPI_t / 100)) \quad (9)$$

where EXP_t is export of rice; WP_t is world rice price (Thai white rice 5% broken); EXR_t is exchange rate; CPI is consumer price index at time t .

Stock change functions of rice are influenced by the changes in production of rice and rice price at the ending and the beginning of the year. However, due to the small number of observations, only changes in production of rice at the ending and the beginning of the year was incorporated in stock change functions given as below.

Stock change functions of rice:

$$STC_t = a_{STC} + b_{STC1} (Q_t - Q_{t-1}) \quad (10)$$

where STC_t refers to stock change of rice; Q_{t-1} denotes total production of milled rice one year before time t .

Local supply of rice is derived from the sum of total production and imported amount of rice minus the exported amount, stock change and feed, seed and waste. The identity of supply of rice is as following.

Supply of rice:

$$QS_t = Q_t + IMP_t - EXP_t - STC_t - (Feed_t + Seed_t + Waste_t + Other_t) \quad (11)$$

where QS_t is a total supply; IMP_t is import of rice; $Feed_t$, $Seed_t$, $Waste_t$ and $Other_t$ represent the amount of rice used for feeding livestock for seed, losses during

transportation and storage and other usages respectively.

The factors affecting demand for rice are consumers' income, rice price and price of substitute good. In this study, maize is assumed to be a substitute good to rice. The model was built as following.

Demand functions of rice:

$$\begin{aligned} \log QC_t &= \log \frac{QS_t}{POP_t} \\ &= a_{QC} + b_{QC1} \log[RFP_t / (CPI_t / 100)] \\ &\quad + b_{QC2} \log[MFP_t / (CPI_t / 100)] \\ &\quad + b_{QC3} \log(GDP_t / POP_t) \end{aligned} \quad (12)$$

where QC_t is per capita consumption of rice; MFP_t maize farm price and POP_t is population at time t .

Supply and demand model of rice was employed to find equilibrium rice price in the future and the other endogenous variables considering the factors affecting demand part and supply part in the model. The flowcharts of production of rice and demand and supply of rice are given in Figure 1 and Figure 2 respectively.

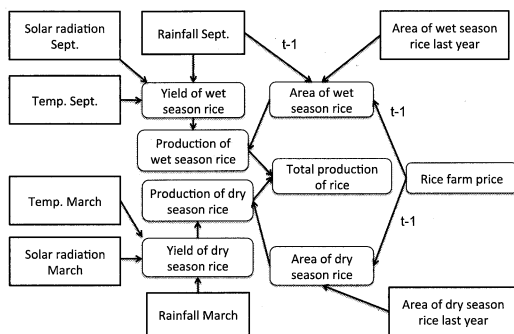


Figure 1. Flowchart of production of rice

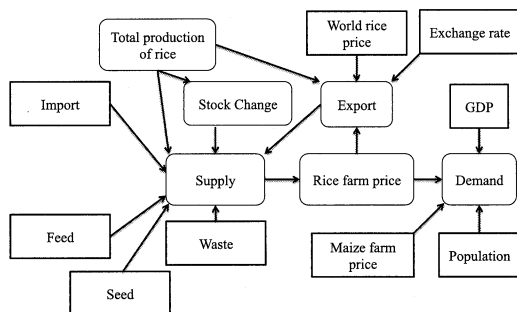


Figure 2. Flowchart of supply and demand of rice

(2) RCPs and SSPs Scenarios

In predicting impacts of climate change on supply and demand of rice in Cambodia in this study, two climate change scenarios were used (RCP4.5 and RCP8.5). They were incorporated with socio-economic scenarios, SSP1 and SSP3 respectively to give a more reliable prediction. RCPs are the new climate change scenarios developed in the 5th assessment report of the

IPCC (Intergovernmental Panel on Climate Change) for a more detailed information, exploration of the impact of different climate policies in addition to the no-climate-policy scenarios. RCPs were categorized into 4 levels – namely RCP8.5, RCP6.0, RCP4.5 and RCP2.6. RCP8.5 is described as a high emission scenario, rising radiative forcing pathway leading to 8.5 W/m^2 ($\sim 1370 \text{ ppm CO}_2 \text{ eq}$) by 2100, while RCP4.5 represents an intermediate mitigation scenario, stabilizing without overshoot pathway to 4.5 W/m^2 ($\sim 650 \text{ ppm CO}_2 \text{ eq}$) at stabilization after 2100. Shared Socio-economic Pathways (SSPs) contain a very large number of socioeconomic pathways that would represent various combinations of challenges to mitigation and adaptation. SSP1 is called sustainability scenario where the number of poor people in low-income countries is reduced with high awareness of environmental protection, while SSP3 represents fragmented world where there is a big gap between the regions. The combination of RCP4.5 and SSP1 are comparable to B1 scenario of SRES (Special Report on Emissions Scenarios) and RCP8.5 and SSP3 are comparable to A2 scenario of SRES.

(3) Data

Based on data availability, the time series data used in the estimation was annual observations from year 1996 through 2009. The data of rice farm price, maize farm price, imports, exports, stock variation, feed, seed, waste and other usages were collected from FAO-STAT. CPI, GDP, population, exchange rate and world rice price were derived from World Bank. Data on yields of wet and dry season rice and areas of wet and dry season rice were disseminated by Ministry of Agriculture, Forestry and Fisheries, Department of Planning and Statistics of Cambodia. Historical climatic data was taken from Data Distribution Center of IPCC and forecasted climatic data from year 2010 to 2030 under RCP 4.5 and RCP8.5 is the value of MIROC 5 (Model for Interdisciplinary Research on Climate), which is a GCM (General Circulation Model) of the University of Tokyo, NIES (National Institute for Environmental Studies) and JAMSTEC (Japan Agency for Marine-Earth Science and Technology). The forecasted exogenous variables of GDP and population data are shared socio-economic pathways (SSPs) of IIASA (International Institute for Applied Systems Analysis).

Explained variables are mainly divided into two parts: supply part and demand part. The supply part includes rice yield and planted area in wet and dry season. Furuya et al. (2008) used import functions in their models. Because of the changing status of Cambodia from a net importer to a net exporter after 2003 and export also affects the supply of rice in the country, it was chosen as an endogenous variable in the model. Another endogenous variable affecting supply part is stock change. On the demand part, the

endogenous variable is per capita consumption, so Endogenous variables in the models are *YW*, *YD*, *AW*, *AD*, *QW*, *QD*, *Q*, *EXP*, *STC*, *QC*, *RFP*, while exogenous variables include *CPI*, *EXR*, *WP*, *GDP*, *POP* and historical climatic variables comprising *TEMP9*, *RAIN9*, *SOLAR9*, *TEMP3* and *SOLAR3*.

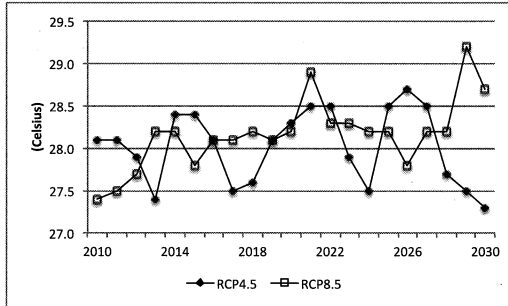


Figure 3. Forecasted temperature in September

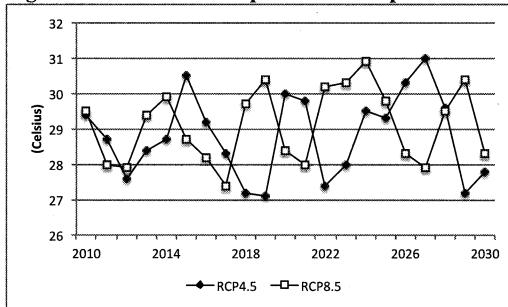


Figure 4. Forecasted temperature in March

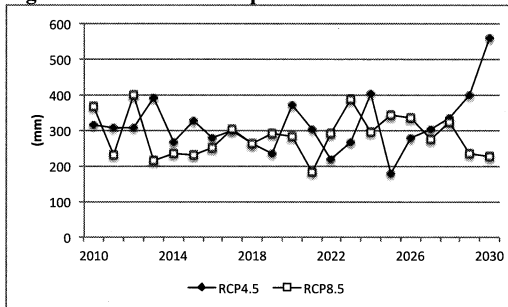


Figure 5. Forecasted rainfall in September

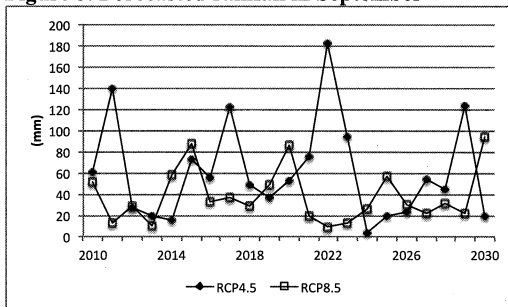


Figure 6. Forecasted rainfall in March

3. Results

(1) Estimation Results of Functions

Estimation results were derived using 2SLS method. Instrumental variables were used to eliminate endogeneity problem. Table 1 - 7 indicate the estimation results and elasticities of yield of wet and dry season rice, area of wet and dry season rice, export of rice, stock change and demand of rice respectively.

Table 1. Yield of wet season rice

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	-5.26	5.059	-1.04	
Log TREND	0.44**	0.088	4.96	
TEMP9	0.24	0.182	1.33	3.32
RAIN9	0.003*	0.001	2.63	0.43
SOLAR9	-0.08*	0.028	-2.82	-0.58
Dummy				
D96	0.65 ⁺	0.298	2.18	
D9900	0.52 ⁺	0.18	2.89	

Adj-R²: 0.81; Durbin Watson: 1.65

Signif. codes: 0.001***0.01**0.05*0.1+.

Table 2. Yield of dry season rice

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	5.95	2.58	2.31	
Log TREND	0.48***	0.06	7.83	
TEMP3	-0.23*	0.97	-2.31	-1.84
SOLAR3	0.15*	0.05	2.92	0.86
Dummy				
D99	1.01 ⁺	0.49	2.05	
D023	-0.39*	0.13	-3.00	

Adj-R²: 0.86; Durbin Watson: 1.82

Table 3. Area of wet season rice

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	62747	338904	0.19	
Lag AW9	0.73**	0.18	4.00	0.72
Lag RFP	0.33	0.42	0.79	0.088
Lag RAIN9	1134.66	713.17	1.59	0.17
Dummy				
D967	-257402 ⁺	140824	-1.83	
D05	267618 ⁺	122205	2.19	

Adj-R²: 0.78; Durbin Watson: 2.74

Table 4. Area of dry season rice

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	-236768	95226	-2.49	
Log TREND	134388*	47083	2.85	
Lag AD	0.37 ⁺	0.22	1.70	0.36
Lag RFP	0.09 ⁺	0.04	1.94	0.16
Dummy				
D9899	-29352**	9070.6	-3.24	
D03	-25062*	10355	-2.42	

Adj-R²: 0.96; Durbin Watson: 2.3

Table 5. Export function of rice

Coefficient	Esti- mates	Std. error	t- value	Elasti- city
Intercept	2393	6941	0.34	
Rice product	0.002*	0.001	2.38	1.63
World rice price	0.001 ⁺	0.0006	1.91	0.002
Rice farm price	-0.03 ⁺	0.014	-1.86	-2.60
Dummy D08	-8122 ⁺	4616	-1.76	

Adj-R²: 0.27; Durbin Watson: 1.64**Table 6. Stock change function of rice**

Coefficient	Esti- mates	Std. error	t- value	Elasti- city
Intercept	190619	50024	3.81	0.36
Changes in rice products	0.53*	0.19	2.74	
Dummy D04	452984*	174226	2.60	
D05	-534118*	247569	-2.16	

Adj-R²: 0.32; Durbin Watson: 1.40

R² values of export function and stock change function are low because Cambodia changes her position from rice importer to rice exporter quickly after year 2003.

Table 7. Demand of rice

Coefficient	Esti- mates	Std. error	t- value	Elasti- city
Intercept	8.72	1.003	8.69	
Log RFP	-0.43**	0.084	-5.09	-0.43
Log MFP	0.14**	0.028	5.11	0.14
Log GDP per capita	0.19**	0.042	4.58	0.19
Dummy D960	0.20	0.044	4.54	
D02	0.13	0.028	4.55	
D05	0.06	0.022	2.75	
D08	-0.03	0.023	-1.15	

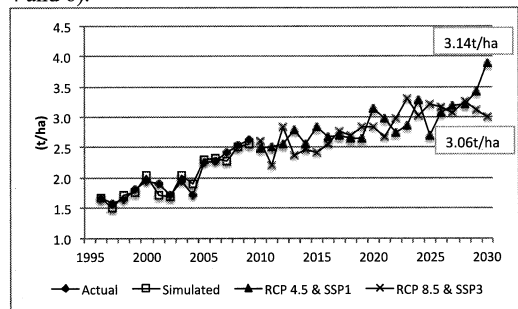
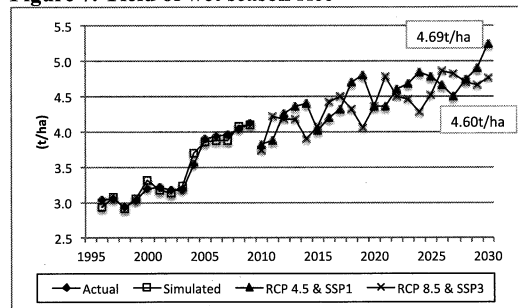
Adj-R²: 0.77; Durbin Watson: 1.63

According to Table 7, 10% increase in income would cause only 2% increase in demand for rice. If rice price increases by 10%, the demand for rice will decrease by 4.5%, but increase by 1.4% when maize price hits a 10% increase. Demand is inelastic to GDP per capita, implying that people will increase their rice consumption very slightly when their income increases. Maize price variable significantly affects the demand for rice, suggesting per capita consumption for rice increases with maize price. Some studies include only price of rice in the demand functions of rice. Including substitute goods to rice into the model may increase the accuracy of simulation, so this study assumes maize as the substitute goods to rice, incorporated into the model.

(2) Simulation Results

After each function was estimated using 2SLS method, system analysis of supply and demand model was conducted to observe the equilibrium price of supply and demand of rice in Cambodia. The forecasted data is from year 2010 through 2030. The simulated and forecasted results were derived from climatic data under two climate change and socio-economic scenarios: RCP 4.5 & SSP1 and RCP 8.5 & SSP3 scenarios.

Simulation results show that average yields of both wet and dry season rice under RCP4.5 & SSP1 scenario from year 2020 through 2030 (3.14t/ha & 4.69t/ha respectively) are higher than that under RCP8.5 & SSP3 scenario (3.06t/ha & 4.60t/ha respectively) as shown in Figure 9 and 10. However, they are predicted to be higher under RCP8.5 & SSP3 scenario at some particular years. This is because the temperature variable, which positively influences yield of wet season rice, is not significant and the temperature under RCP4.5 during those years is high as indicated in Figure 3. On the other hand, rainfall, which has higher value under RCP4.5 than RCP8.5 during those years (Figure 5), significantly and positively influence yield. Solar radiation, which is also a significant variable, has the opposite trend with rainfall value. Therefore, yield of wet season rice takes the trend of rainfall in September. The same case happens to yield of dry season rice. Rainfall variable, which positively influences yield of dry season rice, is not significant, while temperature and solar radiation significantly determine yield of dry season rice (Figure 4 and 6).

**Figure 7. Yield of wet season rice****Figure 8. Yield of dry season rice**

Per capita consumption of rice under RCP4.5 & SSP1 scenario is forecasted to be higher than that of RCP8.5 & SSP3 scenario. This is because forecasted GDP is higher under SSP1. According to Figure 9, average per capita consumption of rice under RCP4.5 & SSP1 scenario is 164.77kg, while that under RCP8.5 & SSP3 is 150.32kg in the last ten years of simulation period. It's also predicted that rice price would be higher under RCP8.5 & SSP3 (1.52 million riels) in comparison to RCP4.5 & SSP1 (1.36 million riels) in the same simulation period as indicated in Figure 10. This is consistent with the trend of per capita consumption of rice where there is more demand for rice under RCP4.5 & SSP1 comparing to RCP8.5 & SSP3 scenario.

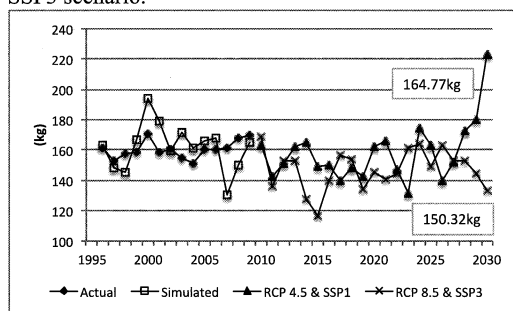


Figure 9. Per capita consumption of rice

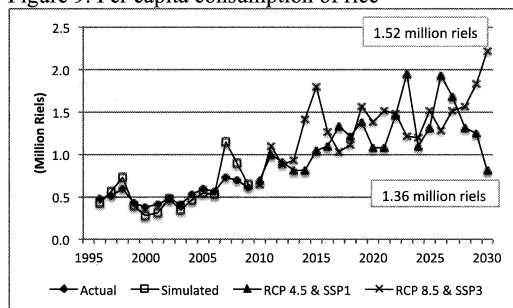


Fig.10 Rice farm price (1USD=4,000 riels in 2004)

4. Conclusions

Supply and demand model of rice was employed in the research to compare the impacts of climate change on rice price and the supply and consumption of rice in Cambodia under RCP 4.5 and RCP 8.5 climate change scenarios, incorporating SSPs. Much supply and demand-related research in the past has been conducted incorporating climatic variables in only yield functions. Furuya et al. (2008) mentioned that including climatic variables in area functions would produce better results. The simulation results show that the average per capita consumption of rice under RCP4.5 & SSP1 scenario is predicted to be higher than that under RCP8.5 & SSP3, while the price of rice would be higher under RCP8.5 & SSP3. The result suggests that climate change and economic progress would affect the marginalized group of people in

Cambodia, especially the net rice consumers. To ensure all people have an adequate access to rice, rice policy, which well specifies rice price ceiling and rice price floor, is necessary in Cambodia.

The available data is limited due to domestic wars in Cambodia. The limitations of this study can be seen in the number of data. Data is the important factor contributing to the accuracy of the simulation results. Thus, future research is suggested to try increasing the number of observations and incorporating more variables into the models.

Acknowledgement

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