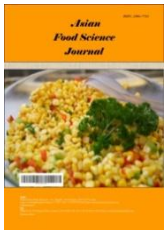

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Welfare Effect of Adaptation Policy for Rice Price Variation under Climate Change in Bangladesh

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Authors' contributions

Author MAS designed the main conceptual ideas, worked all of the technical details, implement the empirical analysis and made the write-up of this manuscript. Author JF contributed to verify the conceptual and analytical framework, the research results and provided constant support to accomplish this manuscript. Author SK helped to design the research ideas and provided constant support to write the manuscript. He also provided financial support to make proof reading of this manuscript. Both of them provided support and supervision for this research. All authors read and approved the final manuscript.

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ABSTRACT

This study was designed to evaluate the welfare effect of the climate adaptation policy for rice price variation in terms of producer surplus, consumer surplus, and net change in social welfare in Bangladesh, using the partial equilibrium model of the adaptation policy. The long-term trend of climate and policy adaptation for climate impact on price variation of the rice in Bangladesh is taken into economic model approach. The base period of this research is 1977-2009 and the extrapolation period is 2010-2030. To execute the designed analysis, the time series data from national and international organization are used. The results for the support price policy show that the total surplus that producers receive is equivalent to USD 1,164 million, substantially higher than the consumer surplus (USD 763 million) during the period 2010–2030. The net change in the social welfare owing to the support price policy is equivalent to –1483 million (USD) during the period 2010–2030. Moreover, analysis of the subsidized price policy shows that the total surplus that consumers receive (USD 1,958 million) is relatively higher than the producer surplus (USD 1,738 million) in the same period. The net change in social welfare owing to the subsidized price policy (–

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197 million USD) is much higher than that owing to price support –1483 million (USD). Implementing the dual price policy would result in a much higher net change in the society's welfare (–1185 million USD) compared to that possible through each policy separately. In conclusion, these adaptation and price stabilization policies are recognized to be more useful in mitigating the severe price rise and fall in the future food market, in favour of both producers and consumers. Even though the change in net social welfare is higher, the higher cost of policy budget is imperative to make stable food supply and security.

Keywords: Climate change; producer and consumer surpluses; procurement; public distribution; Bangladesh.

1. INTRODUCTION

Food policies and advanced technologies affect the productivity of rice producers, thereby improving producers' welfare through the positive effect. Despite technological advancements in crop productivity, climate change has been known to affect crop yields and market prices during the 21st century [1]. Instability of production and price variation are major features of food insecurity in Bangladesh [2,3,4], the former being attributed to climate vagaries.

Rice is a strategic commodity, political stability of the country, which depends on an adequate, affordable, and stable supply of rice [5, 6]. Each food crisis seems to stimulate a government and donor activities, aimed at increasing food production and providing better safety nets for the poor. The almost universal response is a shift in policy sentiment toward greater intervention by governments by increasing food production, lowering food prices, and providing more reliable access to food for poor households. All these interventions come at a cost [7]. Moreover, sharp increases in food prices lower the real income of poor people because they spend a large part of their income on food; as a result, households tend to have more limited access to health, educational services, and nutritious food, making them poorer and increasing their more food insecurity [8-11].

To achieve stable price for rice poses a great challenge in the context of transmission of shocks. Protecting the price of rice from negative consequences requires identification of the precise impact of price changes on welfare. A higher price has the potential to significantly affect household welfare in Bangladesh [12]. Many governments have made their efforts to stabilize commodity prices based on the common belief that households value price stability, and that the poor, especially, benefit from food price stabilization. Eliminating price volatility is indisputably increasing the welfare gains of household, making food price stabilization is a sense of a regressive policy in this context [13]. In the same fashion, the government of Bangladesh attempts to influence domestic market prices of foodgrain through limited procurement (2–4% of production) and distribution (2–7% of demand) [14]. The main goal of public food operation in Bangladesh is to stabilize price for achieving food security. The procurement is meant to boost producers' incomes through the absorption of excess market surplus by government, and the public distribution is intended to stabilize consumers' price variation through increasing the supply of food grain (FPP, 2015). Notably, the policy and institutional environments determine farmers' decisions on rice production and the overall transformation of the rice sector [5].

2. PUBLIC INTERVENTION

2.1 Public Distribution

Public food operation is not a new issue. It has a fairly long history. Public food distribution was first introduced in undivided Bengal in 1943 during the great famine due to disruption of food import from Myanmar and crop damage caused by the Second World War and fungus diseases, respectively [15]. Since its inception, the nature and functions of the public food system have evolved over the last several decades, finally resulting in the currently shaped public food distribution. At that time, it was called ration system. The then British government passed an order pertaining to foodgrain enquiry and control in 1943. Simultaneously, the Department of Civil Supplies set the statutory ration for urban areas, and in 1944, modified ration was initiated for rural areas (ibid). After the partition in 1947, rationing was retained in East Pakistan. Eventually, this rationing system was abolished, leading to the

introduction of the public food distribution system, which requires sufficient storage and procurement activities. In the 1960s, the government procured foodgrains from large-scale farmers at a fixed price as levy. However, during the 1970s, the levy system was replaced by voluntary sales to the government [13]. Public storage was built from domestic procurement and imports in order to meet public distribution needs. Public food distribution operations were expanded in the 1970s and underwent important changes in the early 1980s. Public storage capacity rose to 1.7 million tonnes until 1985 and spread throughout the country [7]. Public food distribution started decreasing in the 1990s after private traders were allowed to participate in food trade under trade liberalization in 1992. However, the government still plays an important role in food price stabilization.

Impacts of high food prices on consumers are a key motivation for public stabilization schemes in developing countries. During periods of high market price, a price stabilization policy for consumers and non-sale from public stock could be pursued. The government holds a fixed quantity of "emergency" stock and releases it to the market to keep prices from rising.

2.2 Procurement

Changes to public food distribution operations have been accompanied by several procurement-related modifications, and these have occurred over a fairly long time period. The National Food Policy Plan of Action was amended again in 2006 to emphasize support to producer prices and to ensure stable prices for consumers. In Bangladesh, this procurement program has not been compulsory since 1983. Compulsory procurement, in conjunction with cordoning and movement controls, became an instrument in the battle to control smuggling until the late 1970s. During the first big voluntary procurement drive, the Ministry of Food (MOF) procured food directly through temporary purchase centers (TPCs) by renting private warehouses and indirectly through approved grain dealers (AGDs). In the second procurement surge, which lasted until the early 1990s, the MOF relied on millers to procure paddy and mill it into rice. In theory, the millers are supposed to pay the government's procurement price to farmers and charge only a fixed milling commission. Since the late 1990s, the government began procurement at a fixed price that is close to the market price. The government decides the national fixed price of rice based on costs estimated by field surveys and announces the procurement price just before the harvesting period. Farmers voluntarily sell paddy during the announced period at the procurement centers on a first-come-first-served basis. Besides impacting the government budget, high procurement price (compared to the market price) increases costs for the government [16]. Therefore, procurement and food distribution are the major policy tools to implement the food price stability policy and to ensure national food security.

Understanding the objectives of public food operation is crucial. It increases government expenditure and impacts its budget [2]. The benefits of price stabilization for food producers and consumers, measured in terms of consumer and producer surpluses, are minimal. The major benefits of food price stability relate to the increase of household investment in productive activities rather than in stocking and heightened access to food for low-income households [17].

Therefore, the greater extent of productive investment in farm activities enhances the farm income and increase the access of food to consumers through cutbacking the price volatility. In addition, high rice prices reflect the need for the government to intervene even though this action can be very costly and ineffective [18,2]. It is strongly believed that price stabilization not only reduces the number of famine victims but also benefits consumers in Bangladesh [14,2,19].

However, a scanty of the previous studies in Bangladesh focus on the price change due to climate as well as welfare of the climate adaptation policy for rice price variation in the context of future climate change. In diminishing the impact of climate change on market supply and price variation, the government is supposed to implement the climate adaptation policy in an attempt to ensure national food security. The price stabilization policy might be one of the major climate adaptation steps to benefit both the producers and consumers in Bangladesh. Considering the context of climate impact, importance of policy measure and suitability of public budget utilization, The present study attempts to measure the welfare effect of the climate adaptation policy through the market price stabilization of rice in terms of the surplus, namely, "to what extent do the producers and consumers actually benefit in terms of welfare," in the context of future climate change.

3. METHODS

3.1 Model Framework

This study evaluates the social welfare effects of the adaptation policy for rice supply and expected consumption in the context of climate change, using a partial equilibrium model, a powerful tool used to estimate producer and consumer welfare. The policy adaptation framework is intended to maintain a smooth supply of rice in the future, as explained in Figs. 1 and 2. Moreover, Figs. 1 and 2 show the effects of climate change on rice supply and of policy adaptation, that is, reducing the negative effect of price fluctuation.

The supply of rice is calculated from data on yield and harvested areas, and the generalized forms of the supply and demand functions are as follows.

3.1.1 Supply function of rice

To estimate impact of climate change on rice production or supply, the relationship between rice area, farm price and climate variables was estimated based on a joint assumption of partial adjustment and adaptive expectations. However, separate yield and acreage functions are developed to capture the dispersion of yields and areas because rice yields and areas differ across varieties and seasons (Table A1-2) [20].

Then national supply function of rice is estimated from yield and areas which could be shown as functional form for simplification as seen below.

$$SSR_t = f_{SSR}(TREND, P_t, Z_t) \quad (1)$$

where SSR_t is the supply of rice in year t, and $TREND$ is the time trend used for the technological progress. P_t is the market price at which producers offer their products and consumers buy in the market, and Z_t is the climate variable that determines whether the supply is positively or negatively affected.

3.1.2 Demand function of rice

The demand function of rice is defined as below.

$$DDR_t = f_{DDR}(P_t, WRP_t, GDP_t / POP_t) \quad (2)$$

where DDR_t is the per capita consumption of rice in year t, and P_t is the price at which the consumer is willing to buy the rice. WPR_t is the market price of wheat, which is the main substitute for rice. GDP_t / POP_t is the per capita income, where GDP is the gross domestic product, and POP is the population in year t.

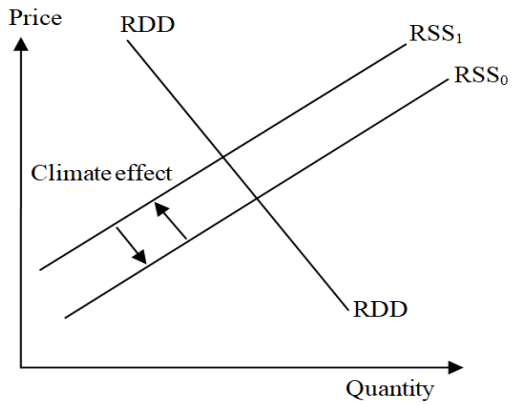

Fig. 1. Effect of climate change on rice supply

Fig. 1 shows the variation in the supply of rice, and thereby, affects the price and consumption. Fig. 2 shows that the supply curve shifts to the left, from RSS_0 to RSS_1 if rice production varies normally. The average normal variation of supply is "A," as indicated in Fig. 2.

However, because of the climate effect, the supply curve shifts further, from RSS_0 to RSS_2. The higher variation of supply is denoted by "B," and the price (P) increases to P_1. This high price negatively affects demand (RDD) and requires the government to implement an adaptation policy. If the government intend to reduce the variation of supply "C," with the public distribution to the lower the price to P_{ad1} in order to diminish the negative effect of climate change.

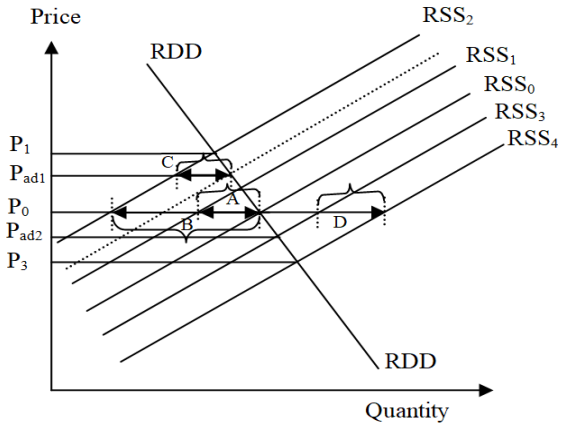

Fig. 2. Adaptation policy for reduction of price instability

Similarly, the government could pay support price P_{ad2} to the farmers during excess market supply, as indicated by the difference between RSS_3 and RSS_4. This study estimates the welfare effect due to the adaptation policy in terms of reducing price variations, measured as producer and consumer surpluses.

3.1.3 Procurement function

The government boosts the farm price by buying the surplus paddy from the market [2]. The government procurement function is given as follows:

$$GQR_t = f_{GQR}(QR_t, AVRP_t, P_t, PBES_{t-1}) \quad (3)$$

where GQR_{it} is the annual public procurement, and $AVRP_t$ is the support price fixed by the government. $PBES_{t-1}$ denotes the government's beginning stock. QR_t is national production of rice.

3.1.4 Public distribution function

The public distribution function is defined as below.

$$PDS_t = f_{PDS}(\Delta RPR_t, PDPR_t, PBES_{t-1}) \quad (4)$$

where PDS_t and $PDPR_t$ are the government distribution and subsidized price, respectively. ΔRPR_t is the change in retail price of rice in domestic market.

Since the 1990s, both the government and private traders have played a role in stabilizing consumer price in the market through imports [2]. The public import function is defined as follows.

3.1.5 Public import function

The public import function is estimated as below.

$$PBIMP_t = f_{PBIMP}(\Delta \sum_{i,v} QR_t, WPR_t, P_t) \quad (5)$$

where $PBIMP_t$ and $\Delta \sum_{i,v} QR_t$ refer to government import and change in domestic production, respectively. WPR_t is the world price of rice.

3.1.6 Public ending stock identity

The public ending stock identity is defined as follows:

$$PBES_t = PBES_{t-1} + GQR_t + PBIMP_t - PDS_t \quad (6)$$

where $PBES_t$ is the government ending stock.

3.1.7 Determination of market equilibrium

Market equilibrium is defined by

$$SSR_t + PDS_t = (DDR_t * POP_t) + GQR_t + IDDR_t \quad (7)$$

where $IDDR_t$ is the indirect demand for rice, created by export, seed requirements, feed requirements, processing, and so on. DDR_t is the per capita consumption of rice in year t.

The market price of rice in Bangladesh is upstream transmission where the farm gate price, which is influenced enormously by the retail price. Both farm gate and retail price were determined by supply and demand interaction [20].

3.1.8 Fiscal cost determination

Fiscal cost incorporates expenses pertaining to procurement and import, as well as the value of food distribution within a fiscal year, as follows:

$$FC_t = GQR_t * AVGP_t + PBIMP_t * (WPR_t * EXR_t) - PBDS_t * PDPR_t \quad (8)$$

Where, FC_t is the fiscal cost. $AVRP_t$ is the support price fixed by the government. $PBIMP_t$ refer to government import. $PDPR_t$ are the government distribution and subsidized price, respectively.

3.2 Data and Scenarios

Data on historical areas and yields were gathered from the Bangladesh Bureau of Statistics BBS, [21] for the period 1977–2009. In addition, the necessary data were collected from World Rice Statistics [n1], FAOSTAT [n2], and World Databank [n3]. Then, data on historical temperature, rainfall, and solar radiation were obtained from the Data Distribution Centre [n4] of the Intergovernmental Panel on Climate Change (IPCC). Forecasts on climatic variables from 2010–2030 were collected from Model for Interdisciplinary Research on Climate (MIROC5), General Circulation Model (GCM) of Japan for the period of 2010–2030. Forecasted GDP and population for the period 1977–2030 were derived from shared socioeconomic pathways (SSPs) of the AR5 in the IPCC scenarios. The IPCC's fifth Assessment Report (AR5) developed four Representative Concentration Pathways (RCPs), defined in terms of radiative forcing and

direction of change. However, we use RCP6.0, which characterizes the medium baseline mitigation stabilized at 6.0 W/m^2 (855 ppm CO_2eq) and the rapid economic growth in Asia. RCP6.0 results in a 2.0–3.7°C increase in temperature by 2100.

The Shared Socioeconomic Pathways (SSPs) Was developed in the consistent with the Representative Concentration Pathways (RCPs) to analyze interlinkage between climate change and socioeconomic factors, such as world population growth, economic development, gross domestic products (GDP) growth and technological progress.

IIASA (International Institute for Applied Systems Analysis) developed many combinations of the SSPs among them, the SSP2 was chosen to be consistent with RCP6.0 and represents intermediate challenges, in which population and GDP in developing countries increase moderately and environmental sustainability is a concern.

3.3 Estimation

Time-series data other than area, production, and prices, are stationary as their means and variances are almost constant over a period of time. For non-stationary variables, we use differences and time trends as explained variables. The procurement and distribution are subject to the constraints of public stock level. However, approximation of the procurement function is the truncated version with upper limit (U_t) of quantity procurement as per public storage capacity. Moreover, in Bangladesh, storage capacity for both rice and wheat does not exceed 1.7 million tons. Domestic production of wheat dramatically decreases as winters become shorter. Public import of wheat has also been very low in recent years. Annual procurement of food grain is maximally coded at $U_t = 1.7$ million ton. However, the latent variable can be declared for the truncated Tobit model of procurement and distribution, with the upper limit as follows:

[a]The following is the density of truncated standard distribution:

$$f(y_t) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(y_t - E(y_t))^2}{2\sigma^2}} = \frac{1}{\sigma}\phi\left(\frac{y_t - E(y_t)}{\sigma}\right), \alpha = \frac{U_t - E(y_t)}{\sigma}$$

[b]The log likelihood functions as follows:

$$lnL = \sum_{i=1}^{N} (\ln[f(y_t] - \ln[1 - \Phi(\alpha)])$$

$$y_t^* = f_{pm}(y_t \,|\, y_t \geq U_t) = \begin{cases} y_t if y_t < U_t \\ U_t if y_t \geq U_t \end{cases} \quad (9)$$

f_{pm} indicates the policy model (procurement and distribution). y_t^* is the latent variable for the procurement and distribution, respectively. Therefore, the Tobit model, which can consider truncation,[a] is applied to estimate the parameters of the procurement and distribution functions. Assuming that the latent variable of procurement and public distribution is normally distributed,

$$y_t^* \sim N[\mu, \sigma^2] \quad (10)$$

Then, the latent variable regression with the random error (ε_i) is conducted as follows.

$$y_t^* = X\beta + \varepsilon_i \quad (11)$$

The expected value of the latent variable model or mean (μ) is

$$E(y_t^*) = X\beta = \mu \quad (12)$$

Then, the empirical model for the estimation of the parameters of procurement and distribution with the application of the log likelihood function[b] is as follows:

$$E[y_t \,|\, y_t \geq U_t] = X\beta + \sigma\lambda(\alpha) \quad (13)$$

$$\lambda(\alpha) = \left[\frac{\phi[\frac{U_t - X\beta}{\sigma}]}{1 - \Phi[\frac{U_t - X\beta}{\sigma}]} \right]$$

where λ is the ratio of $\phi(.)$ and $\Phi(.)$, the standard normal distribution and cumulative density functions, respectively. X is the vector of the independent variables of the procurement and public distribution functions, and β is the vector of the parameters of the aforesaid functions.

The values of adjusted R^2 of all estimated functions range from 0.75 to 0.99, indicating sufficient goodness of fit. In addition, the estimated model is checked for the presence of auto-correlated error terms using Durbin–Watson (DW) *d* and *h* statistics. The values of the DW statistics range from 1.56–2.15. Therefore, the results of the parameter estimation are representative enough to explain the phenomenon of the prediction model. The

estimation period of the basic supply and demand model is 1977–2009. However, the policy model is based on data from 1994–2009 owing to data availability.

4. RESULTS AND DISCUSSION

The simulation results show that the coefficients of variation (CV) of yields and areas are higher in the future (i.e., for the projection data) under the RCP6.0 scenario than for the historical data. This higher variation implies that climate change impacts rice production in Bangladesh (see Fig. 3 and Table A4 in the appendix). Therefore, the fluctuation of seasonal climate variables leads to the unstable rice production and consequently, affects the market price of rice and per capita demand (see Fig. 4 and Table A5 in the appendix).

The public procurement and distribution activities can help the government of Bangladesh to support farmers and consumers during excess harvest as well as shortfall of rice.

The estimation results of the procurement function indicate that procurement is more responsive to domestic production and support price with high elasticities (Table 1), whereas public stock and subsidized price influence supply in the distribution function remarkably. Therefore, support price and the parameter (reaction intensity) of production are possible candidates for policy variables aimed at supporting farmers. On the other hand, the subsidized price of rice and the parameter of government stock are candidates for policy variables aimed at supporting consumers.

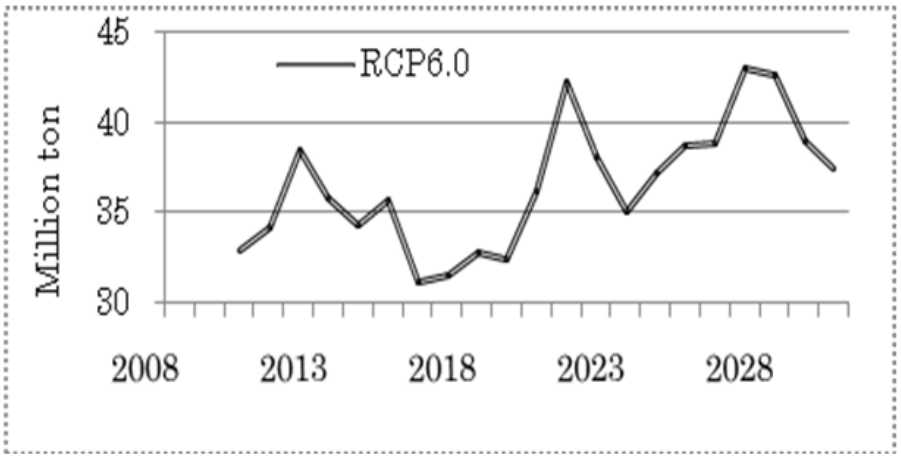

Fig. 3. Forecast supply of rice with the RCP6.0 climate scenarios

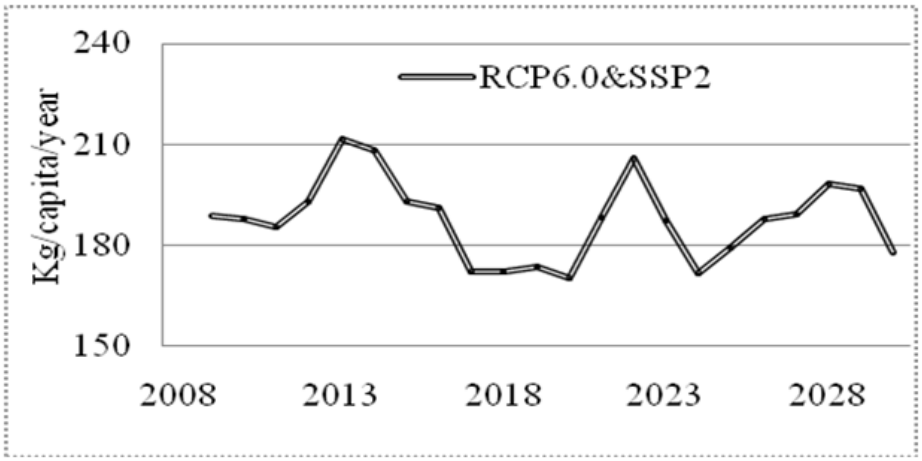

Fig. 4. Forecast demand of rice with the RCP6.0 and SSP2 scenarios

Table 1. Elasticities of procurement and distribution

Policy instruments	Estimates	Elasticities
Procurement		
Production	0.08	2.62
Support price	136.39	1.02
Beginning stock	–0.53	–0.33
Distribution		
Retail price change	23.33	0.002
Subsidized price	–129.96	–1.85
Beginning stock	0.274	0.14

Table 2. Policy efficiency index

	Variation index		Price index	
Procurement	Farm price	Retail price	Farm price	Retail price
Production	–0.05	–0.014	0.014	0.01
Support price	–0.28	–0.20	0.017	–0.028
Beginning stock	–0.07	–0.04	0.016	0.011
Distribution				
Price	0.47	0.54	0.094	0.093
Subsidized price	–0.50	–0.50	–0.01	–0.02
Beginning stock	–0.43	0.033	-0.00	–0.013

To derive more concrete decisions with regard to policy variables, we estimate the policy efficiency index [19], which calculates the extent of price variation or reduction in price per unit of additional budget for public food operation (Table 2). To obtain the index, the elasticities of price variations or prices with respect to candidates of policy variables (E_V), and the elasticities of necessary budget with respect to candidates of policy variables (E_B), are calculated by the following equations (as an example):

$$E_V = \left(\frac{V_{policy} - V_{base}}{V_{base}} \right) / \left(\frac{AVGP_{policy} - AVGP_{base}}{AVGP_{base}} \right) \quad (14)$$

$$E_B = \left(\frac{FC_{policy} - FC_{base}}{FC_{base}} \right) / \left(\frac{AVGP_{policy} - AVGP_{base}}{AVGP_{base}} \right) \quad (15)$$

where the subscript *policy* refers to the policy variables, the subscript *base* denotes variables not pertaining to policy, V is the coefficient of variation of price, $AVGP$ is value of the policy variable candidate, and FC is the necessary budget for public food operation. The policy efficiency index can be calculated as

$$E_{VB} = \frac{E_v}{V_B} \quad (17)$$

where E_{VB} is the policy efficiency index.

To derive the impacts of climate adaptation policy on the producers and consumer surplus for future supply and demand under the scenarios RCP6.0 and SSP2, consider the following example.

In Fig. 5 where, P_0 is the market price and PB is public distribution with the subsidized price (P_{CS}) during a market supply shortage and when the rice is priced high, so as to save the consumers from famine. GP is the government purchase (Q_{PS}) with the support price (P_{PS}) during excess market supply, in order to encourage the producers to continue rice production. The consumers are supposed to receive the additional benefit (aP_0cP_{CS}) and the producers also benefit ($abP_{PS}P_0$) from the adaptation policy (see Fig. 5).

The weight loss is indicated by the triangle abc in Fig. 5 which lessen the total welfare. Under this policy, the producer and consumer surpluses are expressed as follows.

Producer surplus ($\sum_{t=1}^{n} \Delta PS$) =

$$\sum_{t=1}^{n} [Q_0 * (P_{PS} - P_0) + \frac{1}{2} \{ (Q_{PS} - Q_0) * (P_{PS} - P_0) \}]$$

Consumer surplus ($\sum_{t=1}^{n} \Delta CS$)=

$$\sum_{t=1}^{n} [Q_0 * (P_0 - P_{CS}) + \frac{1}{2} \{ (Q_{CS} - Q_0) * (P_0 - P_{CS}) \}]$$

Thus, the total benefit provided by the adaptation policy is

$$\sum_{t=1}^{n}\Delta TSB=\sum_{t=1}^{n}\Delta PS+\sum_{t=1}^{n}\Delta CS$$

where ΔTSB is total welfare change obtained by the summation of the producer and consumer surpluses owing to the adaptation policy for reducing price variation.

The net change in social welfare under the climate adaptation policy is

$$\sum_{t=1}^{n}\Delta NBS=\sum_{t=1}^{n}\Delta PS+\sum_{t=1}^{n}\Delta CS-\sum_{t=1}^{n}\Delta FC-\sum_{t=1}^{n}DWL$$

where ΔNBS is the net change in the social welfare and $\sum_{t=1}^{n}DWL$ is dead weight loss in consequence of the implementation of the adaptation policy.

According to Table 2, the support price is the most efficient for farmer support, and the subsidised price is the most efficient for consumer support. Thus, we adopt the support price and subsidized price as policy variables. Similarly, to examine the effects of the support price policy as a special policy on producer and consumer welfare, we apply an average support price that is 60% higher than the baseline. Once this policy is implemented in the simulation, the producer surplus (USD 1,164 million) is substantially higher than the consumer surplus (USD 763 million). Moreover the net social welfare, which is obtained by subtracting the fiscal cost and deadweight loss from total surplus, is equivalent to –1483 million (USD) (see Fig. 6).

To examine the effects of the subsidized price policies on social welfare in the same fashion, we also apply 75% higher subsidy for rice distribution to consumers in order to mitigate the extreme price rises.

The result shows that total consumer surplus (USD 1,958 million) in the period 2010–2030 is relatively higher than total producer surplus (USD 1,738 million). Eventually, this policy contributes to the net change in social welfare amounting to –197 million (USD), due to deadweight loss, which is much lower than due to the price support policy (USD 1,312 million). Implementing this adaptation policy requires a much higher amount of additional public stock (1.50 million tons), which exceeds the level of the current public ending stock. This is one of the biggest limitations of this policy. As mentioned earlier, the public stock is mainly satisfied via procurement and import, but recently, imports have been limited (less than 1 million tons). Therefore, only one subsidy policy is not likely to benefit producers and consumers simultaneously (see Fig. 7).

To examine the effects of both policies, we assume that each policy is implemented separately in future outlook. This is because the support and subsidized adaptation policies are implemented separately, and each discriminates substantially against either the producers or the consumers surplus.

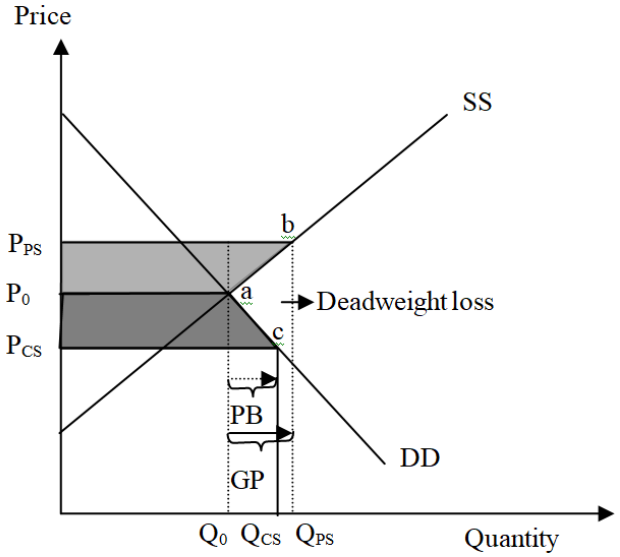

Fig. 5. Producer and consumer surpluses owing to the policy

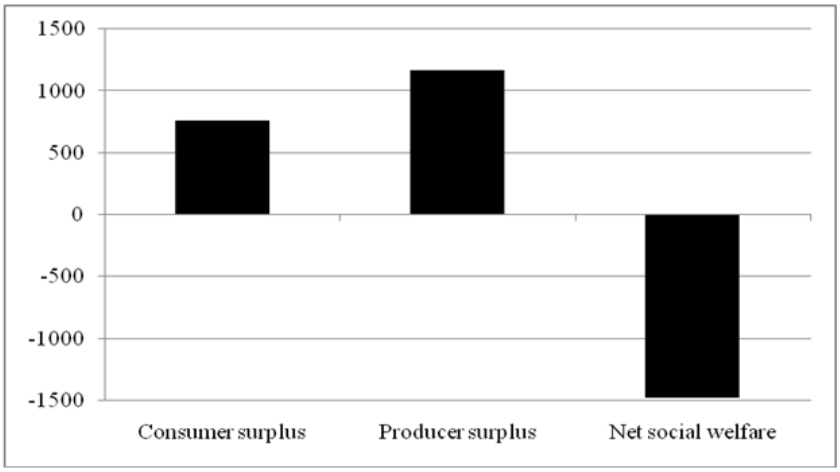

Fig. 6. Welfare effects of the adaptation policy with regard to price support in the period 2010–2030

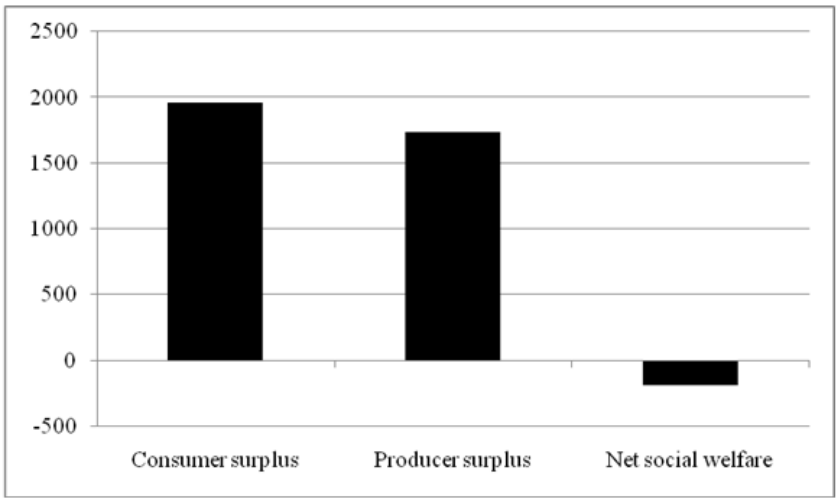

Fig. 7. Welfare effect of the adaptation policy as part of the subsidized price policy in the period 2010–2030

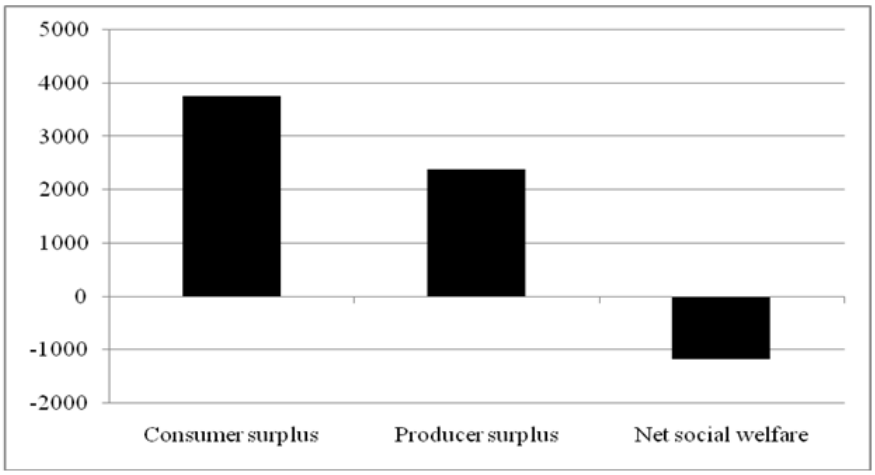

Fig. 8. Welfare effect of the adaptation policy in the dual price policy in the period 2010–2030

On the other hand, as Fig. 6 shows, extended support price for procurement excessively mitigates the price fall in favour of producers, but it does not provide significantly improved benefit to the consumer.

These results imply that to mitigate both price hikes and falls due to climate change, it is necessary to establish a dual policy covering support price and subsidized price. Then, we apply a dual policy, which includes price support for the farmers as well as subsidized price for the consumers. Once the dual price policy is integrated into the simulation, we note a net change in social welfare (worth –1185 million (USD)) that the deadweight loss is much higher compared to that obtained from individual policy implementation (see Fig. 8). Even though the higher deadweight loss and difference in the magnitude of the surplus remains significant, the dual policy dramatically increases the surplus for both producers and consumers.

5. CONCLUSION

This study focused on the effects of the implementation of the adaptation policy in an attempt to reduce the variation in the price of rice due to climate change, and to measure the welfare effect in terms of net change in social benefit. The policy framework is integrated into the supply and demand model in order to evaluate its performance in terms of producer and consumer surplus in the context of future climate change.

We examine the effects of the adaptation price policies as special policies pertaining to producer and consumer welfare, and find that implementing the support price policy creates a producer surplus of USD 1,164 million, which is substantially higher than the consumer surplus (USD 763 million). In addition, the net social welfare is equivalent to –1483 million (USD) in the period 2010–2030.

Furthermore, the result shows that if the subsidized price policy is implemented, the total consumer surplus (USD 1,958 million) in the period 2010–2030 is relatively higher than the producer surplus (USD 1,738 million). Eventually, this policy contributes to a net change of–197 million (USD) in social welfare, which is substantially high compared to that possible through the price support policy (–1483 USD million). However, implementing this adaptation policy would require a considerably higher amount of additional public stock (1.50 million tons), which is considered to be one of its biggest limitations. Therefore, only one policy, the subsidized price policy, is not enough to benefit producers and consumers alike. These results imply that to mitigate both price hikes and falls due to climate change, the government needs to implement a dual policy, which covers support price and subsidized price. Once the dual price policy is integrated into the simulation, we observe a net change of USD –1185 million (USD) in social welfare and the deadweight loss is much higher than that obtained from the separate implementation of each policy. Even though the findings indicate the higher deadweight loss and a lingering difference in the magnitude of the surpluses, the dual policy significantly increases the surpluses for both producers and consumers. These policies are expected to be more suitable compared to other adaptation policies, and implementing them will help secure a stable food market in the future

To adjust the market price variation during the course of climate change, as an alternative proposed policy, public allocation for technology development of rice production and readjustment for the input subsidy to adapt climate shock as alternative policies.

This research only considered the short-term climate impact on price variation of rice in domestic market and price variation of rice due to climate in world market and neighbouring country is beyond this piece of study. Major limitation of this study is partial equilibrium model. It did not consider the sectorial interaction on price variation in the economy. The future research might focus on the long term prediction of climate impact, world market and inter-sectorial interaction on price variation of rice in Bangladesh.

SUPPLEMENTARY MATERIALS

Supplementary material is available in the following link:

1. International Rice Research Institute, World Rice Statistics.
   Accessed on 02 January 2016.
   Avaialable: http://irri.org.
2. Food and Agriculture Organization, FAOSTAT, FAO Statistical Database.
   Accessed 01 January; 2016.
   Available: http://apps.fao.org/default.jsp.
3. World Bank, World Databank.

Accessed 01 Ja+nuary /2016.
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http://databank.worldbank.org/data/home.aspx.
4. DDC of IPCC, Historical Climate Data. Accessed on 01 January 2016. Available: http:// www.ipcc–data.org.

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COMPETING INTERESTS

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APPENDIX

Table A1. Estimates of yield functions

Yield	Trend	Climate variables		AdjR^2 DW
AuM	(1994)	Tmp05	Rf07	0.88
	0.06***	–0.09***	–0.0003**	1.77
	(12.18)	(–4.92)	(–2.40)	
	[0.14]	[–1.42]	[–0.08]	
AuL	0.017***	Rf04		0.91
	(15.26)	0.0005***		2.18
	[0.29]	(2.75)		
		[0.06]		
AmM		Tmp10	Sr10	0.89
	0.02***	–0.09***	–0.003**	1.65
	(10.84)	(–3.76)	(–2.64)	
	[0.15]	[–0.90]	[–0.91]	
AmL		Tmp07	Rf10	0.86
	0.01***	–0.10***	0.0003***	1.73
	(10.02)	(–2.95)	(2.81)	
	[0.15]	[–2.28]	[0.05]	
BoM		Rf03	Rf04	0.93
	0.04***	–0.004***	0.002***	1.60
	(12.4)	(–3.22)	(3.97)	
	[0.28]	[–0.05]	[0.09]	
BoL		Tmpo4	Tmp11_1	0.85
	0.02***	0.14***	0.07**	1.90
	(9.53)	(3.42)	(2.14)	
	[0.44]	[2.47]	[1.10]	

****, **, and * indicate significance at 1, 5, and 10%, respectively. Values in ( ) and [ ] indicate t-vales and elasticities, respectively*

AuM =Aus Modern, AuL=Aus Local, AmM =Aman Modern, AmL=Aman Local, BoM =Boro Modern, BoL=Boro Local

Table A2. Estimates of area functions

Area	Trend	Area (*t*–1)	Price (*t*–1)	Climate variables (*t*–1)		Adj. R^2 DW
AuM				R11_1		0.93
		0.70***	6.6***	–1095***		2.37
		(12.56)	(2.70)	(–5.14)		
		[0.69]	[0.10]	[–0.06]		
AuL	***			Rf04_1	Rf05_1	0.99
	–28372	0.31*	27.3**	334**	-222**	1.79
	(–3.25)	(1.76)	(2.18)	(2.09)	(-2.11)	
	[–0.32]	[0.32]	[0.13]	[0.03]	[-0.04]	
AmM				Rf10_1	Rf11_1	0.99
	30139**	0.74***	51.4**	515**	1654*	2.14
	(2.22)	(5.42)	(2.32)	(2.25)	(1.70)	
	[0.24]	[0.71]	[0.18]	[0.04]	[0.02]	
AmL				Rf05_1		
	–43769*	0.59***	109.9**	915**		0.98
	(–1.68)	(4.14)	(2.41)	(2.28)		2.28
	[–0.16]	[0.61]	[0.18]	[0.05]		

Area	Trend	Area (*t*–1)	Price (*t*–1)	Climate variables (*t*–1)		Adj. R^2 DW
BoM				Rf08_2	Rf10_2	0.99
	36034**	0.73***	36.30*	336**	900***	2.50
	(2.42)	(6.86)	(1.57)	(2.03)	(4.05)	
	[0.25]	[0.69]	[0.11]	[0.05]	[0.06]	
BoL		0.68***	4.34	Rf01_1		0.98
		(9.26)	(1.42)	–2113*		1.95
		[0.69]	[0.12]	(–1.82)		
				[–0.04]		

****, **, and * indicate significance at 1, 5, and 10%, respectively. Values in ( ) and [ ] indicate t-vales and elasticities, respectively*

AuM =Aus Modern, AuL=Aus Local, AmM =Aman Modern, AmL=Aman Local, BoM =Boro Modern, BoL=Boro Local

Table A3. Estimates and elasticities of demand functions

Equation	Constant	Variable estimate	Variable estimate	Variable estimate	Adj.R^2 DW
Demand	229***	RPR_t	PPW_t	GDP_t/POP_t	0.75
(per capita)	(9.68)	–0.005***	0.004***	–0.002	2.18
		(–4.32)	(2.82)	(–1.52)	
		[–0.48]	[0.23]	[–0.13]	

****, **, and * indicate significance at 1, 5, and 10%, respectively. Values in ( ) and [ ] indicate t-vales and elasticities, respectively*

Table A4. Coefficients of variation (%) of seasonal yields and areas from 2010–2030

Season	Variation (%) in RCP6.0			
	Yield		Area	
	Modern	Local	Modern	Local
Aus	9.3	9.7	15.0	13.9
Aman	8.7	8.2	2.6	10.2
Boro	14.7	13.6	2.7	13.9

Table A5. Coefficients of variation (%) of supply, market price, and consumption from 2010–2030

Variables	Historical	RCP6.0 and SSP2
Supply of rice	7.1	9.3
Farm price	21.5	25.5
Retail price	27.0	30.5
Consumption	4.5	6.5

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