Chapter 4

Economic Evaluation and Climate Change Adaptation Measures for Rice Production in Vietnam Using a Supply and Demand Model: Special Emphasis on the Mekong River Delta Region in Vietnam

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4.1 Background

Of the countries most affected by the impact of climate change between 1999 and 2018, Vietnam ranked sixth when factors such as monetary losses, mortality, and frequency of extraordinary climatic events are considered (Eckstein et al. 2020). The agricultural sector is one of the most susceptible to climate change because crop production is directly influenced by climate conditions. Rice is the staple food in Vietnam and, as of 2018, 65.3% of crop production in the country was dedicated to rice cultivation (General Statistical Office of Vietnam, GSO 2020). Flooding and saline intrusion due to sea level rise (SLR), as well as droughts associated with El Niño events, have caused serious problems in the country in the past, and these events have the potential to adversely affect rice production in the future (Lasco et al. 2011; Nhung et al. 2019). Surplus rice can be exported and sold on the global rice market, and Vietnam was the second largest rice exporter and fifth largest producer in 2020 (United States Department of Agriculture, Production, Supply and Distribution, USDA PS&D 2020). Consequently, the effects of climate change on rice production in Vietnam can affect the global rice market. Measures such as shifting transplanting dates, introducing irrigation systems, improving irrigation efficiency, using short-duration and salinity- or thermo-tolerant cultivars have been adopted as adaptation measures to tackle climate change (Masumoto and Tada 2008; Yu et al. 2010, 2013; Shrestha et al. 2014; Trinh et al. 2014). Adaptation is

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complicated by the fact that the effects of climate differ by region; for example, saline water intrusion, drought, flooding, and coastal erosion are the main issues affecting the Mekong River Delta region, while drought is a serious problem in the northern mountainous areas (Trinh et al. 2014). Thus, the development of adaptation measures needs to consider these differences and target specific regions. Investigating the effect of climate change on rice production and the rice market after the introduction of appropriate adaptation measures in each region can be evaluated economically using a supply and demand model (Furuya and Meyer 2008).

The supply and demand model considers yield, planted area, exports, imports, stock changes, and food demand functions of rice. From these functions, supply and demand equilibrium prices can be estimated and the outlook of future rice production and equilibrium prices can be assessed. Inserting climate variables, such as temperature or evapotranspiration into yield and planted area functions, facilitates projections of the effect of climate change on rice production and the market. With these projections as a baseline, rice production and equilibrium prices can then be estimated, and adaptation measures can be implemented based on different scenarios. These methods facilitate analyses based on quantitative values and allow managers to consider adaptation measures that are appropriate for each region. In the next section, we will introduce the concept of the supply and demand model for rice in Vietnam. In Sect. 3, we will demonstrate the economic evaluation methods used to develop adaptation measures in response to climate change using this model. In Sect. 4, we will examine extant adaptation measures and problems for farmers in the Mekong River Delta, which is the main agricultural production region in Vietnam. Finally, we will consider future research prospects.

4.2 Supply and Demand Model with Climate Variables

Market equilibrium is the basic concept of the supply and demand model. The relationship between price (P) and quantity (Q) is shown in Fig. 4.1. The intersection between the supply and demand curves is the equilibrium price. If production is reduced due to climate change, then the price will increase, all things being equal. On the other hand, if the personal income of consumers increases and consumption increases, then prices will increase. The equilibrium price is thus determined based on a balance between the production of farmers (supply) and consumption by consumers (demand). The supply curve can be shifted through technological advancement or large-scale agricultural development (Fig. 4.1), and these would cause the price to decline. In addition to consumer behavior, price reduction can also be affected by trends in exports and/or imports to/from other countries. Thus, the influence of these factors agricultural markets can be assessed using the supply and demand model. In this model, the planted area function with farm prices as explanatory variables can be regarded as a supply function, and the food demand function with farm prices can be regarded as a demand function. The equilibrium prices can be estimated by convergence using the Gauss-Seidel iterative method. By

Fig. 4.1 Concept of supply and demand curve and equilibrium price

simulating the equilibrium price with historical value, medium- and long-term projections of crop production, export, import, and food demand can be estimated (Furuya and Meyer 2008; Furuya 2020).

The flowchart in Fig. 4.2 shows the relationships between supply and demand and climate variables, such as evapotranspiration. Furuya et al. (2010) described the functions and explanatory variables used in the model. The supply and demand rice model can be applied to a country by dividing rice production, which is estimated based on yield and planted area, into distinct regions within that country. When the model is applied to the world, then the supply and demand model needs to consider the main producing and consuming countries and how they are linked to individual countries (see Ishikawa-Ishiwata and Furuya (2021a) for a description of the global supply and demand model).

In the supply and demand rice model, income (GDP) and population can be treated as exogenous variables and rice consumption per capita (kg/person) can be estimated. The amount of rice production (metric tons, MT) can be determined from yield (MT/ha) and planted area (ha). At least 20 years of historical data are needed for the analysis because the model is a historical statistical model. Historical yield, planted area, stock changes, exports and imports, food demand, domestic farm prices, GDP, GDP deflator, population, and the exchange rate can all be obtained from the USDA and Food and Agricultural Organization Corporate Statistical Databases (FAO-STAT). The consumer price index (CPI) can be obtained from the World Development Indicator (WDI) and the global price of rice can be obtained from the World Bank (WB). Provincial yield and planted area can be obtained by GSO.

By measuring the yield and planted area function with climate variables, such as evapotranspiration, the effect of climate change on rice production can be estimated. The solution derived from the model is the baseline. Figure 4.3 indicates the baseline results estimated by the supply and demand model. Evaluations considering climate change adaptation measures can be conducted by incorporating the scenario data into the baseline simulation. Of the many measures that have been proposed to

Fig. 4.2 Flowcharts of the rice production sector (a) and supply and demand sector (b) in the Vietnamese rice model. ET: evapotranspiration. Source: Furuya et al. (2010) with permission of the publisher

mitigate climate change, changing the cultivars is the most practical solution for farmers (Lasco et al. 2011). Here, we will explain the economic evaluation method used to assess the introduction of new cultivars as an adaptation measure.

Fig. 4.3 Production of spring rice in Vietnam (a) and Mekong River Delta (b).

Source: updated Furuya et al. (2010)

4.3 Economic Evaluation of Climate Change Adaptation Measures Using a Supply and Demand Model for Rice

Vietnam rice production has been boosted through the adoption of high-yield cultivars (Kien et al. 2020). Consequently, short duration and salinity- or thermo-tolerant cultivars are considered to play an important role in maintaining the stability of rice production within the context of climate change adaptation measures (Trinh et al. 2014). Detailed functions and an economic evaluation are described in Ishikawa-Ishiwata and Furuya (2020) and Ishikawa-Ishiwata and Furuya (2021a, b), who examined the introduction of new cultivars with a supply and demand model. Here, we describe the scenarios for the introduction of new cultivars. First, detailed historical data should be collected for the region of interest because the local environment should be considered to determine whether the new cultivar has been accepted by local consumers (e.g., factors affecting changes in the taste or appearance). Based on information on the background of why the new cultivar is needed in the region, the year it was developed, time-series changes in the planted area of the cultivar, and changes in production costs (especially the cost of fertilizer and/or pesticide for the new cultivar), a new technology dissemination model (Griliches 1957) is incorporated into the scenario. The reason why farmers require the new cultivars (e.g., adaptation to high temperatures and saline water intrusion) should also be incorporated into scenario projections to provide robust quantitative forecasts of crop production within the context of climate change. In the case of yield projection at higher temperatures, inserting the crop model into the yield function is effective. However, when considering the intrusion of saline water, actual damage should be investigated by field surveys in the scenario setting.

An economic evaluation for the introduction of the new cultivar should then be conducted based on a survey of the production costs. Comparing the planted areas of the new and previous cultivars, economic evaluations of the introduction of the new cultivar can be performed by comparing the production cost from the projection of scenarios.

4.4 Actual Farmer Adaptation Measures in the Mekong River Delta

We have described the economic evaluation of adaptation measures for climate change by considering supply and demand. However, since rice farmers in the Mekong River Delta have been changing their farming systems, these shifts should be considered by the model. In the planted area function for rice in the supply and demand model, lagged planted area, farm price of rice and/or substitute goods need to be considered (Ishikawa-Ishiwata and Furuya 2020). In addition, climate variables, such as evapotranspiration, have been used as explanatory variables (Furuya et al. 2010). In the case of the Mekong River Delta, the farming system is complicated, and hence appropriate substitute goods should be considered. Here, we divided the delta into two major regions, the coastal to central regions of the Mekong River Delta, and the backswamp in the Mekong River Delta areas based on the farming systems used in these regions.

In coastal areas, the main type of farming is shrimp aquaculture in brackish water, and rice is not cultivated. In central regions of the Mekong River Delta, the main type of farming is rice farming-shrimp aquaculture using brackish water, and farmers utilize the saline water that has intruded into this region during the dry period effectively. During the rainy season, this saline water is flushed from the aquifer and sediments by rain water, which enables farmers to cultivate rice in the rainy season. In the backswamp regions of the Mekong River Delta, double- and triple-cropping of rice have been conducted (Japan International Cooperation Agency, JICA 2013). Additionally, climate change issues differ between regions; saline water intrusion during the dry season occurs in the coastal to the middle parts of the Mekong River Delta and flooding occurs during the rainy season in the backswamp areas of the Mekong River (JICA 2013). Consequently, the main countermeasures enacted by the government differ between areas (Table 4.1). Constructing dikes and introducing short-duration cultivars can make it possible for rice farmers to perform double- and triple-cropping of rice in the flood-prone backswamp areas,

Table 4.1 Problems facing rice farmers in the Mekong River Delta and farmers' adaptation measures. Source: Cuc et al. (2008); JICA (2013); Paik et al. (2020)

Main problems	Government adaptation measures	Farmers' adaptation measures	Region
Saline water intrusion	Construction of sluice gates	- Shifting crop farming to aquaculture-based farming. - Introducing salinity tolerant crop cultivars	Coastal to central areas of the Mekong River Delta
Flood	Construction of polder-dikes	- Adopting short-duration crop cultivars to enable early harvest. - Optimizing the crop calendar according to the inundation period	Backswamp areas in the Mekong River Delta

such as in An Giang Province (Fig. 4.4), one of the top rice-producing provinces in the Mekong River Delta; these measures have boosted the rice production in Vietnam (Kien et al. 2020). According to local people, the construction of dikes and the subsequent alleviation of floods allowed farmers to increase the input of fertilizers.

However, while this increase in fertilizer input has enabled local farmers to perform triple-cropping, the soil quality has deteriorated and the amount of fertilizer required to sustain these levels of productivity has increased annually (Nguyen et al. 2018; Tran et al. 2018). In addition to the increased input of fertilizers, pesticide application increased three- to six-fold during 2000–2015 and this has had the effect of increasing production costs (Kien et al. 2020). The low price of Vietnamese rice is a key factor explaining its dominance on the global rice market, and increases in production costs combined with increases in fertilizer input will make it difficult for the country to maintain its global dominance. Such considerations are not only important for export from Vietnam, but also for the importing countries. In addition, increased rice production costs would adversely affect rice farmers, who may turn to aquaculture if their income decreases. Thus, the area under rice cultivation may decrease and this could lead to a reduction in the production of rice in Vietnam that is in excess of the possible reduction in yield due to climate change.

In general, official publicly available statistical data, such as FAO-STAT, USDA, and GSO data, are used in the supply and demand model. Due to the different types of farming systems employed in the Mekong River Delta, application of the model should be carefully considered. For example, according to local people in Soc Trang Province, which extends from the coast to the central region of the Mekong River Delta, mono-cropping of rice has shifted to shrimp aquaculture in coastal areas and double-cropping of rice has shifted to triple-cropping in the inland areas. Although the area under rice cultivation has increased and decreased as styles of farming have changed, the planted area has been stable from 1995 to 2019 (Fig. 4.4). Based on a

Fig. 4.4 Annual rice (upper row) and aquaculture (lower row) production in Kien Giang, An Giang, and Soc Trang provinces. Source: GSO. Note: the vertical axis for aquaculture in An Giang Province differs from that for the other provinces

report published by the Sub-National Institute of Agricultural Planning and Projection (Sub-NIAPP), extensive areas of rice paddies will be converted to brackish water aquaculture due to saline intrusion by 2050 (JICA 2013). This implies that the area under rice cultivation will be reduced significantly in the future. Since the selection of farming systems by farmers varies and affected by profit, competition or changing farming systems based on profitability and risks should be considered by managers when allocating areas to rice cultivation using the supply and demand model in the future.

4.5 Lessons Learned

The climate change adaptation measures required for continued rice production in Vietnam have been investigated in terms of technology, such as by adopting short-duration or salinity-tolerant cultivars. However, farmers not only adopted new technology but also changed the farming systems. For example, rice farmers have shifted to aquaculture-based farming in the coastal and central regions of the Mekong River Delta. Farming systems are expected to change further due to saline intrusion caused by climate change in the future. Considering the actual farmers' situation and a variety of scenarios, practicable evaluations can be conducted in each region. The effect of the area under cultivation on the profitability of different farming systems can be complemented with more practical simulations in the future.

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