Agricultural Investment Impact on Global Rice and Wheat Markets under Climate Change

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PREFACE

There is growing consensus about global warming and that our planet will continue to warm up as the concentration of greenhouse gases increases in the future. Climate change will have severe impacts on food production and food security in vulnerable countries and regions. The agriculture sector is particularly vulnerable to the negative impacts of climate change. Therefore, effective adaptation options with supportive policies to enhance the stability of food availability and reduce climate risk for food systems are urgently needed to mitigate the negative effects of climate change. This book examines how agricultural investments will impact global wheat and rice markets under climate change in the long term. These markets were examined by partial equilibrium models. The baseline projection results show that the volatility of international wheat and rice prices will increase in the next two decades, due to climate change impacts. Simulation studies show that constant increases in agricultural investments in major producing countries will stabilise international wheat and rice prices. In this book, a simulation study examines the role of agricultural investment growth in decreasing food loss, using a partial equilibrium model, and finds that agricultural investments play a crucial role in alleviating climate change risks in the global wheat and rice markets. The author hopes this book will help readers understand the role of agricultural investments in coping with future climate change risks. The views expressed in this book are those of author and do not reflect the official view of the Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries (PRIMAFF).

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CHAPTER 1

INTRODUCTION

There is a growing consensus about global warming and that our planet will continue to warm up as the concentration of greenhouse gasses increases in the future (IPCC, 2013). The working group I (WG I) of the Intergovernmental Panel on Climate Change (IPCC) Six Assessment Report (AR6) was released in August 2021. It examined the physical science underpinning past, present, and future climate change. According to WG I report, each of the last four decades has been successively warmer than any decades that preceded it since 1850. Global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 (0.84 to 1.10) °C higher than 1850–1900. It is likely that human influence contributed to the pattern of observed precipitation changes since the mid-20th century and extremely likely that human influence contributed to the pattern of observed changes in near-surface ocean salinity. Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades (IPCC, 2021).

The working group II (WG II) of the IPCCs AR6 report was also released in February 2022. It assessed the vulnerability of socio-economic and natural systems to climate change, negative and positive consequences of climate change and options for adapting it. According to WG II report, climate change has already had diverse impacts on human systems, including on water security and food production, health and well-being, and cities, settlements, and infrastructure. Climate change will increasingly put pressure on food production and access, especially in vulnerable regions, undermining food security [1] and nutrition (high confidence). At 2°C or higher global warming level in the mid-term, food security risks due to climate change will be more severe, leading to malnutrition and micro-nutrient deficiencies, concentrated in Sub-Saharan Africa, South Asia, Central and South America and Small Islands (high confidence). Effective adaptation options, together with supportive public policies enhance food availability, stability, and reduce climate risk for food systems while increasing their sustainability (medium confidence) (IPCC, 2022). Lobell et al. (2011, 616-620) examined that global maize and wheat yields declined by 3.8-5.9%, respectively, between 1980 and

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[1] The 1996 World Food Summit adopted a more complex definition and refined it in the world Summit on Food Security in 2009: Food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meets their dietary need and food preferences for an active and healthy life (FAO, 2009).

2008. Agricultural production will thus be affected by this climate change in different ways, including changes in yield and harvested area. Furthermore, agriculture is one of the most vulnerable sectors to be impacted from future climate change. Therefore, effective adaptation options with supportive policies to enhance food availability, stability and reduce climate risk for food systems are urgently needed to mitigate the negative impact from climate change.

The global prevalence of undernourishment jumped from 8.0 to 9.3 percent from 2019 to 2020 and rose at a slower pace in 2021 to 9.8 percent. Between 702 and 828 million people were suffering from hunger in 2021 (Fig.1-1).

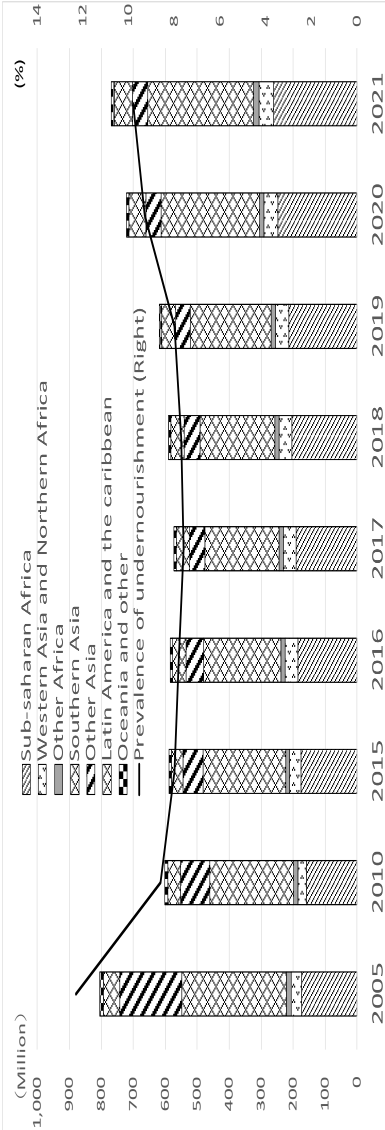

Fig 1-1. Number of Undernourished people and prevalence of undernourishment

Source: FAO et al. (2022).

The number has grown by about 150 million since the outbreak of the COVID-19 pandemic, 103 million more people between 2019 and 2020, and 46 million more in 2021 (FAO et al., 2022).

The prevalence of undernourishment in the Sub-Saharan Africa region accounted for 23% of the world's total number of undernourished people in 2021. The number of hungry people in the world has been increasing, particularly since 2018, and the current trend is not on track to achieve the Sustainable Development Goals (SDGs) target 2.1; *End hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030.* There is real concern that future climate change will exacerbate the current global huger crisis. The volatility of food prices in recent years, particularly that of international cereal and soybean prices, has hurt millions of people, undermining both nutritional status and global food security. After remaining at historic lows for decades, food prices have increased significantly, and have become more volatile since 2007 (Fig.1-2).

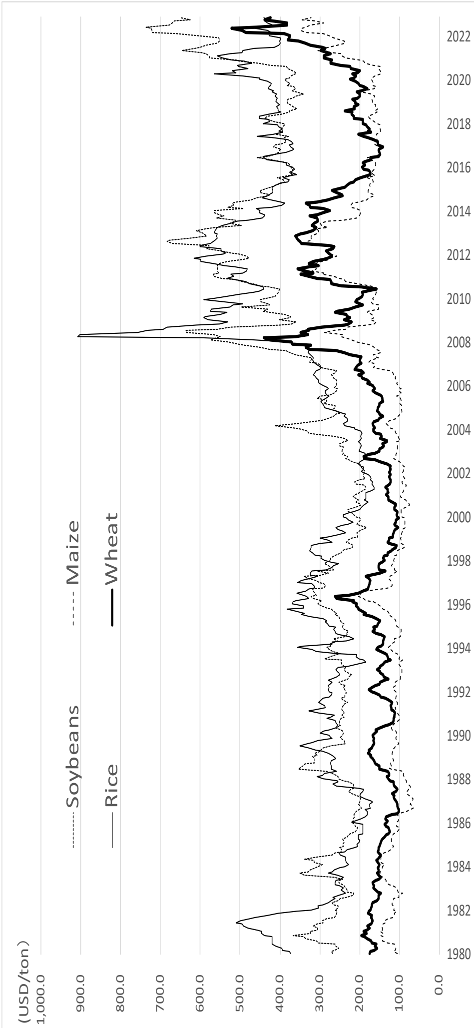

Fig 1-2. International cereal and soybean prices, in normal terms

Source: World Bank (2022).

Note:

1. Wheat (U.S.); no. 2 hard red winter Gulf export price; June 2020 backwards, no. 1, hard red winter, ordinary protein, export price delivered at the US Gulf port for prompt or 30 days' shipment;
2. Maize (U.S.); no. 2, yellow, f.o.b. US Gulf ports;

3. Rice (Thailand); 5% broken, white rice (WR), milled, indicative price based on weekly surveys of export transactions, government standard, f.o.b. Bangkok;
4. Soybeans; from January 2021, U.S Gulf Yellow Soybean #2, CIF Rotterdam; December 2007 to December 2020, U.S. No. 2 yellow meal, CIF Rotterdam; previously US origin, nearest forward.

Price volatility has a strong impact on food security in developing countries (FAO, 2011). The coefficient of variation (CV) for international wheat price was 0.1664 from 1985 to 1995, 0.2425 from 1996 to 2005, 0.2645 from 2006 to 2015[2], and 0.3724 from 2016 to 2022. The CV for international rice price was 0.1913 from 1985 to 1995, 0.2310 from 1996 to 2005, and 0.2548 from 2006 to 2015[3], therefore, the volatilities of wheat and rice prices are an increasing trend. FAO (2011) concluded that agricultural investments could reduce food price volatility through increased productivity and improved technical management of production risk, especially in the face of climate change.

Technological changes in agriculture as influenced by investments in agricultural research, irrigation, roads, and other factors are also essential (Rosegrant et al., 2001, 1-224). Yuize (1979, 111-172) demonstrated that agricultural land and investments were decided by Gross National Products, agricultural price index, and other factors in the case of Japan. Based on previous studies, agricultural investment variables can be affected by agricultural commodity prices and GDP growth rates in the long term.

[2] Calculated from the monthly wheat price (No.2 Hard Red Winter, Gulf export price, June 2020 backwards, no. 1 Hard Red Winter, ordinary protein).
[3] Calculated from the monthly rice price (Thailand, 5% broken, white rice, milled).

Agricultural investments can reduce food price volatility through increased productivity and improved technical management of production risks, especially in the face of climate change. The purpose of this book is to examine how agricultural investments will impact global wheat and rice markets under climate change in the long term. Several partial equilibrium models were used to examine these markets. Chapter 2.1 investigates how agricultural investments will stabilize world wheat markets by factoring in future climate change. Chapter 2.2 examines how decreasing wheat production and exports, and agricultural knowledge and innovation system recovery in Ukraine due to Russian aggression against Ukraine will contribute to stabilizing global wheat markets by considering future climate change. Chapter 3.1 conducts policy simulations for alleviating climate risks to rice production systems and rice markets. Chapter 3.2 also conducts simulations for agricultural investments made to counter the food loss rate of rice and the world rice market. Chapter 4.1 conducts projections and simulations for the global japonica and indica rice markets under climate change in the long term. Chapter 4.2 examines how public agricultural investments will contribute to stabilising global indica and japonica rice prices in the mid- and long-term by developing the partial equilibrium model. Chapter 4.3 examines the impact of the COVID-19 pandemic on global indica and japonica rice markets, and evaluates how agricultural commodity prices and GDP growth rate will affect agricultural investments via endogenous changes in major rice-producing countries. Chapter 5 discusses the role of agricultural investments in alleviating climate change risks for global rice and wheat markets, and the last section concludes.

CHAPTER 2

IMPACT OF AGRICULTURAL INVESTMENTS ON WORLD WHEAT MARKET UNDER CLIMATE CHANGE

2.1. Impact of Agricultural Investments on World Wheat Market under Climate Change: Effects of Agricultural Knowledge and Innovation System, and Development and Maintenance of Infrastructure

Abstract

The role of agricultural investment growth in alleviating climate risks for wheat production systems and markets was examined using a partial equilibrium model, the Wheat Economy Climate Change (WECC) model, which covers the wheat markets of 10 countries and two regions. This study examines how future agricultural investments will affect the world wheat market. The volatility of international wheat price as baseline is expected to increase during 2014–2016 and until 2040 due to climate change. The simulation results suggest agricultural investments in major wheat producing countries will contribute to price stability in mid-long term, by considering climate change. In particular, agricultural investments in Russia and Ukraine are crucial role for stabilizing

international wheat price in mid-long term under future climate change conditions.

Key words: Wheat, agricultural investments, climate change, price stability in mid-long term, Russia, and Ukraine.

2.1.1 Introduction

The increase in global mean surface temperatures in 2081–2100 relative to 1986–2005 is estimated between 0.3 °C to 4.8 °C, depending on representative concentration pathways (RCPs). Agricultural production will thus be affected by this climate change in different ways, including changes in yield and harvested area. Numerous studies exist on how future climate change could impact global agricultural production. Lobel (2007, 229-238) examined the changes in diurnal temperature range and national cereal yield. Furuya et al. (2015, 187-202) developed yield-response functions for the world food model to evaluate climate change effects by incorporating a crop model into the yield-trend functions[4]. Moreover, Furuya and Koyama (2005, 121-134) examined how climate change will impact world grain markets. This chapter examines how agricultural investments will contribute to stabilizing world wheat market by factoring future climate change. This study utilizes Organization of Economic Co-Operation and Development (OECD) based agricultural investment data

[4] For further studies, please refer to Koizumi and Kanamaru (2016, 267-284).

on developed countries and FAO-based data on developing countries to conduct simulations for alleviating climate risks for wheat production systems and markets through a partial equilibrium model.

2.1.2 Structure of the WECC model and data for regression

The Wheat Economy Climate Change (WECC) model covers the wheat markets in 10 countries and two regions (EU, China, India, USA, Russia, Ukraine, Canada, Australia, Argentina, Indonesia, Egypt, and rest of the world). The model also covers Germany, French, and other EU production to aggregate EU wheat production. The base year range is 2014–2016 (three-year average for 2014–2016). Each country's market consists of production, consumption, exports, imports, and ending stock until 2040. The WECC model covers equations for projecting wheat yield and planted area affected by climate change (Fig. 2-1-1).

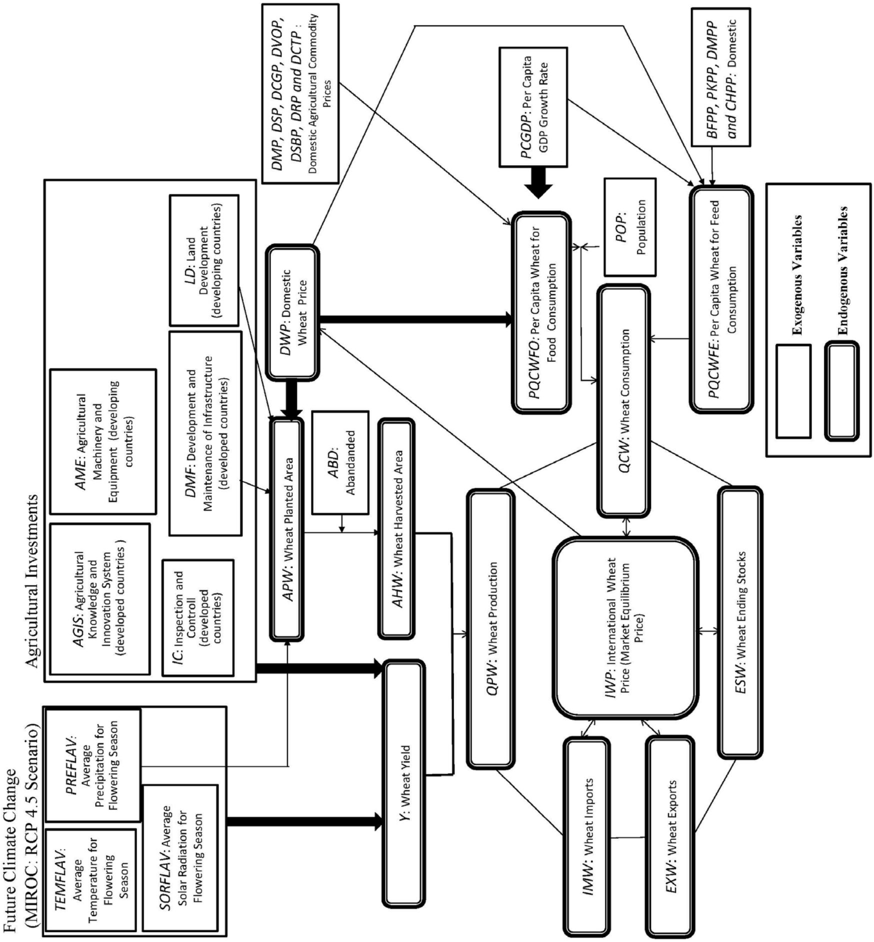

Fig 2-1-1. Structure of the WECC model

The wheat yield equation for developed countries depends on annual flowering season averages of temperature, precipitation, amount of solar radiation and lagging investments. Constant term and time trend are estimated, however they are not applied for projections. Instead of a statistically estimated constant term and time-trend, this study applied a coefficient of calibration to improve reality for the model projection activity. The coefficient of calibration obtained to correct each market activity of the first projection year (2017) is equivalent to updated estimation data (2017) published by USDA-FAS (2017b). The wheat planted area equation depends on the domestic price of wheat, competitive commodity prices, precipitation, and lagging investments. Changing rate from current to previous year of climate variables and price effect on wheat yield and wheat planted area. The lagged changing rate of agricultural investment variables effect on wheat yield and wheat planted area. They mean that agricultural investments can impact wheat yield and wheat planted area with a lag, different from climate and price variables. The WECC model is developed as a new model to cover agricultural investment variables derived from both OECD and FAO.

The wheat harvested area is derived from the difference between the planted and abandoned areas. The wheat production is calculated by multiplying the harvested area and wheat yield as follows:

$$\ln (Y_{t,c} / Y_{t-1,c}) = a1 \ln (TEMFLAV_{t,c} / TEMFLAV_{t-1,c}) + a2 \ln (PREFLAV_{t,c} / PREFLAV_{t-1,c}) + a3$$

$\ln (SORFLAV_{t,c} / SORFLAV_{t-1,c}) + a4 \ln (AGIS_{t,c} / AGIS_{t-1,c}) + a5 \ln (DMF_{t,c} / DMF_{t-1,c}) + a6 \ln (IC_{t,c} / IC_{t-1,c}) + a7 \ln (LD_{t,c} / LD_{t-1,c}) + a8 \ln (AME_{t,c} / AME_{t-1,c})$

where *Y* is wheat yield, *TEMFLAV* is the average temperatue of flowering season, *PREFLAV* is the average precipitation of flowering season, *SORFLAV* is the average of the amount of solar radiation of the flowering season, *AGIS* is the investment amount of agricultural knowledge and innovation system, *DMF* is that of development and maintenance of inflastructure, *IC* is that of inspection and controll, *LD* denotes that of agricultural land development, *AME* denotes that of agricultural machinery and equipment, *c* denotes countries/region, and a1-a8 are parameters. Koizumi (2019, 109-125) listed these estimated parameters.

$$\ln (APW_{t,c} / APW_{t-1,c}) = a9 \ln (DWP_{t,c} / DWP_{t-1,c}) + a10 \ln (PRCAV_{t,c} / PRCAV_{t-1,c}) + a11 \ln (DMP_{t,c} / DMP_{t-1,c}) + a12 \ln (DSP_{t,c} / SP_{t-1,c}) + a13 \ln (DCGP_{t,c} / DCGP_{t-1,c}) + a14 \ln (DVOP_{t,c} / DVOP_{t-1,c}) + a15 \ln (DSBP_{t,c} / DSBP_{t-1,c}) + a16 \ln (DRP_{t,c} / DRP_{t-1,c}) + a17 \ln (DMF_{t,c} / DMF_{t-1,c}) + a18 \ln (DCTP_{t,c} / DCTP_{t-1,c}) + a19 \ln (LD_{t-1,c} / LD_{t-2,c})$$

$$AHW_{t,c} = APW_{t,c} - ABD_{t,c}$$

$$QPW_{t,c} = AHW_{t,c} * Y_{t,c}$$

where *APW* is the planted area of wheat, *DWP* is the domestic wheat price, *PRCAV* is the average precipitation, *DMP* is the domestic corn price, *DSP* is the domestic soybean price, *DCGP* is the domestic coarse grain price, *DVOP* is the domestic vegetable oil price, *DSBP* is the domestic white sugar price, *DRP* is the domestic rice price, *DCTP* is the domestic cotton price, *LD* is the lagging investments in agricultural land development and a9-19 are parameters. Koizumi (2019, 109-125) listed these estimated parameters. *AHW* is the harvested area and *ABD* is the abandoned area. The abandoned area is exogenous variable and will be utilized for simulation in future studies. *QPW* denotes wheat production.

The per capita wheat consumption for food depends on income, domestic prices of wheat and rice, and time trend. Wheat consumption for food is calculated by multiplying the per capita wheat consumption for food and the country's population.

$$\ln (PQCWFO_{t,c} / PQCWFO_{t-1,c}) = a20 \ln (PCGDP_{t,c} / PCGDP_{t-1,c}) + a21 \ln (DWP_{t,c} / DWP_{t-1,c}) + a22 \ln (DRP_{t,c} / DRP_{t-1,c})$$

$$QCWFO_{t,c} = PQCWFO_{t,c} * POP_{t,c}$$

where *PQCWFO* is the per capita wheat consumption for food, *PCGDP* is per capita GDP (Constant price), *QCWFO* is the wheat consumption for food, *POP* is population and a20-a22 are parameters. Koizumi (2019, 109-125) listed these estimated parameters.

The wheat consumption for feed depends on income, domestic wheat price, beef, pork, and cheese prices. This equation is a feed demand element function for livestock production; however, the impact of income elasticity is bigger than that of price elasticity. Consequently, the income elasticity is incorporated into this equation. Wheat consumption is the sum of its consumption for food and feed.

$$\ln (QCWFE_{t,c} / QCWFE_{t-1,c}) = a23 \ln (GDP_{t,c} / GDP_{t-1,c}) + a24 \ln (DWP_{t,c} / DWP_{t-1,c}) + a25 \ln (BFPP_{t,c} / BFPP_{t-1,c}) + a26 \ln (PKPP_{t,c} / PKPP_{t-1,c}) + a27 \ln (CHPP_{t,c} / CHPP_{t-1,c})$$

$$QCW_{t,c} = QCWFO_{t,c} + QCWFE_{t,c}$$

where $QCWFE$ is the wheat consumption for feed, GDP is the GDP (Constant price), $BFPP$ is domestic beef price, $PKPP$ is domestic pork price, $CHPP$ is domestic cheese price, QCW is wheat consumption, and a23-a27 are parameters. Koizumi (2019, 109-125) listed these estimated parameters.

For net wheat exporting countries, wheat imports are based on domestic wheat price. Wheat exports are calculated by the exportable domestic market balance deficit remaining after domestic market has been satisfied.

$$\ln (IMW_{t,c} / IMW_{t-1,c}) = a28 \ln (DWP_{t,c} / DWP_{t-1,c})$$

$$EXW_{t,c} = QPW_{t,c} - QCW_{t,c} + IMW_{t,c} - (ESW_{t,c} - ESW_{t-1,c})$$

where *IMW* is wheat imports and a28 is parameter. Koizumi (2019, 109-125) shows the estimated parameters. *EXW* denotes wheat exports and *ESW* is the ending stocks of wheat.

For net wheat importing countries, wheat exports depend on international wheat price. Wheat imports are calculated by the exportable domestic market balance deficit remaining after domestic market has been satisfied as follows:

$$\ln (EXW_{t,c} / EXW_{t-1,c}) = a29 \ln (IWP_t / IWP_{t-1})$$

$$IMW_{t,c} = QCW_{t,c} - QPW_{t,c} + EXW_{t,c} + (ESW_{t,c} - ESW_{t-1,c})$$

where a29 is parameter, *IWP* is international wheat price, and Koizumi (2019, 109-125) listed the estimated parameters. Wheat ending stocks depend on domestic wheat price. The domestic wheat price depends on international wheat price as follows.

$$\ln (ESW_{t,c} / ESW_{t-1,c}) = a30 \ln (DWP_{t,c} / DWP_{t-1,c})$$

$$\ln (DWP_{t,c} / DWP_{t-1,c}) = a31 \ln (IWP_{t,c} / IWP_{t-1,c})$$

where a30 and a31 are parameters, Koizumi (2019, 109-125) showed the estimated parameters.

The model determines the production, consumption, imports, and ending stocks for each simulation year. The wheat market clearing price is obtained from the following equilibrium conditions using the *Gauss-Seidel* *algorithm*: Wheat, No. 1 Hard Red Winter, ordinary protein, Kansas City, which refers to the international wheat market clearing price[5].

$$\Sigma \quad IMW_{t,c} = \Sigma \quad EXW_{t,c}$$

Historical temperatures, precipitation, and solar radiation data are derived from CRU TS. 3.2 (CRU). For larger countries (West Australia for Australia, Saskatchewan State for Canada, Kansas State for USA, Punjab for India, North China Region for China, and Southern Russia (Black Sea Coastal Area) for Russia), the values for the grids that correspond to major wheat producing areas are averaged. For the other countries, the values for all grids that cover the entire territory are spatially averaged. The historical yield, planted area, harvested area, production, per capita consumption, imports, exports, and ending stock data for wheat[6] are derived from Production, Supply and Distribution (PSD Online) (USDA-FAS, 2017b). This study defines wheat producer price as the domestic wheat price, derived from FAOSTAT (FAO, 2017). These data are used for regression in the time-series analysis.

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[5] Wheat is categorized as 4 types (Hard wheat, soft wheat, intermediate quality wheat and durum) for its application. Among them, hard wheat, especially for *Wheat, No. 1 Hard Red Winter, ordinary protein, Kansas City* is the most typically utilized for world wheat trade.

[6] The results of unit root tests (ADF test) confirmed that the time-series data of dependent variables and explanatory variables used in this study are stationary series.

2.1.3 Baseline assumptions and scenarios

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 (temperatures, precipitation, and amount of solar radiation) for both the baseline outlook and policy scenario come from climate change projections of Model for Interdisciplinary Research on Climate (MIROC), a global climate model under the RCP 4.5 scenario. Spatially averaged climate variables for each country are computed similarly to the historical climate data used for regression. The flowering seasons for model covered countries differ as Table 2-1-1. The standard deviations for temperature, precipitation, and solar radiation during the flowering season in most analyzed countries are projected to increase in 2017–2040 compared to 1980–2009 (Tables 2-1-2, 2-1-3, and 2-1-4). The exogenous variables of per capita GDP growth rate, population, international commodity prices, and livestock production are listed in Koizumi (2019, 109-125). The population data for all countries were obtained from the 2017 Revision (medium variant) of World Population Prospects, United Nations (2017). The per capita real GDP was also treated as an exogenous variable, and GDP growth rate assumptions were based on World Economic Outlook 2017 (IMF, 2017). These GDP growth rates are available up to 2022. This study assumes that the average per capita GDP growth rate from 2017 to 2022 in each country will continue to be the same from 2023 to 2040. Competing commodity prices