

# THE IMPACT OF CLIMATE CHANGE ON INDONESIAN RICE AND COFFEE SECTORS

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# INTRODUCTION



# INTRODUCTION



## RATIONALE: CLIMATE CHANGE AND AGRICULTURE

- **Climate Change and Tropical Agriculture**

- Climate change over the past 30 years has reduced **global agricultural production in the range of 1-5% per global decade** (IPCC, 2015), with particularly **negative effects for tropical cereal crops such as maize and rice** (Porter et al, 2014).
- Low levels of warming (+2°C), **agricultural productivity is likely to decline** worldwide, but particularly in the **tropics** (Challinor et al ,2014)

- **In order to meet demand, environmental related challenges must be addressed**

- Suitable climatic, soil and biophysical conditions need to be analyzed as a basis for developing crop commodities in an area (Sarkar et al. 2014; Bonfante et al. 2018)
- The mismatch of these environmental conditions will have an impact on the low productivity of agricultural commodities.

- **Ideal climatic conditions are also required to avoid crop failure**

- **Rice** → the availability of water, especially from rain, is an important factor. Long drought stress in rice plants results in crop failure (Zhong et al., 2010; Estiningtyas et al, 2012)
- **Plantation crops (eg. coffee)** → suitable temperature and rainfall conditions determine the ideal cultivation location (Camargo, 2010; Davis et al., 2012).

# INTRODUCTION



## RATIONALE: ECONOMIC IMPACTS OF CLIMATE CHANGE

Some studies assessed impact of climate change on the economic value of rice and coffee in Indonesia

### Rice

- The effects of the rainy and dry seasons on rice prices (Jati, 2018)
  - Using the ARMA (0,1)-ARCH (1) model, it is found that dry season significantly affects the conditional variance of rice prices more than the rainy season dummy variable.
- Commodity price anomalies based on the level of climate change vulnerability (Rum and Sihaloho, 2017) .
  - Regions that are vulnerable to climate change tend to have higher price volatility than that of regions which are not vulnerable.

- Previous studies generally focus on the impact on production and prices.
- However, both agricultural commodities have an important role in food security and exports, so it is urgent to analyze the impact of climate change on macroeconomic and sectoral performance

### Coffee

- ENSO (El Nino Southern Oscillation) causes fluctuations in rainfall, which has an impact on the agricultural sector, especially the plantation subsector (Sadelina, 2020)
  - El Nino had a significant effect in increasing coffee prices, and was followed by other factors, namely the price of substitute goods (chocolate prices), productivity and Real GRDP.
- Bongase (2017) stated an increase in temperature and water shortage will negatively affect the suitability of coffee production in the lowlands and vice versa.
  - Only half of the area currently available for coffee production in 2050.
  - Declining yields and rising prices will evidently reduce the coffee market by more than 5 million tons per year.
  - The area suitable for coffee production will decrease by 16% by 2050, especially for Arabica coffee.



# INTRODUCTION

## OBJECTIVES

1

- Analyze the impact of climate change on rice and coffee commodities on Indonesia's macroeconomic performance.

2

- Analyzing the impact of climate change on rice and coffee commodities on Indonesia's sectoral performance

3

- Analyzing the impact of climate change on rice and coffee commodities on Indonesia's households' welfare



# METHODOLOGY



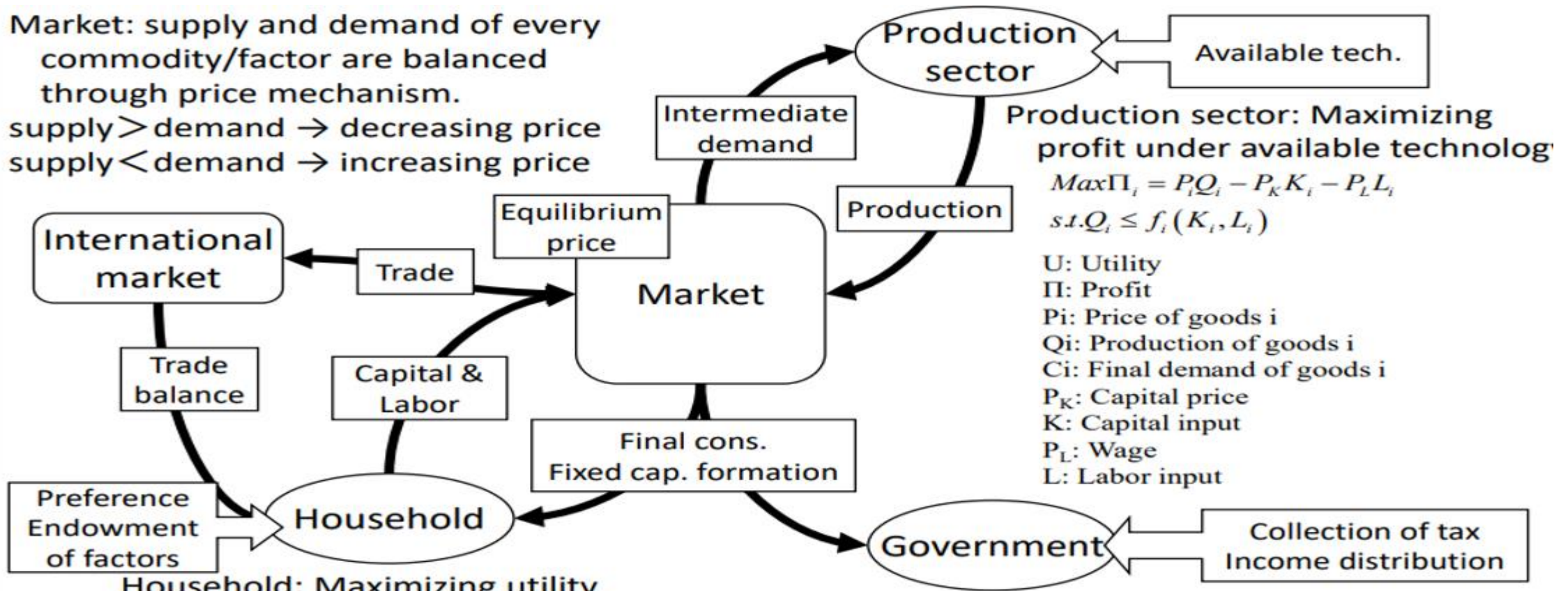
# COMPUTABLE GENERAL EQUILIBRIUM (CGE): NATIONAL MODEL



## LOGICAL FRAMEWORK

Market: supply and demand of every commodity/factor are balanced through price mechanism.

supply > demand → decreasing price  
supply < demand → increasing price



Production sector: Maximizing profit under available technology

$$\begin{aligned} \text{Max } \Pi_i &= P_i Q_i - P_K K_i - P_L L_i \\ \text{s.t. } Q_i &\leq f_i(K_i, L_i) \end{aligned}$$

- U: Utility
- Π: Profit
- P<sub>i</sub>: Price of goods i
- Q<sub>i</sub>: Production of goods i
- C<sub>i</sub>: Final demand of goods i
- P<sub>K</sub>: Capital price
- K: Capital input
- P<sub>L</sub>: Wage
- L: Labor input

Household: Maximizing utility under income constraint

$$\begin{aligned} \text{Max } U &= u(C_i) \\ \text{s.t. } \sum_i P_i C_i &\leq P_K K + P_L L \end{aligned}$$

# RECURSIVE DYNAMIC CGE



## THE MODEL

- The recursive dynamic model is a CGE model where the decision is optimized for a single period with a gradual solution,
- This model is basically a series of static models that are solved in stages
- Model construction refers to INDOF (Oktaviani, 2001) and ORANI GRD (Horridge, et. 2002)

### Equation Blocks

- Demand for labor (demands for labor)
- Demand for primary factors (demands for primary factors)
- Demand for intermediate inputs (demands for intermediate inputs)
- Demands for composite primary factors and intermediate inputs
- Commodity composites of industrial outputs
- Demands for investment goods
- Household demands Export and other final demands

- Demand for manpower Demand for margins
- Purchase price (purchaser's prices)
- Market clearing conditions
- Indirect taxes
- GDP from the income and expenditure sides
- Trade balance and other aggregates
- Rate of return and index (rates of return, indexation)
- Investment-capital accumulation
- Debt accumulation
- Regional Model Extension



# RECURSIVE DYNAMIC CGE DATABASE CONSTRUCTION



<i>Sets</i>	<i>Subsets</i>	<i>Disaggregation</i>
Production Factor	Labour	(1) farmer; (2) operator; (3) administrator (4) manager
	Land	
	Capital	
Region		30 provinces
Institution		Producers, investors, households, exports; government.
HH Groupr	Rural	Rural 1, Rural 2 , Rural 3, Rural 4, Rural 5
	Urban	Urban 1, Urban 2, and Urban 3
Industry		185 goods and services sectors where the commodity set is equivalent to the industrial set

# RECURSIVE DYNAMIC CGE

## SHOCKS JUSTIFICATION



### The Median Value of the median shock all off the districts levels in Indonesia

Scenario 1	Productivity	The Median Value of the median shock all off the districts levels in Indonesia		
		2021-2050	2051-2080	2081-2100
Paddy	4.5	-1.53%	-2.89%	-3.35%
	8.5	-1.95%	-4.75%	-7.50%
Arabica	4.5	-12.03%	-25.43%	-29.71%
	8.5	-15.12%	-39.51%	-63.18%
Robusta	4.5	1.09%	0.76%	0.71%
	8.5	0.93%	-0.58%	-2.66%

### The Median Value of all off the districts levels median values in Indonesia

Scenario 2	Productivity	The Median Value of all off the districts levels median values in Indonesia		
		2021-2050	2051-2080	2081-2100
Paddy	4.5	-19.72%	-23.00%	-21.20%
	8.5	-20.39%	-45.11%	-34.93%
Arabica	4.5	-100.00%	-100.00%	-100.00%
	8.5	-100.00%	-100.00%	-100.00%
Robusta	4.5	-25.39%	-34.33%	-39.14%
	8.5	-46.69%	-51.67%	-68.59%

### The Average value of the median shock all off the districts in Indonesia

Scenario 3	Productivity	The Average value of the median shock all off the districts in Indonesia		
		2021-2050	2051-2080	2081-2100
Paddy	4.5	-1.18%	-2.55%	-3.07%
	8.5	-1.42%	-4.36%	-7.20%
Arabica	4.5	-13.59%	-25.54%	-30.11%
	8.5	-16.15%	-40.79%	-60.61%
Robusta	4.5	2.26%	2.00%	2.12%
	8.5	2.30%	0.89%	-1.39%

- Shock simulation of climate change in the long run (2021-2100)  
→ **productivity decrease for coffee and rice commodities from authors' econometric model**
- **Simulation:**
  - The decline in productivity of rice and coffee based on the median value of the median shock of decreasing productivity in all districts;
  - The decline in productivity of and rice and coffee based on the minimum value of the median shock of decreasing productivity in all districts;
  - The decline in productivity of rice and coffee is based on the average value of the median shock of decreasing productivity in all districts.
- **Assumption:**
  - RCP 4.5 which results in a decrease in air temperature and an increase in rainfall
  - RCP 8.5 tends to decrease rainfall and increase temperature.
  - The magnitude of the decrease in rice productivity of RCP 8.5 is more significant than that of RCP 4.5.



# RESULTS



# MACROECONOMIC IMPACTS

## RESULTS

Description			Consumer price index	Real GDP from expenditure side	Export volume index	Real household consumption	Import volume index
Scenario 1	4.5	2021-2050	0.02	-0.03	-0.02	-0.06	0.01
		2051-2080	0.03	-0.06	-0.05	-0.12	0.02
		2081-2100	0.03	-0.07	-0.06	-0.14	0.02
	8.5	2021-2050	0.02	-0.04	-0.03	-0.08	0.01
		2051-2080	0.04	-0.10	-0.08	-0.21	0.02
		2081-2100	0.06	-0.17	-0.14	-0.34	0.03
Scenario 2	4.5	2021-2050	0.16	-0.45	-0.37	-0.90	0.08
		2051-2080	0.18	-0.53	-0.43	-1.06	0.09
		2081-2100	0.16	-0.51	-0.42	-1.01	0.07
	8.5	2021-2050	0.14	-0.51	-0.42	-1.01	0.05
		2051-2080	0.41	-0.95	-0.77	-1.93	0.24
		2081-2100	0.27	-0.81	-0.67	-1.63	0.13
Scenario 3	4.5	2021-2050	0.01	-0.02	-0.02	-0.04	0.01
		2051-2080	0.02	-0.05	-0.04	-0.11	0.01
		2081-2100	0.03	-0.06	-0.05	-0.13	0.02
	8.5	2021-2050	0.01	-0.03	-0.02	-0.06	0.01
		2051-2080	0.04	-0.09	-0.08	-0.19	0.02
		2081-2100	0.06	-0.16	-0.13	-0.32	0.03

Source: Authors' Calculation

# MACROECONOMIC IMPACTS

## SUMMARY



- Decline in real GDP ranging from -.2-0.51% at RCP 4.5 and 0.3-0.85% at RCP 8.5.
- The decline in rice and production due to climate change will affect the supply of these commodities in Indonesia and the price of the commodity.
  - The increase in inflation (Consumer Price Index) due to climate change ranged .01-0.18% at RCP 4.5 and 0.1-0.41% at RCP 8.5. The increase in inflation in simulation 2 is the largest of the other simulations at 0.14-0.41%.
- In line with the decline in national income, household real consumption also decreased.
- The decline in exports occurred in all simulations both in RCP 4.5 and RCP 8.5 scenarios, particularly for coffee, is feared to worsen the trade balance because it is accompanied by an increase in imports.
- The increase in imports occurred in all simulations, ranging from 0.01 to 0.08 percent (RCP 4.5) and 0.01 and 0.24 percent (RCP 8.5), as it is expected to be driven by reducing domestic coffee supply.

# SECTORAL IMPACTS



## RESULTS

Output	Period	Sim 1		Sim 2		Sim 3	
		Paddy	Coffee	Paddy	Coffee	Paddy	Coffee
4.5	2021-2050	-0.49	-0.40	-6.54	-12.28	-0.38	-0.18
	2051-2080	-0.94	-1.23	-7.64	-14.65	-0.83	-0.91
	2081-2100	-1.09	-1.48	-7.11	-15.78	-1.00	-1.14
8.5	2021-2050	-0.63	-0.62	-6.90	-17.65	-0.45	-0.31
	2051-2080	-1.56	-2.36	-14.73	-19.86	-1.43	-2.04
	2081-2100	-2.47	-4.21	-11.64	-23.71	-2.37	-3.74

Source: Authors' Calculation

# SECTORAL IMPACTS

## SUMMARY



- **The direct and apparent impact of climate variability occur in decline of rice of yield leading towards decreasing output in each scenario.**
- **The magnitude of rice production loss was estimated to be more significant in RCP 8.5 scenario and when simulation 2 was applied.**
  - It was estimated that the rice production will go down by 6.90 percent during the period 2021-2050, 14.73 percent 2051-2080, and 11.64 percent during the period 2081-2100.
  - This is similar to the previous studies (Naylor, 2001 and Naylor, 2007) as the temperature changes plays a major factor in influencing year-to-year variation in rice output.
  - Our estimates were significantly higher than that of predicted by Oktaviani et al (2011).
    - Oktaviani et al (2011) assessed the potential impacts of global climate change by linking IMPACT and Indonesian CGE Model-INDOF and showed that the rice production loss in Indonesia reached 2.94 percent by 2030.
  - Busnita, Oktaviani, and Novianti (2017) also support the argument with their study.
    - Using the ARCH-GARCH methods and VECM (Vector Error Correction Model), this study highlighted that changes of the temperature will cause higher fluctuation in rice prices and eventually will be stabilized after 60 months.

# SECTORAL IMPACTS

## SUMMARY

- **The risks of climate variability are enormous in coffee sector both for Robusta and Arabica coffee.**
  - Our modeling results showed that the potential loss of production will reach 17.65 percent during the period 2021-2050, 19.86 percent 2051-2080, and 23.71 percent during the period 2081-2100 under the simulation 2 and RCP 8.5 scenario.
  - A systematic literature review conducted by Bilen et al (2023) showed that most of the literatures analyzing the influence of climate change on coffee production were negative.
    - This is mainly because global climate change reduces suitable areas for coffee cultivation, and rising infestations and distribution of insect pests and diseases that reduce coffee berry quality and yield.
  - The socio-economic impact causes the decline in production and productivity as well as a decrease in the share of GDP in the agricultural sector is fluctuations in the prices of agricultural products.



# TRADE IMPACTS



## RESULTS

Indicator	Productivity	Period	Sim 1		Sim 2		Sim 3	
			Paddy	Coffee	Paddy	Coffee	Paddy	Coffee
Export	4.5	2021-2050	-1.19	-0.91	-15.60	-28.20	-0.91	-0.39
		2051-2080	-2.27	-2.80	-18.20	-33.66	-1.99	-2.07
		2081-2100	-2.63	-3.38	-16.85	-36.36	-2.40	-2.58
	8.5	2021-2050	-1.52	-1.40	-16.29	-40.72	-1.10	-0.69
		2051-2080	-3.74	-5.40	-35.40	-45.34	-3.43	-4.67
		2081-2100	-5.92	-9.65	-27.69	-54.54	-5.67	-8.58
Import	4.5	2021-2050	3.97	2.93	51.84	91.12	3.05	1.25
		2051-2080	7.54	9.04	60.50	108.76	6.64	6.66
		2081-2100	8.75	10.89	55.98	117.52	7.99	8.32
	8.5	2021-2050	5.07	4.52	54.09	131.65	3.68	2.22
		2051-2080	12.43	17.45	117.78	146.31	11.40	15.06
		2081-2100	19.67	31.16	92.02	176.24	18.86	27.70

# TRADE IMPACTS

## SUMMARY

- **RCP8.5 scenario has a larger impact than the RCP 4.5 scenario on trade**
  - For rice, consequence of a decrease in rice productivity is that nationally there is a potential decrease in export yields ranging from 2 percent - 35 percent and an increase in import needs reaching a maximum range of 117 percent which will occur in scenario 8.5.
  - What really needs attention is that the decline in rice production will have a spiraling impact, namely increasing the relative prices of rice and rice commodities, thereby reducing their competitiveness for exports.
  - The decline in rice exports is in the range of -0.31 to -35 percent in the RCP 4.5 scenario and -0.5 to -52 percent in the RCP 8.5 scenario.
  - Meanwhile, more significant impacts hit coffee trade as export will expected to go down by 54.54 percent and imports rising up to 176.24 percent in simulation 2.
  - Climate change adaptation actions are urgently needed so that Indonesia can maintain its position as a coffee exporting country.

# WELFARE IMPACTS



## RESULTS

Scenario	Period	rural1	rural2	rural3	rural4	rural5	urban1	urban2	urban3
4.5	2021-2050	-0.03	-0.03	-0.03	-0.03	-0.04	-0.03	-0.03	-0.01
	2051-2080	-0.07	-0.06	-0.06	-0.06	-0.08	-0.05	-0.06	-0.01
	2081-2100	-0.08	-0.07	-0.07	-0.07	-0.09	-0.06	-0.07	-0.01
8.5	2021-2050	-0.04	-0.04	-0.04	-0.04	-0.05	-0.03	-0.04	-0.01
	2051-2080	-0.11	-0.10	-0.10	-0.09	-0.13	-0.09	-0.10	-0.02
	2081-2100	-0.18	-0.17	-0.17	-0.15	-0.21	-0.14	-0.17	-0.03
4.5	2021-2050	-0.48	-0.45	-0.45	-0.41	-0.56	-0.39	-0.46	-0.08
	2051-2080	-0.56	-0.52	-0.53	-0.48	-0.66	-0.46	-0.53	-0.09
	2081-2100	-0.54	-0.50	-0.51	-0.46	-0.64	-0.44	-0.51	-0.08
8.5	2021-2050	-0.54	-0.50	-0.51	-0.46	-0.64	-0.44	-0.52	-0.08
	2051-2080	-1.02	-0.95	-0.96	-0.88	-1.19	-0.83	-0.96	-0.17
	2081-2100	-0.87	-0.81	-0.81	-0.74	-1.02	-0.70	-0.82	-0.14
4.5	2021-2050	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	0.00
	2051-2080	-0.06	-0.05	-0.05	-0.05	-0.06	-0.05	-0.05	-0.01
	2081-2100	-0.07	-0.06	-0.06	-0.06	-0.08	-0.06	-0.06	-0.01
8.5	2021-2050	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.03	-0.01
	2051-2080	-0.10	-0.09	-0.09	-0.09	-0.12	-0.08	-0.09	-0.02
	2081-2100	-0.17	-0.16	-0.16	-0.14	-0.20	-0.14	-0.16	-0.03

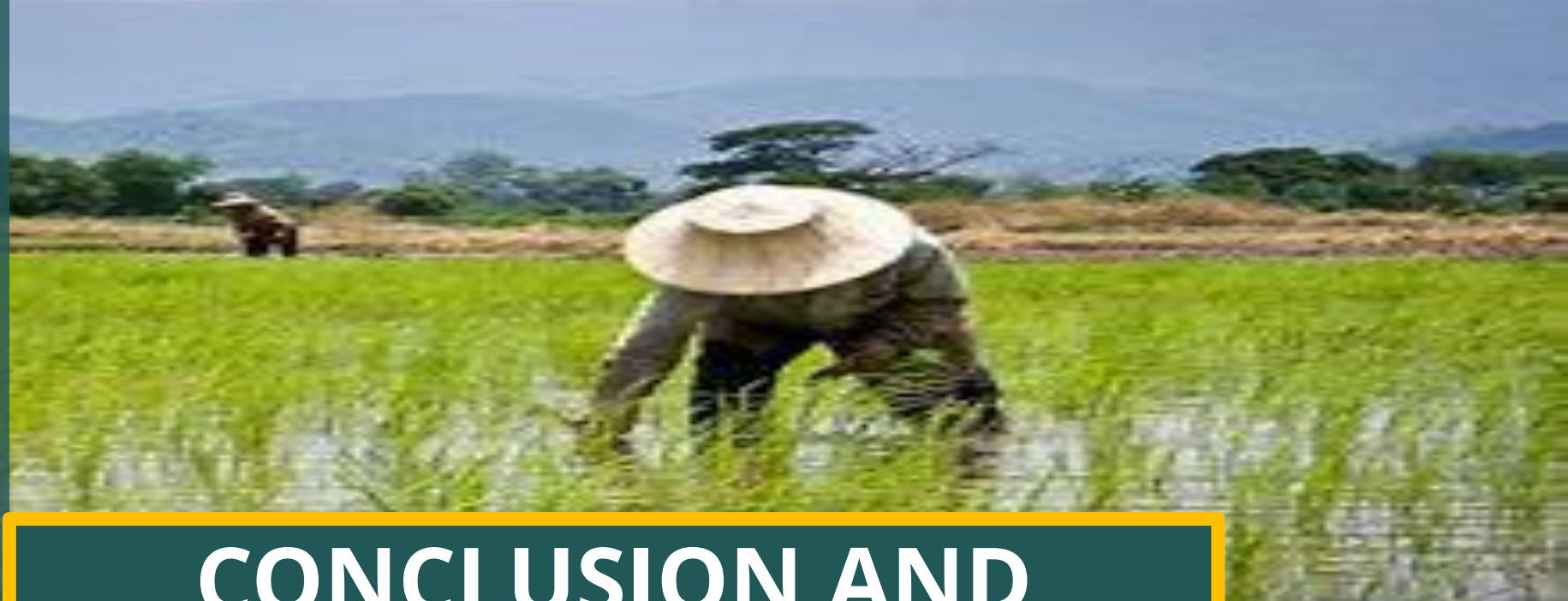
Source: Authors' Calculation

# WELFARE IMPACTS



## SUMMARY

- **Climate change in rice and coffee commodities can represent an income shock as indicated by a decrease in real income for all household groups, both in rural and urban areas.**
  - The highest decline in real income occurred in the rural 1 group of agricultural workers, followed by Rural 2 which were agricultural entrepreneurs. Low-income households in urban areas (urban 5) decreased their welfare more significantly than other urban household groups.
  - A further consequence that may occur is a decrease in the status of food security, especially in vulnerable communities.
- Climate change adaptation policies, especially for rice and coffee commodities, are very important to overcome the decline in productivity and production of these commodities.
- Production stability is very much needed to maintain food security (rice) and maintain Indonesia's position as one of the largest coffee exporters in the world.
- Fiscal policies to maintain people's purchasing power and consumption, especially those with low income due to climate change, need attention.



# CONCLUSION AND RECOMMENDATION



# CONCLUSION



- Climate change that reduces rice and rice productivity affects Indonesia's macroeconomic performance.
  - Climate change will reduce real GDP, real household consumption and exports. On the other hand, climate change will increase Indonesia's imports.
  - Changes in macroeconomic performance in all scenarios of RCP 8.5 are worse than scenario 4.5.
- Climate change poses a negative risk to the quantity and quality of rice and coffee output and has a spiralling impact on increasing domestic prices.
- Reduce Indonesia's trade competitiveness, especially as a major producer and exporter of coffee due to an increase in relative prices.
- Climate change in rice commodities can represent an income shock as indicated by a decrease in real income for all household groups, both in rural and urban areas.
  - The highest decline in real income occurred in the rural 1 group of agricultural workers, followed by Rural 2 which were agricultural entrepreneurs. Low-income households in urban areas (urban 5) decreased their welfare more significantly than other urban household groups.

# POLICY RECOMMENDATION



- Adaptation climate policies on rice and coffee commodities requires multi approach to enhance the resilience of both production systems to climate change, safeguarding livelihoods, food security, and sustainability.
  - Develop heat-tolerant and drought-resistant varieties of rice and coffee
  - Strengthen extension officer to provide training on climate smart agricultural practices
  - Improved infrastructure (irrigation, post-harvest facilities) to enhance the resilient of rice and coffee production.
  - Develop financial support and risk management towards climate change:
    - Providing financial incentives (subsidies and low-interest loan) to encourage rice and coffee farmers to invest in climate adaptation measures
    - Establish crop insurance to protect and stabilize farmers income, and strengthen social safety nets.



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**THANK YOU**