Climate Change under Uncertainty

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Ⅰ. Choice under Uncertainty

1. Definition of Risk
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1. Definition of Risk

Choice under Certainty
Individuals know what is going to happen for sure

Choice under Uncertainty
Economic agents do not know what is going to happen

[Uncertainty]

Risk	Ambiguity
Underlying distribution of random variable (reflecting risk) is known	Events are likely to happen with uncertainty but odds are not known

2. Risk preference and its measure

Expected Utility Hypothesis: EUH

Under regular conditions, risk preference can be represented by utility function and it takes the form of expected utility.

Lottery $L = (x_1, x_2, \dots, x_N; p_1, p_2, \dots, p_N)$; $\sum_{n=1}^{N} p_n = 1$ & $p_n \geq 0 \; \forall n$

$$EU(L) = \sum_{n=1}^{N} p_n * u(x_n)$$

U( ) is called von-Neumann Morgenstern function.

Risk preference can be differentiated by the shape of utility function.

2. Risk preferences and its measures

v. N-M Utility Function

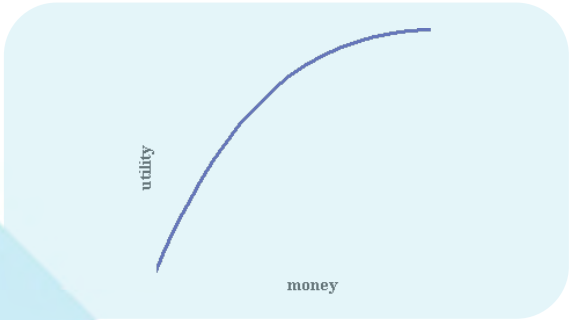
Under uncertainty, decision makers maximize expected utility

$$Max\ EU = \sum p_i \times u(x_i)$$

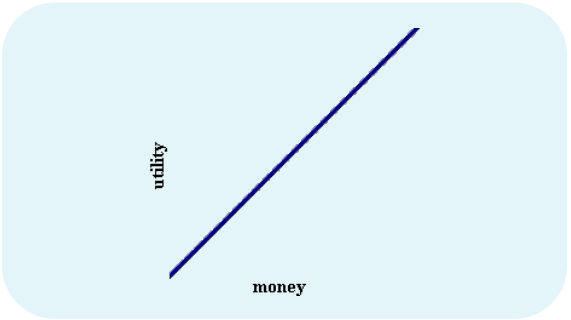
Different risk preferences can be captured by the shape of utility function

[Utility Function]

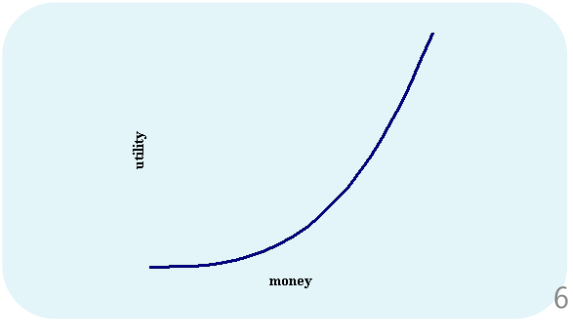
Risk Aversion



Risk Neutrality



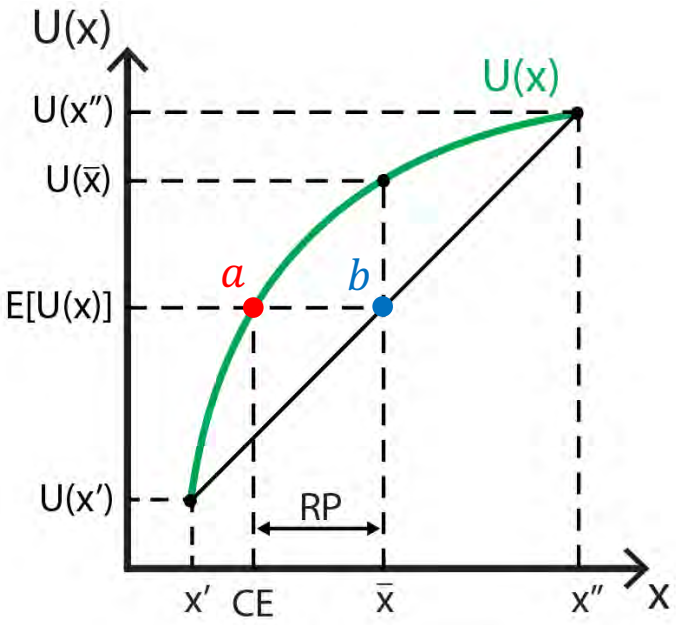
Risk Loving



2. Risk preferences and its measures

Costs of Risk

A risk-averse individual



Lottery

Lottery $L = (x', x''; 0.5,\ 0.5)$

Utility from $x' : u(x')$

Utility from $x'' : u(x'')$

EU : $E[U(x)] = 0.5 * u(x') + 0.5 * u(x'')$

Risk Premium : RP

Cost of Risk

$$EU(X) = U(\bar{X} - RP)$$

Certainty Equivalence : CE

$$CE = \bar{X} - RP$$

The sure amount of money that guarantees the same utility as expected utility

3. Moments and economics

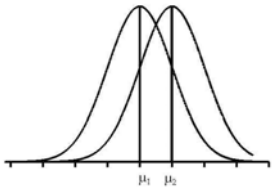
N^{th} Moment –Expected value of random variable X to the Nth power

$$E[X^N]$$

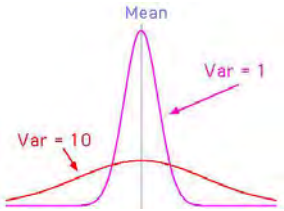
N^{th} Central Moment –Expected value of deviation from the mean to the Nth power

$$E[(X - \bar{X})^N]$$

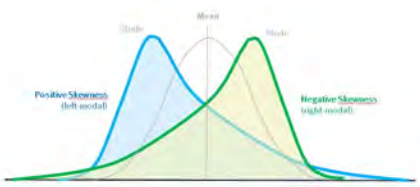
1st moment – location



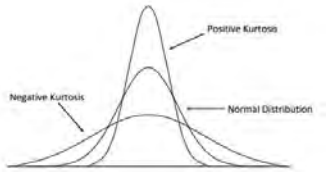
2nd central moment - dispersion



3rd central moment - skewness



4th central moment - kurtosis



3. Moments and economics

Random payoff and expected utility maximization

☐ Random profit $\pi(x, t, e)$

- X : Inputs / e : Random shock / t : Technology

☐ Utility maximization

- $Max\ EU[\pi(x, t, e)]$

Taylor Expansion (TE)

TE around mean profit $\mu_{1\pi} = E[\pi(x, t, e)]$

$$EU(\pi) \approx U(\mu_{1\pi}) + \sum_{i=2}^{m} \frac{1}{i!} \cdot \frac{\partial^i U(\mu_{1\pi})}{\partial \pi^i} \cdot E[(\pi - \mu_{1\pi})^i]$$

EU and Moments

EU – economic valuation of risk depends on:
Mean profit (1st moment),
Dispersion (2nd moment),
Skewness (3rd moment) etc.

Ⅱ. Climate Change under Uncertainty

1. Agriculture and Risk Exposure

2. Climate Change under Risk

3. Empirical Applications

- A Quantile approach

(Rice, Irrigation and Downside Risk: A Quantile Analysis of Risk Exposure and Mitigation on Korean Farms (2014))

- Risk Premium in Korean Rice Farms under Climate Change

(An Analysis of Climate Change Effects on Risk and Spatial Distribution of Rice Production in South Korea (2019))

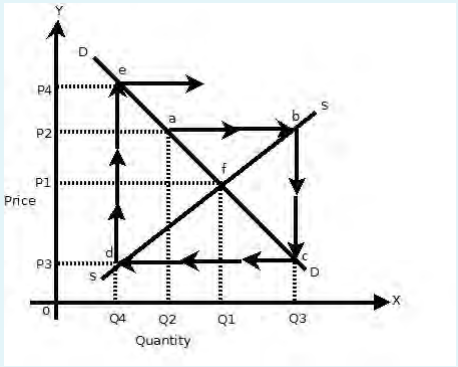
1. Agriculture and Risk Exposure

Agriculture and Variability

Two main source of variability in agriculture

[Agricultural Variability]

Price Variability



Inelastic supply + Time lag

Production Variability

Inherent random shock such as pest or climate change

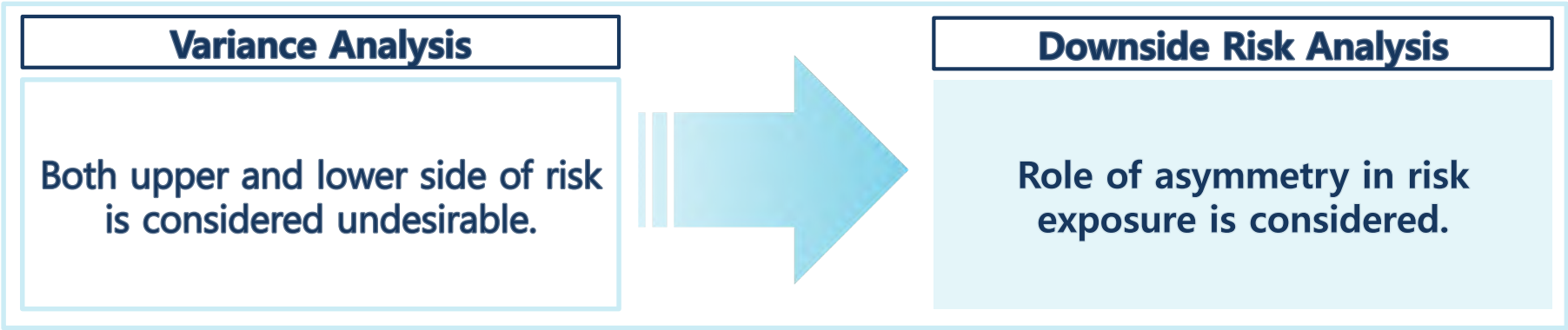
1. Agriculture and Risk Exposure

Traditional perception of risk

Risk exposure can be captured by variance or standard deviation.

More attention is being paid to downside risk

Variance treats both upper side risk and lower side risk equally.



2. Climate Change Under Risk

Climate change and asymmetry in risk exposure

- Risk in agriculture is largely associated with unfavorable events such as climate change.

- Climate change has both **mean effects** and **beyond mean effects**
  Mean effects: changes in level, gradual changes in climatic variables
  Beyond mean effects: changes in variability, extreme weather events

Quantile Analysis

Relative importance of risk exposure in the lower quantile of distribution

3. Empirical Applications

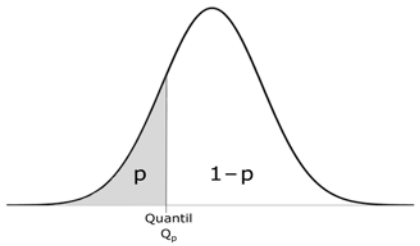
1) A Quantile approach

("Rice, Irrigation and Downside Risk: A Quantile Analysis of Risk Exposure and Mitigation on Korean Farms", Kim et al. (2014))

: studies risk exposure and mitigation strategies of Korean rice farms

[Empirical results]

Quantile



Kim et al. (2014)

■ Fat tail: downside risk in Korean rice farming

→ About 90 percent of costs of risk comes from the lowest quantile of distribution.

2) Risk Premium in Korean Rice Farms under Climate Change

("An Analysis of Climate Change Effects on Risk and Spatial Distribution of Rice Production in South Korea (2019))

Decreasing trend in mean rice productivity

The percentage of reduction range being -1.1% to -7.0% due to temperature rise, disease and insect pest, shortening of growth duration.

Regional heterogeneity of climate change effects

The reduction rate vary considerably across region.

[Mean Rice Productivity across Scenarios]

kg/10a, %

Scenario	RCP 4.5	RCP 8.5
Reference (2001-2010)	561	561
First Stage (2011-2040)	555(-1.1)	544(-3.0)
Second Stage (2041-2070)	538(-4.1)	541(-3.6)
Third Stage (2071-2100)	539(-3.9)	522(-7.0)

Regional Heterogeneity in Climate Change Effects on Mean Rice Productivity

[Mean Rice Productivity across Regions]

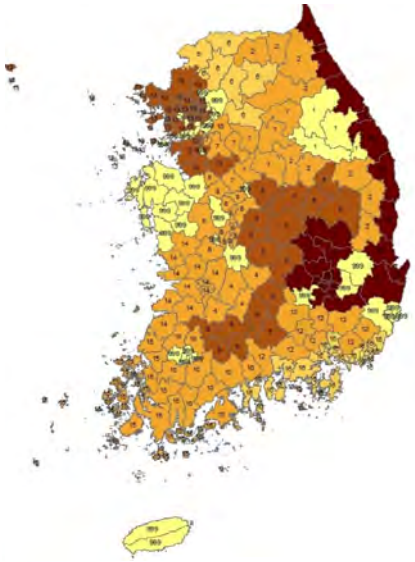
kg/10a, %

Agro-Climatic Zones of Rice	Reference (2001-2010)	First Stage (2011-2040)	Second Stage (2041-2070)	Third Stage (2071-2100)
Taebaek semi-alpine	554	554(0.0)	542(-2.2)	546(-1.4)
Sobaek mountainous	564	564(0.0)	548(-2.8)	552(-2.1)
Noryeong sobaek mountainous	559	561(0.4)	544(-2.7)	549(-1.8)
Yeongnam inland mountainous	563	562(-0.2)	548(-2.7)	551(-2.1)
Northern central inland	549	558(1.6)	542(-1.3)	546(-0.5)
Central inland	555	561(1.1)	542(-2.3)	547(-1.4)
Western sobaek inland	557	559(0.4)	540(-3.1)	544(-2.3)
Noryeong eastern & western inland	562	556(-1.1)	539(-4.1)	543(-3.4)
Honam inland	554	546(-1.4)	531(-4.2)	531(-4.2)
Yeongnam basin	576	566(-1.7)	551(-4.3)	554(-3.8)
Yeongnam inland	560	549(-2.0)	534(-4.6)	536(-4.3)
Western central plain	567	564(-0.5)	542(-4.4)	544(-4.1)
Southern charyeong plain	551	547(-0.7)	529(-4.0)	529(-4.0)
South western coastal	558	545(-2.3)	530(-5.0)	527(-5.6)
Southern coastal	544	536(-1.5)	519(-4.6)	516(-5.1)
North eastern coastal	576	571(-0.9)	550(-4.5)	547(-5.0)
Central eastern coastal	588	577(-1.9)	562(-4.4)	555(-5.6)
South eastern coastal	577	567(-1.7)	547(-5.2)	542(-6.1)

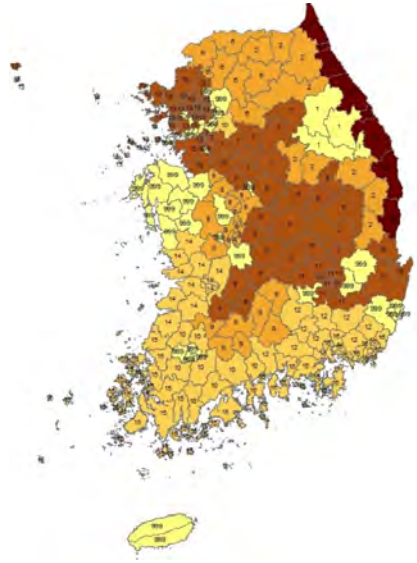
- Change in Mean Rice Productivity across Regions

[Mean Rice Productivities across regions]

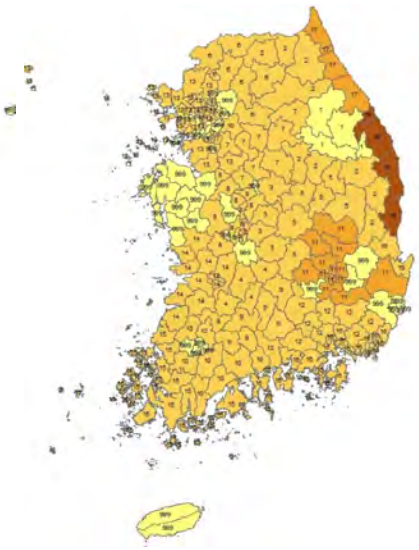
Reference (2001-2010)



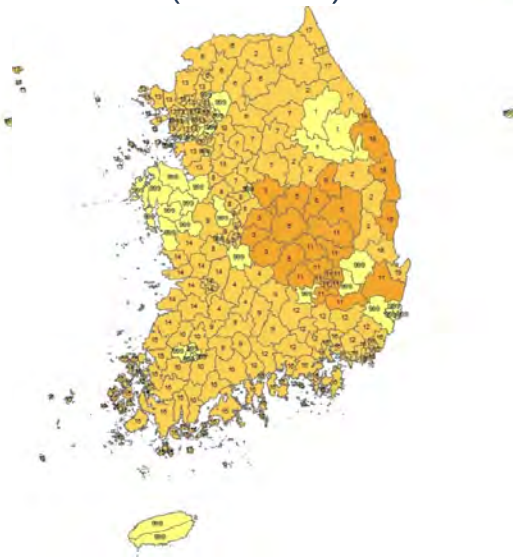
First Stage (2011-2040)

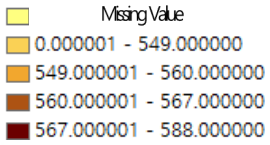


Second Stage (2041-2070)



Third Stage (2071-2100)





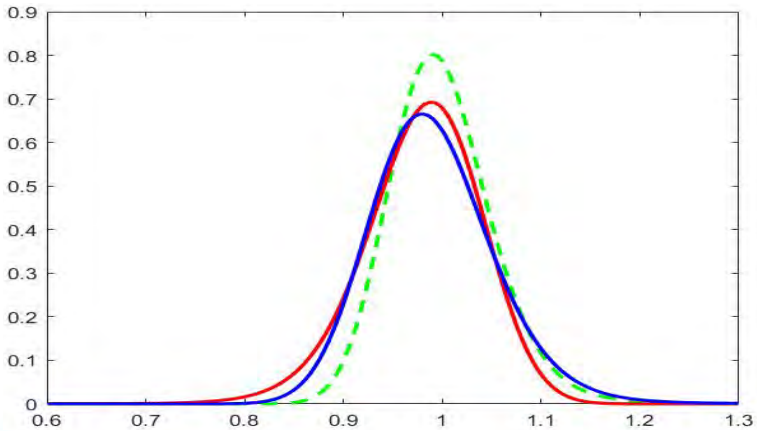
Note: 2 : Taebaek semi-alpine, 3 : Sobaek mountainous, 4 : Noryeong sobaek mountainous, 5 : Yeongnam inland mountainous, 6 : Northern central inland, 7 : Central inland, 8 : Western sobaek inland, 9 : Noryeong eastern & western inland, 10 : Honam inland, 11 : Yeongnam basin, 12 : Yeongnam inland, 13 : Western central plain, 14 : Soutern charyeong plain, 15 : South western coastal, 16 : Southern coastal, 17 : North eastern coastal, 18 : Central eastern coastal, 19 : South eastern coastal

- Risk Premium for Rice Farm Revenue

Distribution and climate change risk

- Risk is an another type of economic cost for a risk-averse decision maker.
- Distributional shape indicates the lower mean and the higher risk in the future.

[Change in Rice Revenue Distribution]



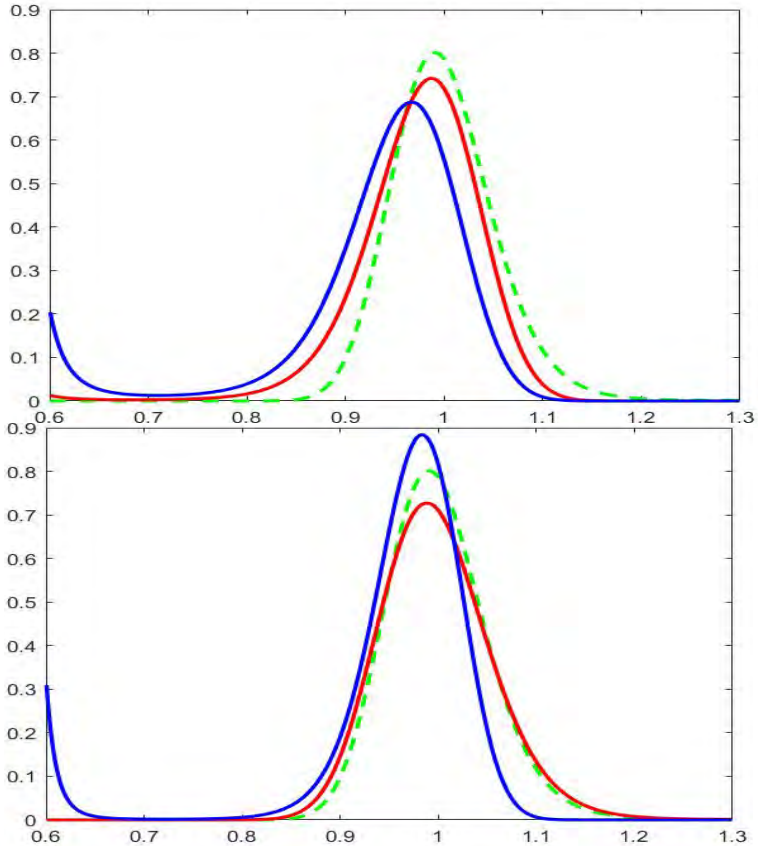
won/10a

(2001~2010) V.S. (2011~2020)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	756,463 (0.98)	2,973 (1.41)	753,490 (0.98)
RCP8.5	765,340 (0.99)	3,022 (1.44)	762,318 (0.99)

Note1 : green line : reference (2001-2010), red line : RCP 4.5, blue line : RCP 8.5
Note2 : figures in parenthesis are the ratio of figures in RCP scenario to figures in reference.

- Risk Premium for Rice Farm Revenue

[Change in Rice Revenue Distribution]



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(2001~2010) V.S. (2021~2030)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	752,815.6 (0.97)	3302.9 (1.56)	749512.7 (0.97)
RCP8.5	723,368.8 (0.94)	8832.8 (4.20)	714535.9 (0.93)

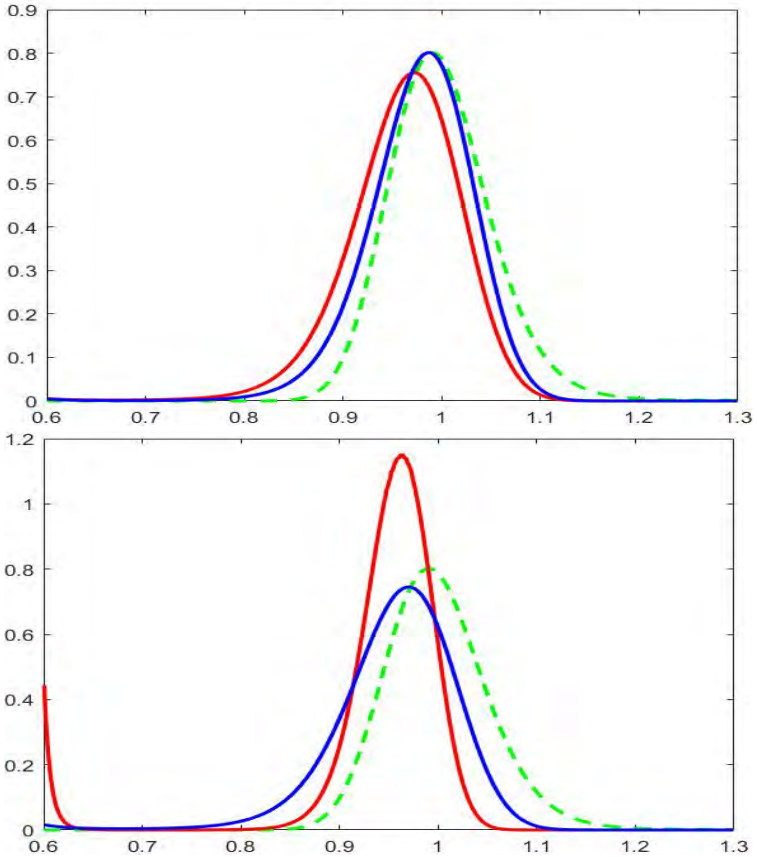
(2001~2010) V.S. (2031~2040)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	771,450 (0.99)	2,534 (1.2)	768,915 (0.99)
RCP8.5	742,735 (0.96)	7,475 (3.55)	735,260 (0.95)

Note1 : green line : reference (2001-2010), red line : RCP 4.5, blue line : RCP 8.5

Note2 : figures in parenthesis are the ratio of figures in RCP scenario to figures in reference.

- Risk Premium for Rice Farm Revenue

[Change in Rice Revenue Distribution]



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(2001~2010) V.S. (2041~2050)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	742,355 (0.96)	2,906 (1.38)	739,449 (0.96)
RCP8.5	754,976 (0.98)	2,452 (1.16)	752,524 (0.97)

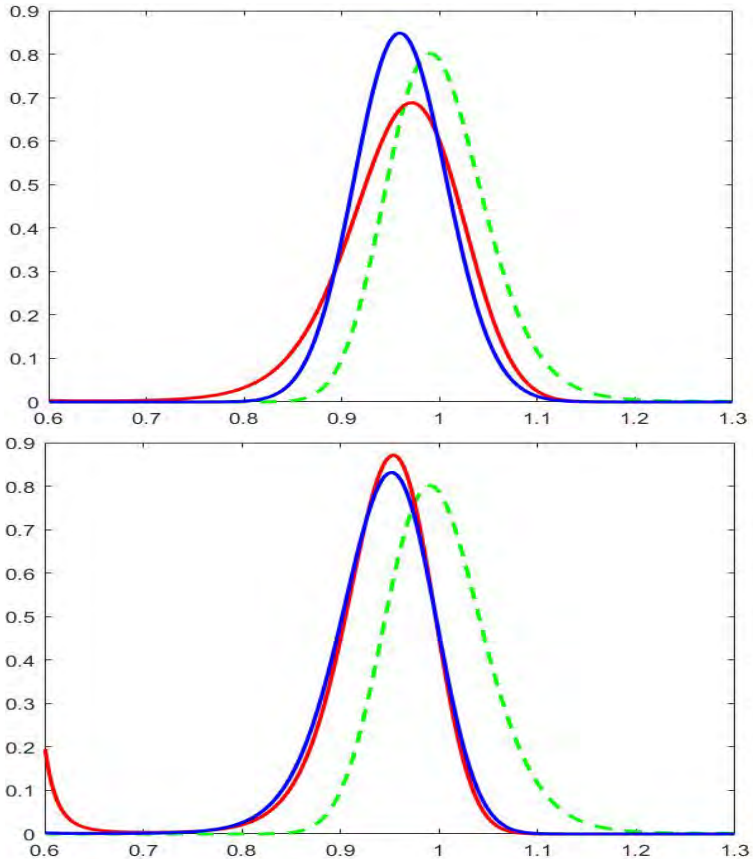
(2001~2010) V.S. (2051~2060)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	731,054 (0.95)	5,806 (2.76)	725,248 (0.94)
RCP8.5	739,024 (0.96)	3,468 (1.65)	735,556 (0.95)

Note1 : green line : reference (2001-2010), red line : RCP 4.5, blue line : RCP 8.5

Note2 : figures in parenthesis are the ratio of figures in RCP scenario to figures in reference.

- Risk Premium for Rice Farm Revenue

[Change in Rice Revenue Distribution]



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(2001~2010) V.S. (2061~2070)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	740,873 (0.96)	3,436 (1.63)	737,437 (0.96)
RCP8.5	742,338 (0.96)	1,789 (0.85)	740,549 (0.96)

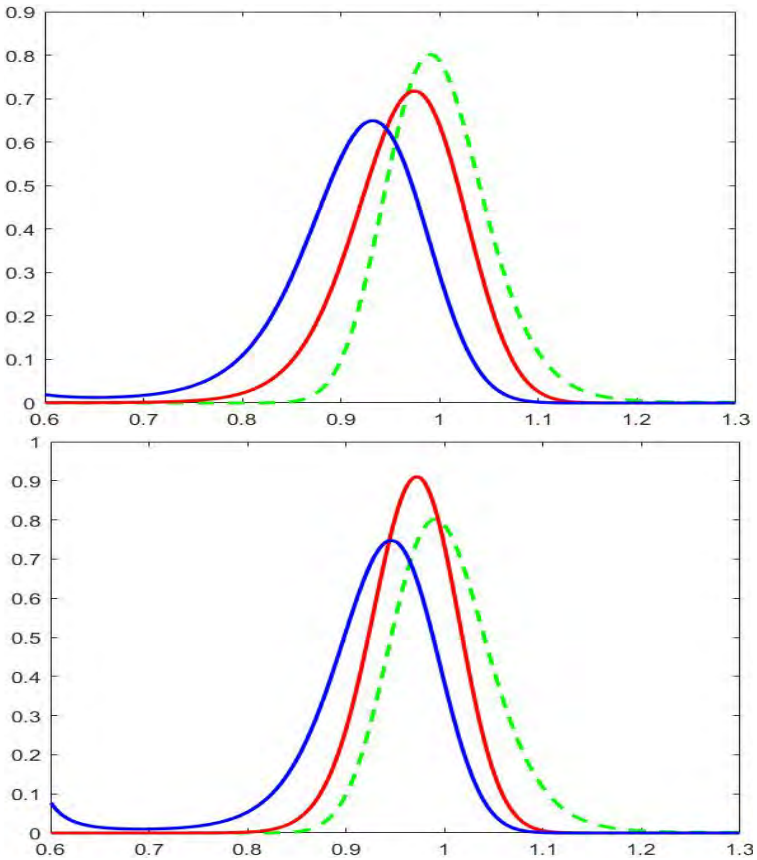
(2001~2010) V.S. (2071~2080)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	721,710 (0.93)	5,673 (2.69)	716,037 (0.93)
RCP8.5	728,211 (0.94)	2,270 (1.08)	725,940 (0.94)

Note1 : green line : reference (2001-2010), red line : RCP 4.5, blue line : RCP 8.5

Note2 : figures in parenthesis are the ratio of figures in RCP scenario to figures in reference.

- Risk Premium for Rice Farm Revenue

[Change in Rice Revenue Distribution]



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(2001~2010) V.S. (2081~2090)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	745,080 (0.96)	2,854 (1.36)	742,227 (0.96)
RCP8.5	705,811 (0.91)	4,748 (2.26)	701,063 (0.91)

(2001~2010) V.S. (2091~2100)			
Scenario	Revenue	Risk Premium	Certainty Equivalent
RCP4.5	747,832 (0.97)	1,589 (0.75)	746,243 (0.97)
RCP8.5	715,571 (0.93)	5,110 (2.43)	710,461 (0.92)

Note1 : green line : reference (2001-2010), red line : RCP 4.5, blue line : RCP 8.5

Note2 : figures in parenthesis are the ratio of figures in RCP scenario to figures in reference.

- Findings

Mean rice productivity tends to decrease across time and space

- Rice productivity is expected to be reduced in the future reflecting an increase in heat stress level and change in growth duration.
- However, reduction rates vary considerably across regions since each region confronts different weather patterns implying regional heterogeneity.

Increase in rice production risk due to risky factors

- Risky Factors with extreme temperature, disease and insect pest create variance increase and a negative skewness tendency in yields.
- Severe yield reduction is found under the RCP 8.5 scenario, however, the risk premium of the RCP 4.5 is relatively higher than the RCP 8.5 in the second stage (2041-2070) implying mild climate change scenario also needs to be treated with great importance.

Thank you and any questions**?**