Chapter 5

Development of the Rice Econometric Model with Endogenous Water in Vietnam (REMEW-VIET)

5-1. Introduction

The international price of rice surged from $385/metric ton (MT) in January 2008 to $962/MT in May 2008. The drought in Australia and the sharp rise in demand for biofuels lead a higher price for wheat and maize. The price spikes of these crops contributed to the increase in rice prices; however, cold weather damage of rice in Vietnam was thought to be the primary factor in the price spike of rice.

Vietnam’s share in world rice trade increased from 15.5% in 2007 to 20.2% in 2008. As Vietnam trade share has increased, the domestic price of rice in Vietnam is increasingly linked to the world price of rice. Modeling supply and demand for rice in this country is then critical for the evaluation of impacts of environmental changes on the world rice market.

5-2. Agricultural policies related to rice production

In the winter season from 2007 to 2008, most nursery rice was stunned decayed due to cold weather in the region. Concerned about domestic supplies, the Government of Vietnam banned the export of rice. Vietnamese rice exports are controlled by the Rice Export Management Committee which is headed by the Prime Minister.

IFPRI (1996) examined impacts of elimination of rice the export quota on the rice price and farm income using a spatial equilibrium model. They also examined the impacts of elimination of internal trade restrictions on the rice market. David (1994) summarized the price policies of agricultural products in 1990’s.

5-3. Model

The model in Vietnam is regional model for eight regions and the basic structure of the model is same as those of other countries. There are three types of cultivation, i.e., spring, summer, and winter season rice. Transplanting of spring season rice occurs in December and the harvest occur from April to May. Transplanting period for summer season rice is from May to June and harvest runs from September to October. Transplanting occurs from September to October for winter season rice and the harvesting occurs during December in the Mekong Delta region. These cultivation periods are based on the cropping calendars in USDA(1994). The spring and summer season rice are cultivated in irrigated fields as a two season crop while the winter season rice is cultivated in rain-fed fields as single season crop. The generalized forms of the supply and demand model of rice are as follows:

Yield function of spring season:
\[ YS' = f_{RS}(T, ET_{DEC', i}, \ldots, ET_{OCT', i}) \]  
Planted Area function of spring season:
\[ AS' = f_{AS}(FP_{i}, EYS', ET_{JAN', i}) \]

Production of spring season:
\[ QS' = YS'AS', QS = \sum QS' \]

Yield function of summer season:
\[ YM = f_{YM}(T, ET_{MAR', i}, \ldots, ET_{OCT', i}) \]

Planted Area function of summer season:
\[ AM' = f_{MS}(FP_{i}, EYM', ET_{JAN', i}, \ldots, ET_{AUG', i}) \]

Production of summer season:
\[ QM' = YMAM', QM = \sum QM' \]

Yield function of winter season:
\[ YW' = f_{RW}(T, ET_{JAN', i}, \ldots, ET_{NOV', i}) \]

Planted Area function of winter season:
\[ AW' = f_{AW}(T, FP_{i}, EYW', ET_{FEB', i}, \ldots, ET_{DEC', i}) \]

Planted Area function of winter season in the Mekong Delta region:
\[ AW_{MDR} = f_{AW}(T, FP_{i}, EYW'_{MDR}, ET_{JAN', i}, ET_{OCT', i}) \]

Production of winter season:
\[ QW' = YW'AW', QW = \sum QW' \]

Total production:
\[ Q = 0.667(QS + QM + QW) \]

Export function:
\[ EXP = f(WP*EXR, Q) \]

Stock change function:
\[ STC = f(FP_{i}, Q_{i}) \]

Total supply:
\[ QD = Q + IMP - EXP - STC \]

Demand function:
\[ QD/POP = f(RP, GDP/POP) \]

Price linkage function:
\[ FP = f(RP), \quad (5-19) \]

where \( i \) is the region, \( t \) denotes that the data are measured at time \( t \), \( T \) is a time trend, \( ET_{i,n} \) through \( ET_{i,12} \) are monthly evapotranspiration values for January through December, \( YS, AS, EYS, \) and \( QS \) are yield, planted area, expected yield, and production of spring season rice, \( YM, AM, EYM, \) and \( QM \) are yield, planted area, expected yield, and production of summer season rice, \( YW, AW, EYW, \) and \( QW \) are yield, planted area, expected yield, and production of winter season rice, \( Q \) is total rice production, \( IMP \) is imports, \( EXP \) is exports, \( STC \) is the annual change of stocks, i.e., ending stock minus beginning stock, \( QD \) is total supply, \( POP \) is population, \( GDP \) is gross domestic products, \( EXR \) is exchange rate, \( WP \) is the world price of rice (Thailand, 35% broken, FOB), \( FP \) is the producer price, \( RP \) is the retail price. All functions are specified as linear functions.

The planted area function is based on the naïve expectation model because Mekong Delta region, where is the main production region, located in lower Mekong River. Water harvesting and forecasting of water supply changes in the lower elevation regions are easier than those in upper regions, therefore the

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![Fig. 5-1. Flowchart of the rice production sector of Vietnam rice model](image-url)

![Fig. 5-2. Flowchart of supply and demand sector of Vietnam rice model](image-url)
planted area functions of the Vietnamese model take a simpler form than those of the Laotian and Cambodian models.

5-4. Data

The time series data for each region for production and planted area for the three types of rice cultivation is provided by the General Statistics Office of the Statistical Publishing House of Vietnam. The rice farm price is obtained from FAO-STAT and the retail rice price is obtained from the USDA. These prices are national average prices for Vietnam. CPI, GDP, GDP deflator and population are from the ADB and the exchange rate and the world price of rice are numbers from the IMF. The estimation period for the yield and planted area functions in the Mekong Delta region, imports, stock change, and demand functions for the country as a whole are from 1985 to 2000 which starts in the earliest available year for CPI and ends in the last year of available ET values. Functions for yield and planted area in regions except the Mekong Delta region are estimated using pooled data from 1985 to 2000 for the seven regions.

5-5. Estimation results of all functions

The yield functions of spring, summer, and winter season rice are not estimated for each region due to the lack of time series data. Parameters are obtained by estimating one function which includes provincial dummies using pooled data. The data set of spring and winter season rice consists of eight regions for sixteen years, and those for summer rice consists of five regions for sixteen years.

The estimation periods of these yield functions are from 1985 to 2000 which starts in the earliest available year for statistics of production of the three seasons and ends in the last year of available ET values.

The planted area functions of the three types of rice are also estimated using pooled data; however, the planted area functions in the Mekong Delta region are estimated using only time series data because the trend of the planted area is quite different from other regions.

Finally, estimated results of export, stock change, demand, and price linkage function are shown. The estimation method of all functions is OLS.

5-5-1. Yield functions

5-5-1-1. Yield function of spring season rice

5-5-1-1-1. Yield function of spring season rice pooled

\[
YS = 27.27637 + 1.05535 \times \text{TREND} \\
\text{(0.98)}
\]

5-5-1-1-2. Yield function of spring season rice in Red River Delta region

\[
YS_{RRD} = 27.2672 + 2.49315 \times \text{TREND} \\
- 4.58713 \times \ln(\text{ETRRD}_\text{DEC},-1) \\
- 3.08812 \times \ln(\text{ETRRD}_\text{JAN}) \\
+ 6.80434 \times \ln(\text{ETRRD}_\text{FEB}) \\
+ 11.35640 \times \ln(\text{ETRRD}_\text{MAY}) \\
- 16.18149 \times \ln(\text{ETRRD}_\text{JUL}) \\
\text{Adj } R^2 = 0.8321 \\
\text{DW} = 1.725
\]
Red River Delta region
ETRRD_MAY Evapotranspiration for May in Red River Delta region
ETRRD_JLY Evapotranspiration for July in Red River Delta region

5-5-1-1-3. Yield function of spring season rice in North East region
YS_NE = +27.27637 + 1.05535 * TREND - 4.58713 * ln(ETNE_DECt-1) + 7.63748*ln(ETNE_JAN) + 11.35640*ln(ETNE_MAY) - 16.18149*ln(ETNE_JLY)
YS_NE Yield of spring rice in North East region TREND Linear time trend 1976=1
ETNE_DECt-1 Evapotranspiration for December (previous calendar year) in North East region ETNE_JAN Evapotranspiration for January in North East region ETNE_MAY Evapotranspiration for May in North East region ETNE_JLY Evapotranspiration for July in North East region

5-5-1-1-4. Yield function of spring season rice in North West region
YS_NW = +27.27637 + 1.05535 * TREND - 4.58713 * ln(ETNW_DECt-1) + 7.63748*ln(ETNW_JAN) + 11.35640*ln(ETNW_MAY) - 16.18149*ln(ETNW_JLY)
YS_NW Yield of spring rice in North West region TREND Linear time trend 1976=1
ETNW_DECt-1 Evapotranspiration for December (previous calendar year) in North West region ETNW_JAN Evapotranspiration for January in North West region ETNW_MAY Evapotranspiration for May in North West region ETNW_JLY Evapotranspiration for July in North West region

5-5-1-1-5. Yield function of spring season rice in North Central region
YS_NC = +27.27637 + 1.05535 * TREND - 4.58713 * ln(ETCH_DECt-1) + 7.63748*ln(ETCH_JAN) + 11.35640*ln(ETCH_MAY) - 16.18149*ln(ETCH_JLY) - 22.97368*ln(ETCH_MAR) + 24.38146*ln(ETCH_APR) + 11.35640*ln(ETCH_MAY) - 16.18149*ln(ETCH_JLY)
YS_NC Yield of spring rice in North Central region TREND Linear time trend 1976=1
ETCH_DECt-1 Evapotranspiration for December (previous calendar year) in Central Highlands region ETCH_JAN Evapotranspiration for January in Central Highlands region ETCH_MAY Evapotranspiration for May in Central Highlands region ETCH_APR Evapotranspiration for April in Central Highlands region ETCH_JLY Evapotranspiration for July in Central Highlands region

5-5-1-1-6. Yield function of spring season rice in South Central region
YS_SC = +27.27637 + 1.05535 * TREND - 4.58713 * ln(ETSC_DECt-1) + 7.63748*ln(ETSC_JAN) + 11.35640*ln(ETSC_MAY) - 16.18149*ln(ETSC_JLY)
YS_SC Yield of spring rice in South Central region TREND Linear time trend 1976=1
ETSC_DECt-1 Evapotranspiration for December (previous calendar year) in South Central region ETSC_JAN Evapotranspiration for January in South Central region ETSC_MAY Evapotranspiration for May in South Central region ETSC_JLY Evapotranspiration for July in South Central region

5-5-1-1-7. Yield function of spring season rice in Central Highlands region
YS_CH = +27.27637 + 1.05535 * TREND - 4.58713 * ln(ETCH_DECt-1) + 7.63748*ln(ETCH_JAN) - 22.97368*ln(ETCH_MAR) + 24.38146*ln(ETCH_APR) + 11.35640*ln(ETCH_MAY) - 16.18149*ln(ETCH_JLY)
YS_CH Yield of spring rice in Central Highlands region TREND Linear time trend 1976=1
ETCH_DECt-1 Evapotranspiration for December (previous calendar year) in Central Highlands region ETCH_JAN Evapotranspiration for January in Central Highlands region ETCH_MAY Evapotranspiration for May in Central Highlands region ETCH_APR Evapotranspiration for April in Central Highlands region ETCH_JLY Evapotranspiration for July in Central Highlands region

5-5-1-1-8. Yield function of spring season rice in South East region
YS_SE = +27.27637 + 1.05535 * TREND - 4.58713 * ln(ETSE_DECt-1) + 7.63748*ln(ETSE_JAN) + 11.35640*ln(ETSE_MAY) - 16.18149*ln(ETSE_JLY)
YS_SE Yield of spring rice in South East region TREND Linear time trend 1976=1
ETSE_DECt-1 Evapotranspiration for December (previous calendar year) in South East region ETSE_JAN Evapotranspiration for January in South East region ETSE_MAY Evapotranspiration for May in South East region ETSE_JLY Evapotranspiration for July in South East region
5.5-1-1-9. Yield function of spring season rice in Mekong River Delta region

\[
YS_{MRD} = 27.27637 + 0.63636 \times \text{TREND} + 0.41566 \times \ln(ETMRD_{DEC} - 1) + 7.63748 \times \ln(ETMRD_{JAN}) + 11.35640 \times \ln(ETMRD_{MAY}) - 16.18149 \times \ln(ETMRD_{JLY})
\]

YS_{MRD} Yield of spring rice in Mekong River Delta region

TREND Linear time trend 1976=1

ETMRD_{DEC} Evapotranspiration for December (previous calendar year) in Mekong River Delta region

ETMRD_{JAN} Evapotranspiration for January in Mekong River Delta region

ETMRD_{MAY} Evapotranspiration for May in Mekong River Delta region

ETMRD_{JLY} Evapotranspiration for July in Mekong River Delta region

5.5-1-2. Yield function of summer season rice

5.5-1-2-1. Yield function of summer season rice pooled

\[
YM = 57.36595 + 4.03 \times 213544 \times \text{DR84} + 0.13312 \times \text{TREND} + 5.11125 \times \text{TREND} \times \text{DR84} + 68.15874 \times \ln(\text{TREND}) \times \text{DR84} - 2.65131 \times \ln(\text{ETMAR}) + 24.22034 \times \ln(\text{ETMAY}) - 25.55856 \times \ln(\text{ETOCT}) - 8.05409 \times \ln(\text{ETOCT})
\]

YM Yield of summer season rice

TREND Linear time trend 1976=1

ETMAR Evapotranspiration value for March

ETMAY Evapotranspiration value for May

ETJUL Evapotranspiration value for July

ETAUG Evapotranspiration value for August

ETSEP Evapotranspiration value for September

ETOCT Evapotranspiration value for October

5.5-1-2-2. Yield function of summer season rice in North Central region

\[
YM_{NC} = 235.60139 + 5.24437 \times \text{TREND} + 68.15874 \times \ln(\text{TREND}) + 2.65131 \times \ln(\text{ETMAR}) - 32.78468 \times \ln(\text{ETMAY}) - 27.27386 \times \ln(\text{ETJUL}) + 43.10634 \times \ln(\text{ETSEP}) - 8.05409 \times \ln(\text{ETOCT})
\]

YM_{NC} Yield of summer season rice in North Central region

TREND Linear time trend 1976=1

ETNC_MAR Evapotranspiration for March in North Central region

ETNC_JUL Evapotranspiration for July in North Central region

ETNC_AUG Evapotranspiration for August in North Central region

ETNC_SEP Evapotranspiration for September in North Central region

ETNC_OCT Evapotranspiration for October in North Central region

5.5-1-2-3. Yield function of summer season rice in South Central region

\[
YM_{SC} = 57.36595 + 0.51996 \times \text{TREND} + 2.65131 \times \ln(\text{ETSC_MAR}) - 8.05409 \times \ln(\text{ETSC_OCT})
\]

YM_{SC} Yield of summer season rice in South Central region

TREND Linear time trend 1976=1

ETSC_MAR Evapotranspiration for March in South Central region

ETSC_JUL Evapotranspiration for July in South Central region

ETSC_AUG Evapotranspiration for August in South Central region

ETSC_SEP Evapotranspiration for September in South Central region

ETSC_OCT Evapotranspiration for October in South Central region

5.5-1-2-4. Yield function of summer season rice in Central Highlands region

\[
YM_{CH} = 57.36595 + 0.13312 \times \text{TREND} + 2.65131 \times \ln(\text{ETCH_MAR}) + 24.22034 \times \ln(\text{ETCH_MAY}) - 25.55856 \times \ln(\text{ETCH_SEP}) - 8.05409 \times \ln(\text{ETCH_OCT})
\]

YM_{CH} Yield of summer season rice in Central Highlands region

TREND Linear time trend 1976=1

ETCH_MAR Evapotranspiration for March in Central Highlands region

ETCH_JUL Evapotranspiration for July in Central Highlands region

ETCH_AUG Evapotranspiration for August in Central Highlands region

ETCH_SEP Evapotranspiration for September in Central Highlands region

ETCH_OCT Evapotranspiration for October in Central Highlands region
ETCH_MAR Evapotranspiration for March in Central Highlands region

ETCH_MAY Evapotranspiration for May in Central Highlands region

ETCH_SEP Evapotranspiration for September in Central Highlands region

ETCH_OCT Evapotranspiration for October in Central Highlands region

5-5-1-2-5. Yield function of summer season rice in South East region

YM_SE = +57.36595
+ 0.13312*TREND
+ 2.65131*ln(ETSE_MAR)
- 8.05409*ln(ETSE_OCT)

YM_SE Yield of summer season rice in South East region
TREND Linear time trend 1976=1
ETSE_MAR Evapotranspiration for March in South East region
ETSE_OCT Evapotranspiration for October in South East region

5-5-1-2-6. Yield function of summer season rice in Mekong River Delta region

YM_MRD = +57.36595
+ 0.24403*TREND
+ 2.65131*ln(ETMRD_MAR)
- 8.05409*ln(ETMRD_OCT)

YM_MRD Yield of summer season rice in Mekong River Delta region
TREND Linear time trend 1976=1
ETMRD_MAR Evapotranspiration for March in Mekong River Delta region
ETMRD_OCT Evapotranspiration for October in Mekong River Delta region

5-5-1-3. Yield function of winter season rice

5-5-1-3-1. Yield function of winter season rice pooled

YW = -21.19495
(-1.31)
- 305.42596*DR81
(-4.64)
- 45.80576*DR84
(-1.25)
+ 146.09079*DR85
(2.56)
+ 0.50778*TREND
(8.59)
+ 0.81935*TREND*DR81
(5.92)
+ 0.39529*TREND*DR82
(3.16)
+ 0.17788*TREND*DR84
(1.36)
- 0.39177*TREND*DR87
(-3.00)
- 18.78781*ln(ETJUN)*DR85
(-2.78)
-1.49071*ln(ETJUN)*DR86
(-9.14)
+ 39.4286*ln(ETJUL)*DR81
(3.57)
+ 6.65991*ln(ETJUL)*DR83
(1.53)
- 9.93575*ln(ETAUG)*DR81
(-1.59)
- 8.72378*ln(ETAUG)*DR83
(-1.99)
- 21.24006*ln(ETAUG)*DR85
(-2.38)
+ 16.49354*ln(ETAUG)*DR87
(1.86)
+ 8.89444*ln(ETSEP)
(2.51)
+ 41.95199*ln(ETSEP)*DR81
(3.33)
- 15.86032*ln(ETSEP)*DR87
(-1.78)
+ 12.77038*ln(ETOCT)*DR84
(1.75)
+ 8.21481*ln(ETOCT)*DR85
(1.41)
- 9.36005*ln(ETOCT)*DR81
(-2.31)
- 2.4949*ln(ETOCT)*DR82
(-3.94)
- 5.37945*ln(ETOCT)*DR84
(-1.33)
Adj R² = 0.9060  
DW = 1.98

YW Yield of winter rice
Trend Linear time trend 1976=1
DR81 Treatment variable for Region 81, Red River Delta
DR82 Treatment variable for Region 82, North East
DR83 Treatment variable for Region 83, North West
DR84 Treatment variable for Region 84, North Central Coast
DR85 Treatment variable for Region 85, South Central Coast
DR86 Treatment variable for Region 86, Central Highlands
DR87 Treatment variable for Region 87, South East
DR88 Treatment variable for Region 88, Mekong River Delta
ETJUN Evapotranspiration value for June
ETJUL Evapotranspiration value for July
ETAUG Evapotranspiration value for August
ETSEP Evapotranspiration value for September
ETOCT Evapotranspiration value for October
ETNOV Evapotranspiration value for November

5-5-1-3-2. Yield function of winter season rice in Red River Delta region

YW_RRD = - 326.62091
+ 1.32713 * TREND
+ 39.4286 * ln(ETRRD_JLY)
- 9.93575 * ln(ETRRD_AUG)
+ 50.84643 * ln(ETRRD_SEP)
5-5-1-3-3. Yield function of winter season rice in North East region

\[ YW_{NE} = -21.19495 + 0.90307 \times \text{TREND} + 8.89444 \times \ln(ETNE_{SEP}) - 2.24949 \times \ln(ETNE_{NOV}) \]

\[ YW_{NE} \] Yield of winter season rice in North East region

TREND Linear time trend 1976=1

ETNE_SEP Evapotranspiration for September in North East region

ETNE_NOV Evapotranspiration for November in North East region

5-5-1-3-4. Yield function of winter season rice in North West region

\[ YW_{NW} = -21.19495 + 0.50778 \times \text{TREND} + 6.65991 \times \ln(ETNW_{JLY}) - 8.72378 \times \ln(ETNW_{AUG}) + 8.89444 \times \ln(ETNW_{SEP}) \]

\[ YW_{NW} \] Yield of winter season rice in North West region

TREND Linear time trend 1976=1

ETNW_JLY Evapotranspiration for July in North West region

ETNW_AUG Evapotranspiration for August in North West region

ETNW_SEP Evapotranspiration for September in North West region

5-5-1-3-5. Yield function of winter season rice in North Central region

\[ YW_{NC} = -67.00071 + 0.68556 \times \text{TREND} + 8.89444 \times \ln(ETNC_{SEP}) + 12.77038 \times \ln(ETNC_{OCT}) - 5.37945 \times \ln(ETNC_{NOV}) \]

\[ YW_{NC} \] Yield of winter season rice in North Central region

TREND Linear time trend 1976=1

ETNC_SEP Evapotranspiration for September in North Central region

ETNC_OCT Evapotranspiration for October in North Central region

ETNC_NOV Evapotranspiration for November in North Central region

5-5-1-3-6. Yield function of winter season rice in South Central region

\[ YW_{SC} = -124.89584 + 0.50778 \times \text{TREND} - 18.78781 \times \ln(ETSC_{JUN}) - 21.24006 \times \ln(ETSC_{AUG}) + 8.89444 \times \ln(ETSC_{SEP}) + 8.23481 \times \ln(ETSC_{OCT}) \]

\[ YW_{SC} \] Yield of winter season rice in South Central region

TREND Linear time trend 1976=1

ETSC_JUN Evapotranspiration for June in South Central region

ETSC_AUG Evapotranspiration for August in South Central region

ETSC_SEP Evapotranspiration for September in South Central region

ETSC_OCT Evapotranspiration for October in South Central region

5-5-1-3-7. Yield function of winter season rice in Central Highlands region

\[ YW_{CH} = -21.19495 + 0.50778 \times \text{TREND} - 1.49071 \times \ln(ETCH_{JUN}) + 8.89444 \times \ln(ETCH_{SEP}) \]

\[ YW_{CH} \] Yield of winter season rice in Central Highlands region

TREND Linear time trend 1976=1

ETCH_JUN Evapotranspiration for June in Central Highlands region

ETCH_SEP Evapotranspiration for September in Central Highlands region

5-5-1-3-8. Yield function of winter season rice in South East region

\[ YW_{SE} = -21.19495 + 0.11601 \times \text{TREND} + 16.49354 \times \ln(ETSE_{AUG}) - 6.96588 \times \ln(ETSE_{SEP}) \]

\[ YW_{SE} \] Yield of winter season rice in South East region

TREND Linear time trend 1976=1

ETSE_AUG Evapotranspiration for August in South East region

ETSE_SEP Evapotranspiration for September in South East region

5-5-1-3-9. Yield function of winter season rice in Mekong River Delta region

\[ YW_{MRD} = -21.19495 + 0.50778 \times \text{TREND} + 8.89444 \times \ln(ETMRD_{SEP}) \]

\[ YW_{MRD} \] Yield of winter season rice in Mekong River Delta region

TREND Linear time trend 1976=1

ETMRD_SEP Evapotranspiration for September in Mekong River Delta region

5-5-2. Planted area functions

5-5-2-1. Planted area function of spring season rice

5-5-2-1-1. Planted area function of spring season rice pooled
(Less Mekong River Delta Region)

\[
\text{APS} = 25.07395 + 531.39551 \times \text{DR81} + 113.38698 \times \text{DR82} + 287.99908 \times \text{DR84} - 295.38267 \times \text{DR87} + 0.00055282 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}} \times \text{EYS}\right) \\
\times \text{SHIFT89} + 0.00132 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}} \times \text{EYS}\right) \times \text{SHIFT89} \times \text{DR81} + 0.00085279 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}} \times \text{EYS}\right) \times \text{SHIFT89} \times \text{DR82} - 0.00033167 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}} \times \text{EYS}\right) \times \text{SHIFT89} \times \text{DR83} + 0.00232 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}} \times \text{EYS}\right) \times \text{DR87} + 8.89679 \times \ln(\text{ETJAN}) \times \text{DR82} + 73.82035 \times \ln(\text{ETJAN}) \times \text{DR87} \\
\text{Adj} R^2 = 0.9976 \quad \text{DW} = 1.336
\]

5-5-2-1.3. Planted area function of spring season rice in North East region

\[
\text{APS}_{\text{NE}} = 138.46093 + 0.00140561 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) + 8.89679 \times \ln(\text{ETNE_JAN}) \\
\times \text{SHIFT89} + 0.0018728 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) \times \text{EYS}_{\text{NE}} \times \text{SHIFT89} + 0.00022115 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) \times \text{EYS}_{\text{NE}} \times \text{SHIFT89} + 8.89679 \times \ln(\text{ETNE_JAN}) \\
\times \text{SHIFT89} \\
\text{APS}_{\text{NE}} \text{ Planted area of spring season rice in North East region} \\
\text{RPPDt-1 Retail paddy price lagged (000dong/MT)} \\
\text{NGDPD GDP Deflator} \\
\text{EYS}_{\text{NE}} \text{ Expected (trend) yield of spring season rice in North East region} \\
\text{SHIFT89 Intercept Shift, SHIFT89=1 in 1989 and beyond, zero before} \\
\text{ETNE_JAN Evapotranspiration for January in North East region}
\]

5-5-2-1.4. Planted area function of spring season rice in North West region

\[
\text{APS}_{\text{NW}} = 25.07395 + 0.00022115 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) + 8.89679 \times \ln(\text{ETNW_JAN}) \times \text{SHIFT89} + 0.00055282 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) \times \text{EYS}_{\text{NW}} \times \text{SHIFT89} + 8.89679 \times \ln(\text{ETNW_JAN}) \times \text{SHIFT89} \\
\text{APS}_{\text{NW}} \text{ Planted area of spring season rice in North West region} \\
\text{RPPDt-1 Retail paddy price lagged (000dong/MT)} \\
\text{NGDPD GDP Deflator} \\
\text{EYS}_{\text{NW}} \text{ Expected (trend) yield of spring season rice in North West region} \\
\text{SHIFT89 Intercept Shift, SHIFT89=1 in 1989 and beyond, zero before}
\]

5-5-2-1.5. Planted area function of spring season rice in North Central region

\[
\text{APS}_{\text{NC}} = 313.07303 + 0.00055282 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) + 8.89679 \times \ln(\text{ETNC_JAN}) \times \text{SHIFT89} + 0.00055282 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) \times \text{EYS}_{\text{NC}} \times \text{SHIFT89} + 8.89679 \times \ln(\text{ETNC_JAN}) \times \text{SHIFT89} \\
\text{APS}_{\text{NC}} \text{ Planted area of spring season rice in North Central region} \\
\text{RPPDt-1 Retail paddy price lagged (000dong/MT)} \\
\text{NGDPD GDP Deflator} \\
\text{EYS}_{\text{NC}} \text{ Expected (trend) yield of spring season rice in North Central region} \\
\text{SHIFT89 Intercept Shift, SHIFT89=1 in 1989 and beyond, zero before}
\]

5-5-2-1.6. Planted area function of spring season rice in South Central region

\[
\text{APS}_{\text{SC}} = 160.44496 + 0.00055282 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) + 8.89679 \times \ln(\text{ETSC_JAN}) \times \text{SHIFT89} + 0.00055282 \times \left(\frac{\text{RPPDt-1}}{\text{NGDPD}}\right) \times \text{EYS}_{\text{SC}} \times \text{SHIFT89} + 8.89679 \times \ln(\text{ETSC_JAN}) \times \text{SHIFT89} \\
\text{APS}_{\text{SC}} \text{ Planted area of spring season rice in North Central region} \\
\text{RPPDt-1 Retail paddy price lagged (000dong/MT)} \\
\text{NGDPD GDP Deflator} \\
\text{EYS}_{\text{SC}} \text{ Expected (trend) yield of spring season rice in North Central region} \\
\text{SHIFT89 Intercept Shift, SHIFT89=1 in 1989 and beyond, zero before}
\]
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5-5-2-1. Plant area function of spring season rice in Central Highlands region

\[
APS_{CH} = + \frac{25.07395}{NGDPD} + \frac{0.00055282 \times RPPDt-1}{NGDPD/100} 
+ \frac{0.00055282 \times EYS_{CH} \times SHIFT89}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.00232 \times RPPDt-1/(NGDPD/100) \times EYS_{CH} \times SHIFT89}{RPPDt-1/(NGDPD/100)} 
+ \frac{3.82035 \times \ln(ETSE_JAN)}{RPPDt-1/(NGDPD/100)} 
+ \frac{5.382035 \times \ln(ETSE_JAN)}{RPPDt-1/(NGDPD/100)} 
\]

5-5-2-1-8. Plant area function of spring season rice in South East region

\[
APS_{SE} = -270.30872 + \frac{0.00055282 \times RPPDt-1/(NGDPD/100)}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.00232 \times RPPDt-1/(NGDPD/100)}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.00232 \times RPPDt-1/(NGDPD/100)}{RPPDt-1/(NGDPD/100)} 
+ \frac{7.382035 \times \ln(ETSE_JAN)}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.00232 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.00232 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR85}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.0019 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR86}{RPPDt-1/(NGDPD/100)} 
+ \frac{0.00378 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR87}{RPPDt-1/(NGDPD/100)} 
+ \frac{-50.50563 \times \ln(ETJUL)}{RPPDt-1/(NGDPD/100)} 
+ \frac{57.92589 \times \ln(ETJUL)}{RPPDt-1/(NGDPD/100)} 
+ \frac{35.9262 \times \ln(ETMAY)}{RPPDt-1/(NGDPD/100)} 
+ \frac{295.61269 \times \ln(ETAUG)}{RPPDt-1/(NGDPD/100)} 
\]

5-5-2-1-9. Plant area function of spring season rice in Mekong River Delta region

\[
APS_{MRD} = -618.98587 + \frac{338.21281}{DR85} + \frac{262.30685}{DR86} - \frac{126.79262}{DR86} 
+ \frac{4.96 \times APS_{MRDt-1}}{DR86} + \frac{16.35357 \times TREND}{DR86} 
+ \frac{0.00310 \times RPPDt-1/(NGDPD/100)}{DR86} 
+ \frac{0.00282 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89}{DR86} 
+ \frac{0.00232 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \timesSHIFT89 \times DR85}{DR86} 
+ \frac{0.0019 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR86}{DR86} 
+ \frac{0.00378 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR87}{DR86} 
+ \frac{-50.50563 \times \ln(ETJUL)}{DR86} 
+ \frac{57.92589 \times \ln(ETJUL)}{DR86} 
+ \frac{35.9262 \times \ln(ETMAY)}{DR86} 
+ \frac{295.61269 \times \ln(ETAUG)}{DR86} 
\]

5-5-2-2. Plant area function of summer season rice

5-5-2-2-1. Plant area function of summer season rice pooled

(Less Mekong River Delta Region)

\[
APM = 338.21281 + 262.30685 \times DR85 - 126.79262 \times DR86 
+ 4.96 \times APS_{MRDt-1} - 16.35357 \times TREND 
+ 0.00310 \times RPPDt-1/(NGDPD/100) 
+ 0.00282 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 
+ 0.00232 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR85 
+ 0.0019 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR86 
+ 0.00378 \times ((RPPDt-1/(NGDPD/100)) \times EYM) \times SHIFT89 \times DR87 
+ 50.50563 \times \ln(ETJUL) 
+ 57.92589 \times \ln(ETJUL) \times DR85 
+ 35.9262 \times \ln(ETMAY) \times DR86 
+ 295.61269 \times \ln(ETAUG) \times DR87 
\]

Adj R² = 0.9320

5-5-2-2-2. Plant area function of summer season rice

(Less Mekong River Delta Region)
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VNRPPt-1 Retail paddy price (000dong/MT)
VNGDPD GDP Deflator
EYM Expected (trend) yield of summer season rice

5-5-2-2-2. Planted area function of summer season rice in North Central region

APM_NC = - 338.21281
+ 0.00028 * RPPDt-1/(NGDPD/100)
* EYM_NC * SHIFT89
- 0.50563 * ln(ETNC_JLY)

APM_NC = Planted area of summer season rice in North Central region
RPPDt-1 Retail paddy price lagged (000dong/MT)
NGDPD GDP Deflator
EYM_NC Expected (trend) yield of summer season rice in North Central region
SHIFT89 Intercept Shift, SHIFT89 = 1 in 1989 and beyond, zero before
ETNC_JLY Evapotranspiration for July in North Central region

5-5-2-2-2-3. Planted area function of summer season rice in South Central region

APM_SC = + 75.90596
+ 0.00050 * RPPDt-1/(NGDPD/100)
* EYM_SC * SHIFT89
+ 7.42026 * ln(ETSC_JLY)

APM_SC = Planted area of summer season rice in South Central region
RPPDt-1 Retail paddy price lagged (000dong/MT)
NGDPD GDP Deflator
EYM_SC Expected (trend) yield of summer season rice in South Central region
SHIFT89 Intercept Shift, SHIFT89 = 1 in 1989 and beyond, zero before
ETSC_JLY Evapotranspiration for July in South Central region

5-5-2-2-2-4. Planted area function of summer season rice in Central Highlands region

APM_CH = + 211.42019
+ 0.00282 * RPPDt-1/(NGDPD/100)
* EYM_CH * SHIFT89
- 50.50563 * ln(ECH_JLY)

APM_CH = Planted area of summer season rice in Central Highlands region
RPPDt-1 Retail paddy price lagged (000dong/MT)
NGDPD GDP Deflator
EYM_CH Expected (trend) yield of summer season rice in Central Highlands region
SHIFT89 Intercept Shift, SHIFT89 = 1 in 1989 and beyond, zero before
ECH_JLY Evapotranspiration for July in Central Highlands region

5-5-2-2-2-5. Planted area function of summer season rice in South East region

APM_SE = - 1202.76176
+ 0.00472 * RPPDt-1/(NGDPD/100)
* EYM_SE * SHIFT89

APM_SE = Planted area of summer season rice in South East region
RPPDt-1 Retail paddy price lagged (000dong/MT)
NGDPD GDP Deflator
EYM_SE Expected (trend) yield of summer season rice in South East region
SHIFT89 Intercept Shift, SHIFT89 = 1 in 1989 and beyond, zero before
ETSE_JLY Evapotranspiration for July in South East region

5-5-2-2-2-6. Planted area function of summer season rice in Mekong River Delta region

APM_MRD = - 2259.94485
(-3.86)
+ 89.48408 * TREND
(26.56)
+ 0.00845 * RPPDt-1/(NGDPD/100)
* EYM_MRD * SHIFT89
(1.72)
+ 402.13189 * ln(ETMRD_MAY)
(3.08)
+ 189.50938 * D99
(3.27)

Adj R² = 0.9877
DW = 1.521

5-5-2-3. Planted area function of winter season rice

5-5-2-3-1. Planted area function of winter season rice pooled (Less Mekong River Delta Region)

APW = 390.12531
(6.37)
- 4.73004 * TREND * D84
(-8.26)
- 0.51195 * TREND * D86
(-3.82)
+ 1.76444 * TREND * D87
(4.33)
+ 0.00034398 * ((RPPQt-1/NGDPD)*EYW)

5-5-2-3-2. Planted area function of winter season rice in Mekong River Delta region

APM_MRD = - 2259.94485
(-3.86)
+ 89.48408 * TREND
(26.56)
+ 0.00845 * RPPDt-1/(NGDPD/100)
* EYM_MRD * SHIFT89
(1.72)
+ 402.13189 * ln(ETMRD_MAY)
(3.08)
+ 189.50938 * D99
(3.27)

Adj R² = 0.9877
DW = 1.521
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*SHIFT89  
(1.56)  
+ .00116 *(RPPDt-1/NGDPD)*EYW  
*DR81  
(2.13)  
+ .00179 *(RPPDt-1/NGDPD)*EYW  
*DR81  
(1.51)  
- 17.54514 *ln(ETJUN)  
(-1.72)  
+ 93.45954 *ln(ETJUL)*DR81  
(72.99)  
+ 74.1484 *ln(ETJUL)*DR82  
(3.71)  
+ 36.67058*ln(ETJUL)*DR84  
(23.06)  
- 35.9352 *ln(ETAUG)  
(-4.03)  
+ 33.9763 *ln(ETAUG)*SHFT89  
(2.43)  
- 17.54514 *ln(ETOCT)  
(-1.72)  
+ 93.45954 *ln(ETOCT)*DR81  
(72.99)  
+ 36.67058 *ln(ETOCT)*DR82  
(23.06)  
- 35.9352 *ln(ETOCT)*DR83  
(-4.03)  
+ 33.9763 *ln(ETOCT)*DR84  
(2.43)  
- 17.54514 *ln(ETOCT)*DR87  
(-1.72)  
Adj R^2 = 0.9980  
DW = 1.187

TREND  
Linear time trend 1976=1  
DR81  
Treatment variable for Region 81, Red River Delta  
DR82  
Treatment variable for Region 82, North East  
DR83  
Treatment variable for Region 83, North West  
DR84  
Treatment variable for Region 84, North Central Coast  
DR86  
Treatment variable for Region 86, Central Highlands  
DR87  
Treatment variable for Region 87, South East  
SHFT89  
Intercept Shift, SHFT89=1 in 1989 and beyond, zero before  
RPPDt-1  
Retail paddy price lagged (000dong/MT)  
NGDPD  
GDP Deflator  
EYW  
Expected (trend) yield of winter season rice  
ETJUN  
Evapotranspiration value for June  
ETJUL  
Evapotranspiration value for July  
ETAUUG  
Evapotranspiration value for August  
ETOCT  
Evapotranspiration value for October

5-5-2-3-3. Planted area function of winter season rice in North East region

APW_NE = + 390.12531  
+ 0.00034398 * RPPDt-1/(NGDPD/100)  
*EYW_NE * SHFT89  
- 17.54514 * In(ETNE_JUN)  
+ 74.14840 * In(ETNE_JLY)  
- 35.93520 * In(ETNE_AUG)  
- 33.14568 * In(ETNE_OCT)  
APW_NE  
Planted area of winter season rice in North East region  
RPPDt-1  
Retail paddy price lagged (000dong/MT)  
NGDPD  
GDP Deflator  
EYW_NE  
Expected (trend) yield of winter season rice in North East region  
SHFT89  
Intercept Shift, SHFT89=1 in 1989 and beyond, zero before  
ETNE_JUN  
Evapotranspiration for June in North East region  
ETNE_JLY  
Evapotranspiration for July in North East region  
ETNE_AUG  
Evapotranspiration for August in North East region  
ETNE_OCT  
Evapotranspiration for October in North East region

5-5-2-3-4. Planted area function of winter season rice in North West region

APW_NW = + 390.12531  
+ 0.00034398 * RPPDt-1/(NGDPD/100)  
*EYW_NW * SHFT89  
- 17.54514 * In(ETNW_JUN)  
- 1.95837 * In(ETNW_JLY)  
- 42.04150 * In(ETNW_OCT)  
APW_NW  
Planted area of winter season rice in North West region  
RPPDt-1  
Retail paddy price lagged (000dong/MT)  
NGDPD  
GDP Deflator  
EYW_NW  
Expected (trend) yield of winter season rice in North West region  
SHFT89  
Intercept Shift, SHFT89=1 in 1989 and beyond, zero before  
ETNW_JUN  
Evapotranspiration for June in North West region  
ETNW_JLY  
Evapotranspiration for July in North West region  
ETNW_AUG  
Evapotranspiration for August in North West region  
ETNW_OCT  
Evapotranspiration for October in North West region

5-5-2-3-2. Planted area function of winter season rice in Red River Delta region

APW_RRD = + 390.12531  
+ 0.00034398 * RPPDt-1/(NGDPD/100)  
*EYW_RRD * SHFT89  
+ 0.00116 * RPPDt-1/(NGDPD/100)  
*EYW_RRD  
- 17.54514 * In(ETRRD_JUN)  
+ 93.45954 * ln(ETRRD_JLY)  
- 35.93520 * ln(ETRRD_AUG)  
APW_RRD  
Planted area of winter season rice in Red River Delta region  
RPPDt-1  
Retail paddy price lagged (000dong/MT)  
NGDPD  
GDP Deflator  
EYW_RRD  
Expected (trend) yield of winter season rice in Red River Delta region  
SHFT89  
Intercept Shift, SHFT89=1 in 1989 and beyond, zero before  
ETRRD_JUN  
Evapotranspiration for June in Red River Delta region  
ETRRD_JLY  
Evapotranspiration for July in Red River Delta region  
ETRRD_AUG  
Evapotranspiration for August in Red River Delta region  
ETRRD_OCT  
Evapotranspiration for October in Red River Delta region
5-5-2-3-5. Planted area function of winter season rice in North Central region

\[ \text{APW}_{\text{NC}} = 390.12531 + 4.73004 \times \text{TREND} + 0.00034398 \times \frac{\text{RPPDt-1}}{\text{NGDPD/100}} - 0.00179 \times \frac{\text{RPPDt-1}}{\text{NGDPD/100}} + 17.54514 \times \ln(\text{ETNC}_\text{JUN}) + 36.67058 \times \ln(\text{ETNC}_\text{JUL}) - 35.93520 \times \ln(\text{ETNC}_\text{AUG}) \]

**Definitions:**
- **APW**: Planted area of winter season rice
- **RPPDt-1**: Retail paddy price lagged (000dong/MT)
- **NGDPD**: GDP Deflator
- **EYW**: Expected (trend) yield of winter season rice
- **SHIFT89**: Intercept Shift, \( \text{SHIFT89}=1 \) in 1989 and beyond, zero before
- **ETNC**: Evapotranspiration for North Central region

5-5-2-3-6. Planted area function of winter season rice in South Central region

\[ \text{APW}_{\text{SC}} = 390.12531 - 0.51195 \times \text{TREND} - 0.00526 \times \frac{\text{RPPDt-1}}{\text{NGDPD/100}} + 199.47094 \times \ln(\text{ETSC}_\text{JUN}) - 214.79842 \times \ln(\text{ETSC}_\text{JUL}) - 47.92462 \times \text{D96}(\text{1.92}) \]

**Definitions:**
- **APW**: Planted area of winter season rice
- **RPPDt-1**: Retail paddy price lagged (000dong/MT)
- **NGDPD**: GDP Deflator
- **EYW**: Expected (trend) yield of winter season rice

5-5-2-3-7. Planted area function of winter season rice in Central Highlands region

\[ \text{APW}_{\text{CH}} = 390.12531 - 0.5195 \times \text{TREND} + 0.00034398 \times \frac{\text{RPPDt-1}}{\text{NGDPD/100}} - 17.54514 \times \ln(\text{ETCH}_\text{JUN}) - 35.93520 \times \ln(\text{ETCH}_\text{AUG}) \]

**Definitions:**
- **APW**: Planted area of winter season rice
- **RPPDt-1**: Retail paddy price lagged (000dong/MT)
- **NGDPD**: GDP Deflator
- **EYW**: Expected (trend) yield of winter season rice

5-5-2-3-8. Planted area function of winter season rice in South East region

\[ \text{APW}_{\text{SE}} = 390.12531 + 1.76444 \times \text{TREND} + 0.00034398 \times \frac{\text{RPPDt-1}}{\text{NGDPD/100}} - 17.54514 \times \ln(\text{ETSE}_\text{JUN}) - 35.93520 \times \ln(\text{ETSE}_\text{AUG}) + 18.80624 \times \ln(\text{ETSE}_\text{OCT}) \]

**Definitions:**
- **APW**: Planted area of winter season rice
- **RPPDt-1**: Retail paddy price lagged (000dong/MT)
- **NGDPD**: GDP Deflator
- **EYW**: Expected (trend) yield of winter season rice

5-5-2-3-9. Planted area function of winter season rice in Mekong River Delta region

\[ \text{APW}_{\text{MRD}} = 1606.51866 - 40.25703 \times \text{TREND} - 0.00526 \times \frac{\text{RPPDt-1}}{\text{NGDPD/100}} + 199.47094 \times \ln(\text{ETMRD}_\text{JUN}) - 214.79842 \times \ln(\text{ETMRD}_\text{JUL}) - 47.92462 \times \text{D96}(\text{1.92}) \]

**Definitions:**
- **APW**: Planted area of winter season rice
- **RPPDt-1**: Retail paddy price lagged (000dong/MT)
- **NGDPD**: GDP Deflator
- **EYW**: Expected (trend) yield of winter season rice

**Additional Information:**
- **TREND**: Linear time trend, 1976=1
- **SHIFT89**: Intercept Shift, \( \text{SHIFT89}=1 \) in 1989 and beyond, zero before
- **ET**: Evapotranspiration
- **D**: Dummy variable
5-5-3. Production identities

5-5-3-1. Production identities of spring season rice

5-5-3-1-1. Production identity of spring season rice in Red River Delta region

\[ QS_{RRD} = \frac{YS_{RRD}}{10} \cdot APS_{RRD} \]

- \( QS_{RRD} \): Spring season rice production, Red River Delta (1000 metric tons)
- \( YS_{RRD} \): Spring season rice yield, Red River Delta (1000 kg/hectare)
- \( APS_{RRD} \): Spring season rice planted area, Red River Delta (1000 hectares)

5-5-3-1-2. Production identity of spring season rice in North East region

\[ QS_{NE} = \frac{YS_{NE}}{10} \cdot APS_{NE} \]

- \( QS_{NE} \): Spring season rice production, North East (1000 metric tons)
- \( YS_{NE} \): Spring season rice yield, North East (1000 kg/hectare)
- \( APS_{NE} \): Spring season rice planted area, North East (1000 hectares)

5-5-3-1-3. Production identity of spring season rice in North West region

\[ QS_{NW} = \frac{YS_{NW}}{10} \cdot APS_{NW} \]

- \( QS_{NW} \): Spring season rice production, North West (1000 metric tons)
- \( YS_{NW} \): Spring season rice yield, North West (1000 kg/hectare)
- \( APS_{NW} \): Spring season rice planted area, North West (1000 hectares)

5-5-3-1-4. Production identity of spring season rice in North Central region

\[ QS_{NC} = \frac{YS_{NC}}{10} \cdot APS_{NC} \]

- \( QS_{NC} \): Spring season rice production, North Central Coast (1000 metric tons)
- \( YS_{NC} \): Spring season rice yield, North Central Coast (1000 kg/hectare)
- \( APS_{NC} \): Spring season rice planted area, North Central Coast (1000 hectares)

5-5-3-1-5. Production identity of spring season rice in South Central region

\[ QS_{SC} = \frac{YS_{SC}}{10} \cdot APS_{SC} \]

- \( QS_{SC} \): Spring season rice production, South Central Coast (1000 metric tons)
- \( YS_{SC} \): Spring season rice yield, South Central Coast (1000 kg/hectare)
- \( APS_{SC} \): Spring season rice planted area, South Central Coast (1000 hectares)

5-5-3-2. Production identities of summer season rice

5-5-3-2-1. Production identity of summer season rice in North Central region

\[ QM_{NC} = \frac{YM_{NC}}{10} \cdot APM_{NC} \]

- \( QM_{NC} \): Summer season rice production, North Central Coast (1000 metric tons)
- \( YM_{NC} \): Summer season rice yield, North Central Coast (1000 kg/hectare)
- \( APM_{NC} \): Summer season rice planted area, North Central Coast (1000 hectares)

5-5-3-2-2. Production identity of summer season rice in South Central region

\[ QM_{SC} = \frac{YM_{SC}}{10} \cdot APM_{SC} \]

- \( QM_{SC} \): Summer season rice production, South Central Coast (1000 metric tons)
- \( YM_{SC} \): Summer season rice yield, South Central Coast (1000 kg/hectare)
- \( APM_{SC} \): Summer season rice planted area, South Central Coast (1000 hectares)

5-5-3-2-3. Production identity of summer season rice in Central Highlands region

\[ QM_{CH} = \frac{YM_{CH}}{10} \cdot APM_{CH} \]

- \( QM_{CH} \): Summer season rice production, Central Highlands (1000 metric tons)
- \( YM_{CH} \): Summer season rice yield, Central Highlands (1000 kg/hectare)
- \( APM_{CH} \): Summer season rice planted area, Central Highlands (1000 hectares)
5-5-3-3. Production identities of winter season rice
5-5-3-3-1. Production identity of winter season rice in Red River Delta region
QM_RRD = (YW_RRD/10)*APW_RRD
YW_RRD Winter season rice yield, Red River Delta (100kg/hectare)
QM_RRD Winter season rice production, Red River Delta (1000 metric tons)
APW_RRD Winter season rice planted area, Red River Delta (1000 hectares)

5-5-3-3-2. Production identity of winter season rice in North East region
QM_NE = (YW_NE/10)*APW_NE
YW_NE Winter season rice yield, North East (100kg/hectare)
QM_NE Winter season rice production, North East (1000 metric tons)
APW_NE Winter season rice planted area, North East (1000 hectares)

5-5-3-3-3. Production identity of winter season rice in North West region
QM_NW = (YW_NW/10)*APW_NW
YW_NW Winter season rice yield, North West (100kg/hectare)
QM_NW Winter season rice production, North West (1000 metric tons)
APW_NW Winter season rice planted area, North West (1000 hectares)

5-5-3-3-4. Production identity of winter season rice in South Central region
QM_SC = (YW_SC/10)*APW_SC
YW_SC Winter season rice yield, South Central (100kg/hectare)
QM_SC Winter season rice production, South Central (1000 metric tons)
APW_SC Winter season rice planted area, South Central (1000 hectares)

5-5-3-3-5. Production identity of winter season rice in Central Highlands region
QM_CH = (YW_CH/10)*APW_CH
YW_CH Winter season rice yield, Central Highlands (100kg/hectare)
QM_CH Winter season rice production, Central Highlands (1000 metric tons)
APW_CH Winter season rice planted area, Central Highlands (1000 hectares)

5-5-3-3-6. Production identity of winter season rice in South East region
QM_SE = (YW_SE/10)*APW_SE
YW_SE Winter season rice yield, South East (100kg/hectare)
QM_SE Winter season rice production, South East (1000 metric tons)
APW_SE Winter season rice planted area, South East (1000 hectares)
5-5-3-4-2. Production identity in North East region

\[ Q_{\text{NE}} = Q_{\text{NW}} + Q_{\text{SE}} + Q_{\text{MRD}} \]

5-5-3-4-3. Production identity in North West region

\[ Q_{\text{NW}} = Q_{\text{SE}} + Q_{\text{MRD}} + Q_{\text{W}} \]

5-5-3-4-4. Production identity in North Central region

\[ Q_{\text{NC}} = Q_{\text{SE}} + Q_{\text{MRD}} + Q_{\text{W}} \]

5-5-3-4-5. Production identity in South Central region

\[ Q_{\text{SC}} = Q_{\text{SE}} + Q_{\text{MRD}} + Q_{\text{W}} \]

5-5-3-4-6. Production identity in Central Highlands region

\[ Q_{\text{CH}} = Q_{\text{SE}} + Q_{\text{MRD}} + Q_{\text{W}} \]

5-5-3-4-7. Production identity in South East region

\[ Q_{\text{SE}} = Q_{\text{MRD}} + Q_{\text{W}} \]

5-5-3-4-8. Production identity in Mekong River Delta region

\[ Q_{\text{MRD}} = Q_{\text{MRD}} + Q_{\text{W}} \]

5-5-3-5. Production identities for rice types

5-5-3-5-1. Production identity of spring season rice

\[ Q = Q_{\text{SC}} + Q_{\text{W}} + Q_{\text{MRD}} + Q_{\text{R}} + Q_{\text{Ch}} + Q_{\text{SE}} + Q_{\text{MRD}} \]

5-5-3-5-2. Production identity of summer season rice

\[ Q = Q_{\text{SC}} + Q_{\text{W}} + Q_{\text{MRD}} + Q_{\text{R}} + Q_{\text{Ch}} + Q_{\text{SE}} + Q_{\text{MRD}} \]

5-5-3-5-3. Production identity of winter season rice

\[ Q = Q_{\text{SC}} + Q_{\text{W}} + Q_{\text{MRD}} + Q_{\text{R}} + Q_{\text{Ch}} + Q_{\text{SE}} + Q_{\text{MRD}} \]

5-5-3-6. Production identity for whole country

\[ Q = Q + Q + Q \]
5-5-3-7. Production identity for milled rice

\[ QME = (1000*Q*0.6667) \]

QME: Total rice production, milled equivalent (metric tons)
Q: Total (All Seasons) Rice Production, Vietnam (1000 metric tons)

5-5-4. Rice export function

\[ FEX = -1626586 \]
\[ + 0.15504*QME \]
\[ + 605.98133*(WP*NEXGI) / (NGDPD/100) \]
\[ +327.07807*(WP*NEXGI) / RRPD * SHIFT90 \]
\[ +1325.5420*(WP*NEXGI) / RRPD * SHIFT96 \]
\[ +1086048*D99 \]
\[ (4.26) \]
\[ (2.76) \]
\[ (1.51) \]
\[ (4.32) \]
\[ (3.44) \]

Adj R^2 = 0.9539  \quad \text{DW} = 2.52

QME: Rice production (milled equivalent)
WP: Thai 35% broken price in $US as reported by USDA
NEXGI: Exchange rate
NGDPD: Gross Domestic Product Deflator
RRPD: Retail paddy rice price(units)
SHIFT90: Intercept Shift, SHIFT90=1 in 1990 and beyond, zero before
SHIFT96: Intercept Shift, SHIFT96=1 in 1996 and beyond, zero before
D99: Dummy variable, D99=1 in 1999, otherwise 0

5-5-5. Rice stock change function

\[ STC = -263803 \]
\[ + 0.55952*(QME-QME_{i-1}) \]
\[ +10644*(RRPD/(NGDPD/100)-log(NRRP/(NGDPD/100)))*SHIFT96 \]
\[ +2587487*SHIFT90 \]
\[ (-1.42) \]
\[ (2.89) \]
\[ (-2.43) \]
\[ (6.61) \]

Adj R^2 = 0.7103  \quad \text{DW} = 2.294

QME: Rice production (milled equivalent)
RRPD: Retail paddy rice price (1000dong/metric ton)
NGDPD: Gross Domestic Product Deflator
SHIFT90: Intercept Shift, SHIFT90=1 in 2001 and beyond, zero before

5-5-6. Supply identity

Total supply
\[ QD = QME + IMPME - EXPME - STCME \]

QD: Total supply
QME: Total rice production, milled equivalent (metric tons)
IMPME: Rice imports, milled equivalent (metric tons)
EXPME: Rice exports, milled equivalent (metric tons)
STCME: Stock change, milled equivalent (metric tons)

5-5-7. Consumption identity

Consumption per capita
\[ QC = QD / POP / 1000 \]

QC: Rice consumption per capita (kilo gram/person)
QD: Rice supply (metric tons)
POP: Population (million people)

5-5-8. Rice demand function

\[ QC = 182382 \]
\[ + 18.15899*(RRPD/(NGDPD/100)) \]
\[ +103217*(NGDPRGI/POP) \]
\[ +6609.72483*SHTFT96 \]
\[ (-2.92) \]
\[ (5.95) \]
\[ (2.32) \]
\[ (2.26) \]

Adj R^2 = 0.9684  \quad \text{DW} = 1.877

QC: Rice consumption per capita (kilo gram/person)
QD: Rice supply (metric tons)
POP: Population (million person)
RRPD: Retail rice price (1000dong/metric ton)
NGDPRGI: Gross Domestic Product (real)
D86: Dummy variable, D86=1 in 1986, otherwise 0

5-5-9. Price linkage function

\[ RPME = -533.20297 \]
\[ +1.47755*RPPD \]
\[ +249.9007*log(TREND) \]
\[ (-2.47) \]
\[ (30.02) \]
\[ (2.61) \]

Adj R^2 = 0.9968  \quad \text{DW} = 1.271

RPME: Retail milled rice price (1000dong/metric ton)
RPPD: Retail paddy rice price (1000dong/metric ton)
TREND: Linear time trend 1975=1
Chapter 5
Development of the Rice Econometric Model with Endogenous Water in Vietnam (REMEW-VIET)

Table 5-1. Elasticities of yield of spring season rice for evapotranspiration and trend

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Red River Delta</td>
<td>1.007</td>
<td>-0.106</td>
<td>-0.071</td>
<td>0.157</td>
<td>0.262</td>
<td>-0.374</td>
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<tr>
<td>North East</td>
<td>0.619</td>
<td>-0.154</td>
<td>0.256</td>
<td>0.380</td>
<td>-0.542</td>
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<tr>
<td>North West</td>
<td>0.585</td>
<td>-0.145</td>
<td>0.242</td>
<td>0.360</td>
<td>-0.513</td>
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</tr>
<tr>
<td>North Central</td>
<td>0.551</td>
<td>-0.137</td>
<td>0.228</td>
<td>0.339</td>
<td>-0.483</td>
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<td></td>
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<tr>
<td>South Central</td>
<td>0.524</td>
<td>-0.130</td>
<td>0.217</td>
<td>0.322</td>
<td>-0.459</td>
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</tr>
<tr>
<td>Central Highlands</td>
<td>0.443</td>
<td>-0.110</td>
<td>0.183</td>
<td>-0.551</td>
<td>0.585</td>
<td>0.272</td>
<td>-0.388</td>
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</tr>
<tr>
<td>South East</td>
<td>0.539</td>
<td>-0.134</td>
<td>0.223</td>
<td>0.331</td>
<td>-0.472</td>
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<tr>
<td>Mekong River Delta</td>
<td>0.230</td>
<td>0.009</td>
<td>0.158</td>
<td>0.234</td>
<td>-0.334</td>
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Table 5-2. Elasticities of yield of summer season rice for evapotranspiration and trend

<table>
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<tr>
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<tbody>
<tr>
<td>North Central</td>
<td>0.852</td>
<td>0.096</td>
<td></td>
<td></td>
<td>-1.184</td>
<td>-0.985</td>
<td>1.556</td>
<td>-0.291</td>
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<tr>
<td>South Central</td>
<td>0.225</td>
<td>0.066</td>
<td></td>
<td></td>
<td>-0.199</td>
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<tr>
<td>Central Highlands</td>
<td>0.384</td>
<td>0.473</td>
<td>3.991</td>
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<td>-4.212</td>
<td>-1.327</td>
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<tr>
<td>South East</td>
<td>0.073</td>
<td>0.083</td>
<td></td>
<td></td>
<td>-0.252</td>
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<tr>
<td>Mekong River Delta</td>
<td>0.121</td>
<td>0.075</td>
<td></td>
<td></td>
<td>-0.229</td>
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</table>

Table 5-3. Elasticities of yield of winter season rice for evapotranspiration and trend

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Red River Delta</td>
<td>0.613</td>
<td>1.041</td>
<td>-0.262</td>
<td>1.342</td>
<td>-0.247</td>
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<tr>
<td>North East</td>
<td>0.579</td>
<td></td>
<td>0.326</td>
<td>0.453</td>
<td>-0.082</td>
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<tr>
<td>North West</td>
<td>0.453</td>
<td>0.339</td>
<td>-0.445</td>
<td>0.453</td>
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<td>North Central</td>
<td>0.553</td>
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<td>0.410</td>
<td>0.558</td>
<td>-0.248</td>
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<tr>
<td>South Central</td>
<td>0.338</td>
<td>-0.716</td>
<td>-0.809</td>
<td>0.339</td>
<td>0.314</td>
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<tr>
<td>Central Highlands</td>
<td>0.416</td>
<td>-0.070</td>
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<td>0.416</td>
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<tr>
<td>South East</td>
<td>0.080</td>
<td>0.653</td>
<td>-0.276</td>
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<tr>
<td>Mekong River Delta</td>
<td>0.315</td>
<td></td>
<td></td>
<td>0.316</td>
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Table 5-4. Elasticities of planted area of spring season rice

<table>
<thead>
<tr>
<th>Region</th>
<th>Trend</th>
<th>Price (t-1)</th>
<th>ET (Jan.)</th>
<th>ET (Feb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red River Delta</td>
<td>0.035</td>
<td></td>
<td></td>
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<tr>
<td>North East</td>
<td>0.060</td>
<td>0.050</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North West</td>
<td>0.065</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Central</td>
<td>0.015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Central</td>
<td>0.030</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Highlands</td>
<td>0.193</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South East</td>
<td>0.445</td>
<td>1.045</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>0.305</td>
<td>0.040</td>
<td>0.091</td>
<td>0.059</td>
</tr>
</tbody>
</table>


Table 5-5. Elasticities of planted area of summer season rice

<table>
<thead>
<tr>
<th>Region</th>
<th>Trend</th>
<th>Price (t-1)</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Central</td>
<td>0.164</td>
<td>-0.419</td>
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<tr>
<td>South Central</td>
<td>0.044</td>
<td>0.064</td>
<td></td>
</tr>
<tr>
<td>Central Highlands</td>
<td>3.689</td>
<td>-31.94</td>
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</tr>
<tr>
<td>South East</td>
<td>-0.027</td>
<td>0.375</td>
<td>-0.527</td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>1.316</td>
<td>0.063</td>
<td>0.338</td>
</tr>
</tbody>
</table>

Table 5-6. Elasticities of planted area of winter season rice

<table>
<thead>
<tr>
<th>Region</th>
<th>Trend</th>
<th>Price (t-1)</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red River Delta</td>
<td>0.030</td>
<td>-0.029</td>
<td>0.157</td>
</tr>
<tr>
<td>North East</td>
<td>0.007</td>
<td>-0.051</td>
<td>0.216</td>
</tr>
<tr>
<td>North West</td>
<td>0.015</td>
<td>-0.158</td>
<td>-0.018</td>
</tr>
<tr>
<td>North Central</td>
<td>-0.339</td>
<td>0.062</td>
<td>-0.072</td>
</tr>
<tr>
<td>South Central</td>
<td>0.016</td>
<td>-0.122</td>
<td>-0.250</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>-0.066</td>
<td>0.014</td>
<td>-0.130</td>
</tr>
<tr>
<td>South East</td>
<td>0.118</td>
<td>0.008</td>
<td>-0.067</td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>-0.828</td>
<td>0.036</td>
<td>0.234</td>
</tr>
</tbody>
</table>

5-6. Simulation results

5-6-1. Results of estimation of yield functions

Table 5-1 through Table 5-3 show elasticities of yield for ET of spring, summer, and winter season rice respectively.

The planting of spring season rice occurs from December to February and harvesting occurs from June to July. The planting and harvest time of summer season rice is May to June and September to October. The summer season rice is cultivated only in southern regions because typhoons hit the northern regions during the harvesting period. Winter season rice follows spring season rice in the northern regions, and planting and harvest time of winter season rice is September to October.

The estimation results for spring season rice show that higher ET in January and May leads higher yield. These results suggest that water supply during the planting and flowering period is important for the growth of spring season rice, and if water supply decreases 1% in May in Mekong River Delta region, yield will decrease 0.234%. The results of summer rice show that higher ET in March leads higher yield. The water supply during the flowering season is not as critical due to high precipitation in July and August. The results for winter season rice show that higher ET in September, which is the flowering time, is important for the growth of the rice, and if ET decreases 1% in September in Red River Delta region, yield will decrease 1.342%.

5-6-2. Results of estimation of planted area functions

Planted area function of spring, summer, and winter season rice are specified as linear functions based on a naive expectation model. The explanatory variables are time trend, one-year lagged price, and current ET for each month. The elasticities evaluated at the average are shown in Table 5-4 through Table 5-6.

The elasticities of planted area of spring season rice for ET are null in most regions; however, in the South East region it is quite sensitive, i.e., if ET increases 1% in January in the region, the planted area will increase 1.045%. The elasticities of planted area of summer rice for ET in May in Southern regions are high. These results suggest that if the water supply increases during the planting season of spring and summer season rice, the planted area will increase in southern regions. Results for winter season rice differ from other two season rice. The elasticities of planted area of winter season rice for ET are negative in June and August. These results suggest that the excess supply of water during the rainy season will decrease the planted area of winter season rice.

5-6-3. Simulation results of supply and demand model

The simulation term is from 2003 to 2015. The assumptions of the simulation are as follows: (1) the growth value of GDP deflator for the simulation period is the average annual growth between 1999 and 2004, (2) the growth value of real GDP is the average...
annual growth between 1996 and 2003, (3) the growth value of the exchange rate is the average annual growth between 1998 and 2004, (4) the growth value of population is the average annual growth between 1996 and 2003, (5) the linear trend of the yield functions are continued, (6) the trend of planted area functions are flat.

Figure 5-3 and Figure 5-4 show the simulation results for the production of spring and summer season rices in Mekong River Delta region, and Figure 5-5 through Figure 5-7 show the simulation results of the production of spring, summer, and winter season rices for the country as a whole.

The production of spring rice in Mekong River Delta region will increase 524 thousand metric tons (MT) from 2010 to 2015. On the other hand, the production of summer rice in the region will be stable at around 7.5 million MT (mMT). Summer rice production in the Mekong River Delta region drastically increased from 7.7 mMT in 2003 to 8.6 mMT in 2004; however, the model did not follow the change.

The production of spring, summer, and winter season rice will increase 1.6 mMT, 0.4 mMT, and 0.9 mMT respectively.

Figure 5-8 shows per capita rice consumption, and it will be stable around 200 kilogram (KG) Figure 5-9 shows the simulation result of the equilibrium real price. These prices are converted to real currency units using a CPI whose value is 100 in 1989. The farm price is estimated to be stable at around 200 thousand Dong per KG.
5-7. Conclusions

The supply and demand model presented can analyze changes in yield and planted area independently and consider supply responses and demand changes to the market price for rice while equating supply and demand. The baseline analysis indicates that productions of all season rice steadily increase due to an increase in yield. The planted area for the country as a whole has been decreasing in recent years and is a trend that is expected to continue in the outlook.

The cold weather and the insect disease outbreak in Vietnam are significant contributors to the sharp increase in the world price of rice in 2008. Not only high yield but climate change tolerant varieties of rice are necessary for stable rice farm management.