Maize Supply Response in Vietnam

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ABSTRACT

This study used a supply response model to determine factors affecting maize supply in Vietnam. It estimated response coefficients from semi-annual time-series data for the period 1986-2011. Using three criteria, it chose the rational expectation hypothesis supply response model (Model I) with the separated price expectation formation hypothesis according to the information set at time (t-1) to estimate the supply response model for maize. Farmers used the available information set to form their expected price. Estimated parameters' results in Model I indicate that the farmers' supply had a positive response to the expected price of maize, but was negative to that of cassava. This means that maize and cassava are close substitutes in the supply response models. Maize production also positively responds to the amount of fertilizer per hectare, maize area, one-period lagged investment, irrigation, trend variable, and agricultural extension policy.

Recommended policies include: enhancement of the judicious use of fertilizers and possible establishment of local factories; increase in maize area by changing the crop structure and multiple cropping with long-term industrial trees like perennials and fruit trees; improvement of the irrigation system in two deltas and in high production regions; increase in government support to farmers; increase in government spending on research and development of new maize varieties; and improvement of the extension system to provide farmers the needed market and technological information.

Keywords: supply response, rational expectation, maize, Vietnam

JEL classification: Q11

INTRODUCTION

Maize has been cultivated in Vietnam for about 300 years. It is one of three major grains (after paddy and wheat) cultivated for food and feeds in the country. People eat maize in the form of boiled corn, baked corn, and popcorn, or processed products such as candy, corn milk, beverage (high-quality vegetable), tinned food, oil, and wine. Maize is an important crop also for the feeds industry in Vietnam. It is the main ingredient of synthetic feeds, providing about 70 percent of the starch (Tuan, Tuan, and Dung 2005). The share of feeds in the total maize consumption had averaged around 70 percent from 1996 to 2011, and reached 82 percent of the total maize consumption in 2011 (GSO 2012).

From 1986 to 2011, Vietnam's maize output grew by 748.6 percent, with an average annual growth rate of 9.2 percent. The area planted to maize increased by about 179.7 percent during this period. Moreover, maize yields increased from 1.0 to 4.3 metric tons per hectare (mt/ha), with an average increase of 4.4 percent per year (GSO 2012). The impressive output growth was triggered by more intensive cultivation, increased areas of planting, enhanced yield, and adoption of both open-pollinated variety (OPV) and hybrid seeds starting in 1991 (Tinh 2009).

An important agriculture development strategy is to ensure the production of a substitute for an import commodity (e.g., maize) at a level that can satisfy the domestic demand. Such self-sufficiency in production should first be targeted before exporting the commodity to foreign markets. Hence, it is necessary to determine the response of maize farmers to institutional factors and market policies to provide an understanding of the maize supply's response to government intervention. This study attempted to address this concern. Its specific objectives were to estimate a supply response model for maize and determine the factors affecting change in supply and to recommend policies appropriate for the development of Vietnam's maize industry.

Most studies on supply response in the agricultural sector are based on Nerlove's (1956) model with the addition of expected variables, though expected values are not directly observable. The model introduced an adjustment coefficient that is assumed to be constant over time, which is a proportion of the difference between the desired and the previous current level of output or acreage. The price expectation is formulated from the past price and errors in expectation are partially adjusted in the process. This model is the foundation of econometric models of supply response with the dynamics of time. Many modified models have resulted from the traditional Nerlove model by incorporating more variables both in static and dynamic modes in order to capture the uncertainty in the production of maize and other crops in the real world.

Habibullah (1986) used the rational expectation model, suggesting a similarity as the value of $P_t^e = E[P_t]$ is obtained by regressing P_t on all one- and two-lag variables of that model. The hypothesis about rational expectation of Muth (1961) passed all three tests for agricultural supply and demand by Goodwin and Sheffrin (1982). The latter has received strong support and can be applied to many agricultural markets. Ghosh and Neogi (1995), on the other hand, introduced a modified model of rational expectation for agricultural supply expounded by Sheffrin (1983). Their modified model includes government intervention and incorporates some key relationships that work to shape the market supply, and consequently the market price.

METHODS

Source of Data

The study used time-series data from published sources in Vietnam covering the period 1986–2011. There were 52 observations with each observation covering six months. Secondary data were collected from the General Statistical Offices (GSO), other publications, and legal documents.

Specification of Variables

Domestic maize production (Q_t). The variability of the domestic production of maize is oftentimes affected by factors including maize's own price, price of the substitute crop, per hectare fertilizer (urea), area planted, rainfall, changes in the technology, one-period lagged production, agricultural extension policy.

Expected price of maize (P_t^e) and cassava (PC_t^e). Most models assume that farmers base expected prices of production from past prices as in the Cobweb model, extrapolative expectation, adaptive expectation, and rational expectation. That is, farmers do not use current information, thus repeating errors during their production decisions (Garcia 2004). In Vietnam, the expected price of output is not recorded. In this study, expected prices were used by the rational expectation model.

Farmgate price of maize (P_t) and cassava (PC_t). The output price has an important role in farmers' decision on what to produce and how in a particular season. If there are no substitute crops, farmers could have continuous production until their profit decreases to zero. However, in reality, there is much substitution with other crops. Farmers may eventually stop producing maize when the profit from maize equals that from the substitute crop. The price ratios of maize and cassava (P_t/PC_t) were used because the absolute price of a commodity may have an indirect effect on the farmers' decisions to allocate area through changes in the incremental profit ratio. On the other hand, the prices of a crop relative to a competing crop correctly specify the price effect (Deshpande 1996). The real farm-gate price/price ratios (constant price in 1994) of maize and cassava were the price by which the farmers sell their products during harvest (also called harvest price).

Volume of total fertilizer per hectare (F_t). There was no record of volume of total fertilizer for maize planted by the private sector but only volume of fertilizer per hectare as represented by some studies done on small-scale farms in particular years. Hence, the volume of urea per hectare served as proxy for fertilizer use.

Area of maize (A_t). Vietnam has 2–3 maize seasons per year in six regions. Harvest area of maize was used as proxy for cultivated area of maize at the same time (seasons) in the four models in this study.

Rainfall (R_t) or weather. Irrigation significantly affects maize production. While maize has good abilities against drought (or lack of irrigation), it can grow much better with adequate irrigation facilities. Hence, semi-annual average rainfall (in mm) data were collected and used as proxy for weather condition in this study.

Investment cost for research and development (INV_t). Investment cost for research and development (R&D) included researchers' salaries and benefits, fixed and administrative overhead costs, and operating research costs. In this study, the operating research costs were used for the R&D variable. As investment takes time to have an effect, this variable was used with lags.

Agricultural extension policy (D93). The country implemented an agricultural extension policy using various ways to encourage farmers to cultivate maize starting in 1993. The annual cash expenses allocated from the government's budget for agricultural extension was used as a variable. Agricultural extension policy was used as proxy for some government policies that encourage maize farmers to enhance their production, or as a dummy variable. In this study, this variable was represented by a dummy: 0 for the period 1986–1992 and 1 for 1993–2011.

Technological change (T). Technology helps farmers reduce production costs, increase yield, and enhance product quality. Maize technology research includes the selection and adoption of new maize varieties. These varieties are high-yielding; tolerant to stressful conditions such as drought, cold, alum soils, and waterlogging; resistant to herbicides; and high pollination rates. In such research, it may be difficult to precisely identify how much of a given change is attributable to environment factors. Hence, empirical studies use a time trend as an all-encompassing variable without specifically identifying the factor response for the change in both demand and supply. In this study, the time trend served as proxy for the technology variable.

The other symbols are defined as follows: α_0, φ_0, β_0, δ_0 are the intercept of model; and $U_{\alpha t}$, $U_{\varphi t}$, $U_{\beta t}$, $U_{\delta t}$ are the error term in the above models.

Empirical Supply Response Model

The production response function was first used by Sheffrin (1983) and modified by Ghosh and Neogi (1995). This was adopted in this study with modifications in the expected price of the substitute commodity. The output response function is given as:

$$Q_t = a_0 + a_1 P_t^e + a_2 PC_t^e + a_3 F_t + a_4 A_t + a_5 R_t + a_6 INV_{t-1} + a_7 INV_{t-2} + a_8 T_t + a_9 Q_{t-1} + a_{10} D93 + U_{at} \tag{1}$$

$$P_t^e = E(P_t \mid I_{t-1}) \tag{2}$$

$$PC_t^e = E(PC_t \mid I_{t-1}) \tag{3}$$

From equation (1) on total maize production, four models were used to estimate the price expectations using the available information in period $t-1$.

Model I (4)

$$Q_t = \alpha_0 + \alpha_1 E(P_t \mid I_{t-1}) + \alpha_2 E(PC_t \mid I_{t-1}) + \alpha_3 F_t + \alpha_4 A_t + \alpha_5 R_t + \alpha_6 INV_{t-1} + \alpha_7 INV_{t-2} + \alpha_8 T_t + \alpha_9 Q_{t-1} + \alpha_{10} D93 + U_{\alpha t}$$

Model II (5)

$$Q_t = \varphi_0 + \varphi_1 E(P_t \mid I_{t-1}) + \varphi_2 E(PC_t \mid I_{t-1}) + \varphi_3 F_t + \varphi_4 A_t + \varphi_5 R_t + \varphi_6 INV_{t-1} + \varphi_7 INV_{t-2} + \varphi_8 T_t + \varphi_9 Q_{t-1} + \varphi_{10} D93 + U_{\varphi t}$$

Model III (6)

$$Q_t = \beta_0 + \beta_1 E\left(P_t/PC_t \mid I_{t-1}\right) + \beta_2 F_t + \beta_3 A_t + \beta_4 R_t + \beta_5 INV_{t-1} + \beta_6 INV_{t-2} + \beta_7 T_t + \beta_8 Q_{t-1} + \beta_9 D93 + U_{\beta t}$$

Model IV (7)

$$Q_t = \delta_0 + \delta_1 E\left(P_t/PC_t \mid I_{t-1}\right) + \delta_2 F_t + \delta_3 A_t + \delta_4 R_t + \delta_5 INV_{t-1} + \delta_6 INV_{t-2} + \delta_7 T_t + \delta_8 Q_{t-1} + \delta_9 D93 + U_{\delta t}$$

The instrumental variable (IVs) method gives consistent estimates, but it is not efficient because the estimation may tend to be biased for small samples (Koutsoyiannis 1977). This method was used for models I and III. In Model I, the value of $E(P|I_{t-1})$ was determined by regressing P_t on one-period and two-period lagged price of maize to obtain $\widehat{P}_t$ (expected value of P_t). The value of $E(PC|I_{t-1})$ was determined by regressing PC_t on one-period and two-period lagged price of cassava to obtain $\widehat{PC}_t$ (expected value of PC_t). For Model III, the value of $E(PR_t|I_{t-1})$ was estimated by regressing PR_t (price ratio of maize to cassava) on P_{t-1}, P_{t-2}, and PC_{t-1}, PC_{t-2} to obtain $\widehat{PR}_t$.

The other approach used the information in the structure of the model to derive an explicit expression for P_t^e (two-stage least squares or 2SLS method). In the first stage of the 2SLS method, a univariate time series was specified and estimated to provide the expected values of the endogenous variable, as:

$$P_t^e = \mu + \sum \gamma_i Z_t + \varepsilon_t \tag{8}$$

where Z_t represents the variables or set of information variables available to the farmer at period t-1.

Essentially, the expected price estimate was obtained by regressing P_t on all the predetermined variables (one-period lagged variables) of the model to find the $\widehat{P}_t$, an estimate of P_t^e (Maddala 2001). This method was used for models II and IV. In Model II, the value of $E(P|I_{t-1})$ was obtained by regressing P_t on all exogenous variables. It used a one-period lag of all the exogenous variables (P_{t-1}, PC_{t-1}, F_{t-1}, A_{t-1}, R_{t-1}, INV_{t-2}, INV_{t-3}, T_{t-1}, Q_{t-2}, and $D93_{t-1}$) to obtain $\widehat{P}_t$. For Model IV, the value of $E(PR_t|I_{t-1})$ was estimated by regressing (P_{t-1}, PC_{t-1}, Fv, A_{t-1}, R_{t-1}, INV_{t-2}, INV_{t-3}, T_{t-1}, Q_{t-2}, $D93_{t-1}$) to obtain $\widehat{PR}_t$.

Statistical Description of Variables

Supply response models usually involve autocorrelation (serial correlation) problems and non-normality of errors because expectation models of supply response always cover lagged variables (exogenous or endogenous variables) and use time-series data (Gujarati 2004).

If the classical least-squares procedures are not directly applicable, there are three methods that could be used to correct the problems in these models. These are ordinary least squares (OLS) with first-order autoregressive or AR (1) method, instrumental variables, and 2SLS method.

In the serial correlation problem, the joint hypothesis test of the Ljung-Box (LB) statistic was used to test whether time-series is white noise. In large samples, it is approximately distributed as the chi-square distribution with m degrees of freedom, but in small samples, this statistical test is better. In the normality problem of a time-series, the Jarque-Bera (JB) test of normality is asymptotic: a large sample test was used to find out whether the error term follows the normal distribution (Gujarati 2004).

Table 1 shows that based on the test of normality of variables using the JB test, farm-gate price of maize, fertilizer use, investment for R&D, and agricultural extension policy were identified as a time-series without a normal distribution. Hence, testing these variables using the t-test method should be done very carefully. The JB test for the remaining variables showed that the hypothesis of normality was statistically accepted, which means using the t-test on them could be reliable. In addition, the result of the Q test showed that there are problems of serial autocorrelation in all variables. Hence, methods involving autoregressive error corrections were given importance to meet the limitations of the time-series data in the supply model (Danh 2004).

Test for Rationality of Price Expectation

The rational expectation hypothesis has two versions: weak and strong. In addition, the difference between realized value and expected value should be uncorrelated with all the variables in the information set at the time the expectation was formed. Hence, the test for rationality of price expectation was used to determine whether or not the forecast error $(P_t - P_t^e)$ at the current period is uncorrelated with the variables in the information set (I_{t-1}) in the previous period. This meant finding out whether or not the difference between the actual price value and the expected price value was affected by the information set in the past. This information set was necessary to shape the confidence on the values of the expected price that was used in the supply model (Maddala 2001).

$$P_t - P_t^e = \rho_0 - \rho_1 P_{t-1} + \varepsilon_t \quad (9)$$

$$PC_t - PC_t^e = \sigma_0 - \sigma_1 PC_{t-1} + \pi_t \quad (10)$$

The test based on examination of P_{t-1} in Equation 9 and PC_{t-1} in Equation 10 is known as the weak version of the rational expectation hypotheses and is a test for weak rationality. That is, it tests whether the coefficients of P_{t-1} and PC_{t-1} are significantly different from zero, and if the test of hypothesis $\rho_0=0$, $\sigma_0=0$ and $\rho_1=0$, $\sigma_1=0$ gives true results. This implies that the information contained in past forecast errors is fully used in forming future predictions. On the other hand, the strong version stipulates that the forecast errors $(P_t - P_{t-1})$ and $(PC_t - PC_{t-1})$ are uncorrelated with all the variables known to the forecaster. Hence, the predicted

Table 1. Statistical description of variables used in the maize supply response equation in Vietnam (2011)

Variable	Unit	Mean	Std. Dev.	Skewness	Kurtosis	JB test	Q-test[n]
Farmgate price of maize *(P)*	VND/kg	1563	536	0.95	4.19	10.8366 (0.0044)	26.074 (0.0000)
Farmgate price of cassava *(PC)*	VDN/kg	1239	447	-0.40	3.37	1.6567 (0.4368)	28.103 (0.0000)
Fertilizer use (urea) *(F)*	kg/ha	133	61	-0.54	1.58	6.9006 (0.0317)	46.922 (0.0000)
Rainfall *(R)*	mm	941	367	0.30	1.70	4.4611 (0.1075)	36.165 (0.0000)
Investment for R&D *(INV)*	Million VND	952	805	2.78	9.80	167.2584 (0.0000)	30.991 (0.0000)
Cultivated areas *(A)*	000 ha	370	131	0.32	1.59	5.1994 (0.0743)	49.998 (0.0000)
Production quantities *(Q)*	000 tons	1119	747	0.51	1.75	5.6351 (0.0598)	48.683 (0.0000)
Trend *(T)*		27	15	0.00	1.80	3.1246 (0.2097)	48.889 (0.0000)
Agricultural extension policy *(D93)*		0.73	0.45	-1.04	2.08	11.2066 (0.0037)	46.752 (0.0000)

Note: [n] Application for null-difference level AR(0)
P-values of all test statistics are given in parentheses

Table 2. Test for the rationality of price expectation formation models in Vietnam (2011)

Equation	Variable	Null Hypotheses	Degrees of Freedom	Critical Value *a*	t-stat	Hypothesis Evaluation
Equation (9)	Intercept	$\rho 0 = 0$	50	2.009	-4.19E-07	Accepted
	P_{t-1}	$\rho 1 = 0$	50	2.009	4.18E-07	Accepted
Equation (10)	Intercept	$\sigma 0 = 0$	50	2.009	5.08E-07	Accepted
	PC_{t-1}	$\sigma 1 = 0$	50	2.009	-4.95E-07	Accepted

Note: *a* significant at α=0.05 level using two-tail test

prices in the supply response under the rational expectation hypotheses were considered as proxies of unobservable expected prices that were confidently estimated (Maddala 2001).

Table 2 shows that the values of t-stat test for intercept and one-period lagged variables in equations (9) and (10) are all smaller than the critical value of 2.009 with significance at α = 0.05 level using two-tailed test. This means the test for rationality (weak version) accepts the hypotheses that the expected price of maize and the expected price of cassava were determined separately from a regression of the respective prices against the lagged value for two periods. Further, the forecast errors in the previous period could be used rationally to form the expected price of farmers.

RESULTS AND DISCUSSION

This section presents the parameters of the rational expectation models developed in the past sections. The regression analysis used the semi-annual time-series data from 1986 to 2011 for maize and cassava in Vietnam.

Results of the Q test show that there are problems of serial autocorrelation in all variables in this study (Table 1). First, there is a lagged endogenous variable in the right-hand side of the supply response model. Second, a trend variable was used in each model. Third, the supply response model used a dummy variable. Fourth, the model used time-series data; this type of data may exhibit consistency according to nature's cycle. Appendix tables 2 to 5 also show autocorrelation between some pairs of variables.

Methods to correct autoregressive errors include the instrumental variable method, two-stage least square method, and change in some characteristics of the model by estimating a supply response model in double-log form. In addition, the regression estimation of the second stage of the instrumental variable method was done using three approaches: ordinary least square (OLS), OLS with Prais-Winsten transformation, and OLS with Cochrance-Orcutt transformation. However, it is noted that R^2 might increase or decrease when instrumental variable and two-stage least square (2SLS) methods are used as compared to OLS (Maddala 2001).

In these four models, the expected prices of maize and cassava were estimated simultaneously as endogenous variables in models I and III. The expected price ratios of maize and cassava were also determined as endogenous variables in models II and IV. All the variables in the four models were used in the natural logarithm, except the agricultural extension policy variable, which is a dummy variable.

Each model used the rational expectation hypothesis with one or two assumptions to form the expectations. Two assumptions are whether the information set is available at time *(t−1)* and whether the information set is not available at time *(t−1)* to form the expectations. This means the exogenous variables in the four models could be known or not known at time *(t−1)*. If the information set is assumed to be known at time *(t−1),* the 2SLS method was used. If the information set is assumed not to be known at time *(t−1)*, the instrumental variable (IVs) method was used (i.e., using past history of the variable).

In the case where the exogenous variables are assumed to be known at time *(t−1)*, the rational expectation hypothesis implies that the expected price is formatted as follows: $P_t^e = P_t - v_t$, where v_t is an error term uncorrelated with the exogenous variables in the information set (I_{t-1}) at time *(t−1)*. Hence, the value of $(P_t - v_t)$ is substituted for P_t^e and the error term is combined with the error term in both models II and IV of the supply response model. This is because v_t has the same properties as $U_{\varphi t}$ in Model II and $U_{\delta t}$ in Model IV, and the 2SLS method was used to estimate models II and IV. The instrumental variable method is used to get consistent results of the parameters under rational expectations when the exogenous variables at time *t* are not known at time *(t−1)*. In this case, the error term (v_t) can be correlated with the exogenous variables.

Maddala (2001) suggests the use of lagged exogenous variables as instruments in the estimation method. The instrumental variable method can be used to estimate the parameters in models I and III. Hence, choosing the appropriate instruments becomes the more important problem in estimation in this method. In addition, results by the Durbin-Watson Test (Appendix Equation Test) show negative first-order serial correlation of the price of maize in time *t* when regression followed the price of maize in time *(t−1)*. Hence, in the instrumental variable method, the information set at time *(t−2)* was used instead of *(t−1)*. These instrumental variables are completely appropriate with Maddala's (2001) suggestion that two-period lagged variable values be used as an instrument in the instrumental variable method.

The regression results from the four models for the different econometric methods are presented in Table 3. In the four models, the adjusted R^2 statistic (about 0.99) was used as a measure of goodness of fit (Carter and Nagar 1977). Hence, the models for each estimated method have a high degree of explanatory power.

Based on the three criteria given at the beginning of this section, the rational expectation hypothesis supply response model with the separated price expectation formation hypothesis according to the information set at time *(t−1)* (Model I) was chosen as an appropriate model to estimate the supply response model for maize in Vietnam. The estimated coefficients had the expected signs as earlier hypothesized and can be interpreted in terms of elasticities with the sample mean of the data. Only the expected price variable of cassava significantly and negatively affected the average production of maize. Other significant variables had positive effects on the average output. The investment cost variable had the same sign as hypothesized but was insignificant in the four models.

The expected price of maize was significant at 5 percent level in Model I, and its magnitude is around 0.13. This means the estimated coefficient (or own-price elasticity with respect to supply) in Model I is approximately 0.13, which is consistent with the results of Lubulwa and Davis (1996). In Lubulwa and Davis' study, which obtained the farmgate prices for maize from CIMMYT (1992), the maize price supply elasticity in Vietnam was 0.1.

The own-price elasticity with respect to maize production is 0.13 in Model I. The 0.13 parameter value of the expected price of maize

Table 3. Coefficients of models I-IV of maize supply estimation in Vietnam (2011)

	Model I	Model II	Model III	Model IV
C	-2.756034*** (0.5758)	-2.823161*** (0.6012)	-3.144779*** (0.5129)	-3.394039*** (0.5582)
LnP	0.134836** (0.0647)	0.104014 (0.0655)		
LnPC	-0.042768** (0.0175)	-0.023322 (0.0153)		
LnPPC			0.034491 (0.0597)	0.289032 (0.5163)
LnF	0.039392* (0.0220)	0.039666* (0.0230)	0.046055* (0.0229)	0.050179** (0.0227)
LnA	1.322670*** (0.1234)	1.321016 (0.1294)	1.382745*** (0.1177)	1.442323*** (0.1090)
LnR	0.085383*** (0.0137)	0.078457 (0.0139)	0.081047*** (0.0145)	0.082555*** (0.0145)
LnINV(-1)	0.042910* (0.0226)	0.031430 (0.0230)	0.014288 (0.0221)	0.011491 (0.0208)
LnINV(-2)	-0.036281 (0.0215)	-0.027551 (0.0226)	-0.025095 (0.0225)	-0.017189 (0.0198)
T	0.005152* (0.0028)	0.005342* (0.0029)	0.005867* (0.0034)	0.005993* (0.0033)
LnQ(-1)	0.067467 (0.0553)	0.085943 (0.0568)	0.110028* (0.0563)	0.109171* (0.0563)
D93	0.064217** (0.0305)	0.079073** (0.0312)	0.085146** (0.0346)	0.097529*** (0.0263)
F-statistic	1928.98	1765.38	1800.79	1799.82
R^2	0.9980	0.9979	0.9977	0.9977

Note: ***, **, and * statistically significant at 1%, 5%, and 10% level, respectively
Figures in parenthesis are standard errors.

means that an increase by 1 percent in this variable results in an increase of 0.13 percent in maize production in the same period. The price formation was based on the information set available in the previous period of all variables for this model. The results show that the price was less elastic, which may be due to several reasons. First, the expected price formation of maize farmers was completely based on calculations using their records of prices during past time periods. It is like relying solely on previous prices or mainly on experience to make production decisions. Second, Vietnam's economy has had many fluctuations such as the devaluation of the Vietnamese dong (VND), unstable interest rate, inflation, and so on. Inflation rate was very high in some years such as in 1986 (453.5%), 1987 (360.4%), and 1988 (374.4%), although it decreased in 1989 (95.8%) and 1993 (10%) (World Bank 2016). The instability of the above factors had negative effects on farmers. For instance, it sowed confusion, fear, and indifference to the fluctuations in the market price. Third, agricultural production is seasonal and completely dependent on the natural elements. A severe flooding in the north in 2008 reduced the bulk of corn production in 2009 despite rising prices (MARD 2009). Fourth, in some regions, maize is cultivated in two-crops paddy land and intercropped with long-term industrial trees (perennials). In this case, maize is considered as a supplemental crop only. Fifth, Vietnam's infrastructure is underdeveloped in the rural and mountainous regions where more than 70 percent of the maize areas are found. These areas lack irrigation systems and are thus completely dependent on rainfall (DOCP 2011). Sixth, the majority of maize producers (98%) do not know where to sell their products. As they have to sell their produce right after harvest, they have a low bargaining power as regards the selling price of maize (Huan et al. 2002).

On the other hand, the -0.04 parameter value (at 5 percent level) of the expected price of cassava in Model I shows that an increase by 1 percent in this variable results in a decrease of 0.04 percent in maize production in the same period. This result indicates that maize and cassava are substitutes. In Vietnam, maize and cassava are planted in most areas, especially in upland areas where soil is not fertile. Farmers' decision whether to grow maize or cassava on the same acreage is based primary on existing prices.

The coefficient of fertilizer per hectare in Model I (0.04 at 10% level) indicates that an increase in urea per hectare positively affects maize production. In fact, farmers used 120-140 kg/ha of fertilizer (DOCP 2011). This is lower than the recommended rate of 270 kg/ha by the National Maize Research Institute (Ha 2011). In Vietnam, fertilizer use includes organic and inorganic fertilizers. NPK fertilizers and urea are the most widely used in maize. Fertilizer must be rationally used to maximize profits, reduce the vulnerability of maize to pests and diseases, increase yield and optimize maize quality, and protect the environment. On the contrary, insufficient use of fertilizer hinders maize growth and decreases yield, as well as increases soil infertility (NMRI 2011). This means that farmers may increase their maize production by increasing the amount of fertilizer per hectare.

In Model I, the area variable (1.32) contributed the greatest to production and is significant at 1 percent level. In the agricultural sector, the area planted by farmers is completely dependent on the derived economic benefits from the crop and farm size. With the introduction of the national agricultural extension system in 1993, farmers were motivated to produce more maize given the new technologies and necessary market information. This increased the revenues from maize production to VND 50 million per hectare, higher than other crops in 2011 (Ha 2011). This increase was an offshoot of having two maize croppings in a year at the Red River Delta; after the first maize cropping, farmers planted maize again instead of other upland crops because it generated a higher value than either soybean or upland rice (Thao 2005).

The parameter of production variable in the previous period was 0.06, which is not significant at 10 percent level. This means that if maize output in the previous period increased by 1 percent, there would also be an increase of 0.06 percent in the next period. Farmers follow their old farming practices, operating based on experience but expecting that the yield will increase in the next period. On the other hand, their application of new farming techniques learned from the agricultural extension program has resulted in increased maize yield over time.

The estimated coefficient of rainfall was 0.08, which is significant at 1 percent level. This means that rainfall has a positive impact on maize supply, especially in the upland and hilly regions where rainfall is the main water source as the irrigation system is not yet developed. Maize needs 70–100 liters of water throughout its growing season. Fortunately, the annual rainfall of 1700–2000 mm in these areas is sufficient for the crop's water requirement (NMRI 2011). However, this natural water supply becomes a problem in the dry season. This is where the irrigation system plays an important role to maximize the potentials of technological innovations such as improved maize varieties. Only two of the country's regions with large maize areas have irrigation: Red River Delta and Mekong Delta. The different situations in terms of water supply has contributed mainly to the differences in maize production levels in six areas in Vietnam (Appendix Table 1).

The one-period lagged investment variable's coefficient (0.04) is significant at 10 percent level, but that of the two-period lagged investment variable is not. It is noted that it takes at least one year to complete a research project; some projects take about five years to finish. Thus, the effectiveness of investment in R&D in the form of applied research for maize may manifest in the long term but not in the short term. This result indicates that capital from foreign investment projects, investment from domestic projects, and state budget for the research, selection and breeding of new varieties do not manifest significant effect in the short term.

The parameter of trend variable (0.005) is significant at 10 percent level, indicating the positive impact of some factors. First, the adoption of improved production technologies such as in sowing, planting, tending, fertilizing, pest and disease management, and harvesting, and, more importantly, the development of new maize varieties (OP and hybrid) has increased maize production over time. Second, there have been policy reforms and improvement in market access. Third, the infrastructure system from the central regions to the rural and mountainous regions had been improved, connecting more production areas to the market.

The dummy representing agricultural extension has an estimated coefficient of 0.6, which is significant at 5 percent level. This indicates that appropriate extension policy positively affects maize production. In fact, an extension policy was promulgated in 1993 to enhance the production process. It included training and skills development as well as sharing of improved production technologies and market information to farmers.

CONCLUSION AND RECOMMENDATIONS

Among the four supply response models considered, Model I, where the relative price of maize and cassava were separately determined from a regression of exogenous variables with one-period lagged values, came out the best based on three selection criteria. Results showed that farmers made use of the available information set in forming their expected prices.

The results of the estimated parameters in Model I indicate that the farmers' supply response to the expected price of maize is positive, but not to the expected price of cassava. This suggests that maize and cassava are substitutes in the supply response models. Maize production also positively responds to fertilizer per hectare, maize area, one-period lagged in investment, irrigation, trend variable, and agricultural extension policy. The trend variable and agricultural extension policy have important roles because farmers need access to new technologies and market information to guide their production decisions.

Policy Implications

This study identified the influence of various factors on the supply response of maize at the national level. The policy recommendations below seek to strengthen the development of government policies and programs that would have a positive impact on maize production in Vietnam.

Enhance the judicious use of fertilizers and, if possible, establish local factories. Fertilizer plays an important role in the growth and development of the maize industry because it is a major input in maize production. This study shows the positive effect of fertilizer on production. Increasing fertilizer use increases maize yield. Hence, the government may consider the establishment of local fertilizer factories in Vietnam that will produce additional high-quality fertilizers at reasonable prices. This would reduce input costs and assure the fertilizers' availability. However, through the extension system, maize farmers must be taught to be judicious in their fertilizer application.

Increase the maize area by changing the crop structure and by multiple cropping with long-term industrial trees (e.g., perennials and fruit trees). The study shows that having a bigger maize area had contributed much to the increase in production from 1986 to 2011. The area planted to maize in Vietnam may be increased by changing the crop structure. That is, maize may be planted in areas that are rain-fed and without irrigated systems in lieu of rice or other upland crops (e.g., cassava, sweet potatoes) with low economic efficiency. The second way involves intercropping maize with long-term industrial trees (perennials or fruit trees).

Improve the irrigation system in the two deltas and in intensive production regions. This study shows that water is necessary to maximize the potentials of technological innovations such as improved maize varieties; it has a positive effect on maize production. Hence, improved irrigation in maize areas is needed. The government can plan for the repair/upgrade of existing irrigation systems in the two deltas or the construction of new ones in other regions with high maize production.

Increase government support to farmers. The government can enhance maize production by providing a loan program to enable maize farmers to buy improved seeds and apply new technologies. The use of new maize varieties can significantly increase yield and enhance production and economic efficiencies because these varieties are high-yielding; tolerant to drought, waterlogging, and other adverse environmental conditions; and resistant to pests and diseases. In addition, the government can invest in the development of other infrastructure for harvesting, post-production, processing, and marketing of maize. Improving the transport systems in rural and remote areas would facilitate farmers' access to the market. Consequently, areas for maize production may be spread across the country rather than concentrated in a few areas that are accessible to the market or to sources of water.

Increase government spending on R&D of new maize varieties, especially those that are drought tolerant, disease resistant, and high yielding. Further, field trials of maize varieties should be conducted to ensure their suitability to particular ecological zones in the country. Additionally, subsidy for newly developed maize varieties is needed to enable seed companies to expand their seed distribution channels in the different regions of the country, especially the remote and isolated areas.

Improve the extension system to provide needed market and technological information to farmers. The agricultural extension policy in Vietnam established in 1993 has had positive effects on maize cultivation. A good agricultural extension system must be able to provide or make accessible vital market and technological information to maize farmers. Such information will help them in making decisions on maize production. This extension system must have stronger programs, especially capacity building programs including non-formal education (e.g., training). Farmers must have the knowledge, skills, and enabling capacities for better production or a sustainable production model for economic efficiency.

Since future directions in maize production include planting in the uplands, the farmers need to be trained in controlling soil nutrient erosion and upland cultivation technologies. Other areas for capacity building include the use of new technologies (e.g., varieties, machineries, production practices), marketing (e.g., forecasting), and farm management (e.g., regular planning, climate change adaptation and mitigation, pest forecasting).

It must be stressed that the expected improvements in maize production are dependent on the content of each policy or program. Moreover, there may be delays between policy issuance and its implementation or application.

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APPENDICES

Appendix Table 1. Maize production of six regions in Vietnam, 1986–1998

Region	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Red River Delta	61.2	68.2	212	232	148	113	166	191	200	255	334	359	317
Northern Midland and Mountainous	217	217	301	302	247	278	283	352	380	334	404	457	486
North Central and Central Coast	78.2	76.2	94.5	95.5	87.6	92	101	110	161	171	217	260	259
Highlands	92.3	88.1	95.7	96.5	91.5	90.7	92.9	94.4	109	113	170	212	217
Southeast	100	90.2	81.5	80.5	71.7	72	76.5	93.8	210	221	322	307	279
Mekong Delta	20.9	21.8	30.3	32.2	25.6	26	28.2	40.4	84.4	84	90.5	55.3	54.1
Total	570	561	815	838	671	672	748	882	1144	1177	1537	1651	1612

Source: General Statistical Office of Vietnam, 2012

Appendix Table 2. Maize production of six regions in Vietnam, 1998–2011

Region	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Red River Delta	331	293	241	261	318	363	356	343	375	429	308	441	444
Northern Midland and Mountainous	542	640	704	799	883	992	1043	1057	1402	1545	1515	1527	1701
North Central and Central Coast	309	354	417	465	599	770	800	823	818	843	777	852	837
Highlands	227	320	364	507	785	750	963	1014	1057	1079	1117	1165	1210
Southeast	296	347	341	368	402	384	435	429	448	448	459	423	427
Mekong Delta	48.1	51.8	95.5	112	150	172	190	189	204	229	194	200	217
Total	1753	2006	2162	2511	3136	3431	3787	3855	4303	4573	4372	4607	4836

Source: General Statistical Office of Vietnam, 2012

Appendix Table 3. Correlation matrix for Model I (maize and cassava) in Vietnam

	lnQ	lnPe	lnPCe	lnF	lnA	lnA	lnINV	lnT	lnQlag1	D93
lnQ	1.0000									
lnPe	0.0157	1.0000								
lnPCe	0.1777	-0.3268	1.0000							
lnF	0.8418	-0.4576	0.2900	1.0000						
lnA	0.9945	0.0722	0.1487	0.8053	1.0000					
lnR	0.0997	-0.1193	0.0778	0.1300	0.0481	1.0000				
lnINV	-0.5829	0.0923	0.0762	-0.6110	-0.5713	0.1618	1.0000			
lnT	0.8830	-0.2705	0.4233	0.8728	0.8641	0.0896	-0.5245	1.0000		
lnQlag1	0.9883	0.0139	0.1964	0.8191	0.9848	0.0296	-0.5720	0.9044	1.0000	
D93	0.7736	-0.4154	0.3379	0.8877	0.7306	0.0639	-0.6519	0.8300	0.7440	1.0000

Source: General Statistics Office of Vietnam, 2012

Appendix Table 4. Correlation matrix for Model II (maize and cassava) in Vietnam

	lnQ	lnPe	lnPCe	lnF	lnA	lnA	lnINV	lnT	lnQlag1	D93
lnQ	1.0000									
lnPe	0.1278	1.0000								
lnPCe	0.1856	-0.3157	1.0000							
lnF	0.8418	-0.3568	0.2915	1.0000						
lnA	0.9945	0.1661	0.1591	0.8053	1.0000					
lnR	0.0997	0.1233	0.1309	0.1300	0.0481	1.0000				
lnINV	-0.5829	0.1695	0.2722	-0.6110	-0.5713	0.1618	1.0000			
lnT	0.8830	-0.1530	0.4626	0.8728	0.8641	0.0896	-0.5245	1.0000		
lnQlag1	0.9883	0.1279	0.2087	0.8191	0.9848	0.0296	-0.5720	0.9044	1.0000	
D93	0.7736	-0.3180	0.2957	0.8877	0.7306	0.0639	-0.6519	0.8300	0.7440	1.0000

Source: General Statistics Office of Vietnam, 2012

Appendix Table 5. Correlation matrix for Model III (maize and cassava) in Vietnam

	lnQ	lnPe/ lnPCe	lnF	lnA	lnA	lnINV	lnT	lnQlag1	D93
lnQ	1.0000								
lnPe/ lnPCe	-0.0984	1.0000							
lnF	0.8418	-0.4580	1.0000						
lnA	0.9945	-0.0483	0.8053	1.0000					
lnR	0.0997	-0.0525	0.1300	0.0481	1.0000				
lnINV	-0.5829	0.0158	-0.6110	-0.5713	0.1618	1.0000			
lnT	0.8830	-0.4239	0.8728	0.8641	0.0896	-0.5245	1.0000		
lnQlag1	0.9883	-0.1153	0.8191	0.9848	0.0296	-0.5720	0.9044	1.0000	
D93	0.7736	-0.4656	0.8877	0.7306	0.0639	-0.6519	0.8300	0.7440	1.0000

Source: General Statistics Office of Vietnam, 2012

Appendix Table 6. Correlation matrix for Model IV (maize and cassava) in Vietnam

	lnQ	lnPe/ lnPCe	lnF	lnA	lnA	lnINV	lnT	lnQlag1	D93
lnQ	1.0000								
lnPe/ lnPCe	0.0157	1.0000							
lnF	0.8418	-0.3850	1.0000						
lnA	0.9945	-0.0415	0.8053	1.0000					
lnR	0.0997	-0.0404	0.1300	0.0481	1.0000				
lnINV	-0.5829	-0.1246	-0.6110	-0.5713	0.1618	1.0000			
lnT	0.8830	-0.4178	0.8728	0.8641	0.0896	-0.5245	1.0000		
lnQlag1	0.9883	-0.0964	0.8191	0.9848	0.0296	-0.5720	0.9044	1.0000	
D93	0.7736	-0.3700	0.8877	0.7306	0.0639	-0.6519	0.8300	0.7440	1.0000

Source: General Statistics Office of Vietnam, 2012