Analyzing maize price elasticity in the US

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INFOMTADS: Thesis Applied Data Science

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1 Introduction

It is acknowledged that food security will remain one of the major global challenges for the 21st century. There are around 828 million people suffering from food insecurity by the end of 2021 and 3.1 billion people could not live on a heathy diet due to unaffordable prices in 2020 (FAO, 2022). Moreover, food price spike of 2007-2008 has led to social unrest and economic instability, drove over one million population into hunger and poverty (Headey & Fan, 2008). Many governments continue to prioritize price stability in their agricultural policies (Demeke et al. 2012; Spasojević et al. 2018) Therefore, an analysis of the factors of price stability deserves more attention.

According to the Law of Supply and Demand by Steuart (1796), price is determined where demand quantity is equal to supply quantity. This is a balanced price of the market components which implies that the producers get to sell the units while purchasers buy right enough amount product as they want. So, the price could eventually regulate itself based on the supply and demand in the market. This law has become one of the fundamental economic theorems for analyzing price mechanism (GALE, 1955). Specifically, the law of demand assumed the higher the price, the fewer quantity demanded by buyers whilst the law of supply pertains that the higher the price, the more quantity of goods will be provided to the market. Intuitively, there is a negative association between demand and price, and a positive association between supply and price.

To measure these two relations, one way is to calculate the price elasticity. Price elasticity in economics examines the percentage of change of one variable in response to changes in another variables (DEAN, 1951). It is used to measure the how sensitive one factor is to price. More elastic means the quantity demanded or supplied is more responsive to price change. Additionally, price elasticity has been widely used as an important indicator. Roberts and Schlenker (2013) evaluated how price elasticities of agricultural commodities impact the US ethanol mandate. Muslim (2011) studied the price elasticity of maize and its implication to the farmers.

The main goal of this paper is to explore the effect of demand and supply quantity on maize price by looking at price elasticity. Two measures of price elasticity are implemented in this study, which are price elasticity of supply (E_s) and price elasticity of demand(E_d). Price elasticity of supply measures the responsiveness to the quantity supplied to the market to a change in price. Price elasticity of demand examines the change in consumption with respect to a change in its price. We can have the following assumptions on the sign of E_d and E_s. E_d equals to the percentage change in quantity demanded divided by the percentage change in price. It is generally assumed to be negative owing to the negative relation between demand and price. E_s equals to the percentage change in quantity supplied divided by the percentage change in price. It is assumed to be positive due to the positive correlation between supply and price.

The maize market of the USA was chosen to be the study object due to the availability of high-quality survey data and the importance of maize in a global crops' consumption and in domestic market. In addition, agriculture price stabilization has remained a major issue in the USA since last centuries (Robinson, 1976). The supply of maize mainly comes from maize production and maize storage. Production of maize is mainly concentrated in the middle west states – commonly known as the U.S. Corn Belt. The demand of maize could be divided into three categories: Feed; food, seed and industrial (FSI); and exports (Kenyon, 1998). This study adopts a similar categorization of the supply and demand factors which can been seen in Appendix A. Understanding these factors' effect on maize price will assist policy makers and farmers better understanding how supply and demand affect maize price, allowing them to adjust crop output and ensuring a greater food security.

This empirical analysis was conducted at two geographic level within the USA, which is national level and the finer state level. At national level, the maize supply and maize demand represent the domestic supply quantity and demand quantity of USA. In terms of the more in-depth state-level analysis, each state has its own maize supply and maize demand factors. States are identified as corn-belt states and non-corn-belt states based on corn belt states criteria declared by USDA. Corn-belts states are Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin. These ten states produced over 83% of total maize production according to USDA (2012). It is reasonable to anticipate that the demand and supply effect on maize price within corn-belt states and non-corn-belt states should differ. Moreover, corn-belt states could be less sensitive to price since they are mostly production in large scale, and therefore it is harder to change planted area compared with small household maize producers in non-corn-belt states. Therefore, we could assume maize production in corn-belt states should be less adaptive to price thus yields a smaller price elasticity of supply.

Based on two geographical level and two price elasticity measures, our research objectives could be divided into following research questions:

- How do supply factors affect maize price at national level?
- How do demand factors affect maize price at national level?
- How do supply factors affect maize price at state level?
- How do demand factors affect maize price at state level?

We answer the questions by calculated the E_d and E_s at national and state level. In addition, we test the validity of the following hypotheses:

- There is a negative correlation between prices and demand. (E_d < 0)
- There is a positive correlation between price and supply. (E_s >0)
- E_s in corn-belt states is smaller than it in non-corn belt states. (E_sc < E_sn)

2 Methods

2.1 Theoretical frameworks and models

The purpose of this paper is to evaluate the supply and demand influence on maize price by assessing the supply elasticity (E_s) and demand elasticity (E_d). To quantify the supply and demand effects on maize price and obtain the price elasticity, this study employed ordinary least squares regression (OLS) model, which takes price as the dependent variable (y) and quantity demanded for different usages and maize quantity supplied as the independent variables (x). This is a multiple linear regression (aka multivariable linear regression) which pertains to one dependent variable and multiple independent variables. In multiple linear regression, we are interested in what happens when each variable changes its value one at a time, while holding other variables constant. We improve the goodness of fit of linear regression model by performing statistical transformation and using the stepwise regression to select factors with most robust estimation.

The multiple linear regression population model can be written as

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots . + \beta_j x_j + \varepsilon_i \quad (1)$$

With

y: the dependent variable, maize price

x_j: independent variables for j = 1, 2, …..., j

β_0: intercept, the value when all independent variables are 0

β_j: coefficients for j = 1, 2, …..., j

ε_i: random errors

By performing an Ordinary Least Squared (OLS) approach, the fitted parameters are realized while the error term is minimized. The obtained equation for estimating the mean of y is written as follows:

$$\hat{Y} = \widehat{\beta_0} + \widehat{\beta_1} x_1 + \cdots + \widehat{\beta_J} x_j \tag{2}$$

To achieve a higher explanation of the variance, variables with a robust coefficient estimation are selected by using stepwise regression. Stepwise regression is an automatic procedure which fitting the regression model by choosing predictive independent variables and leave out the rest variables. The R squared and adjusted R squared, which are measures of variance of y explained by the model, would achieve a higher value.

To assess how well the model fit, one informative method is the to check whether the model fulfills the following characteristics.

Linearity: there is linear relationship between x and y

Homoscedasticity: ε_i should have a constant variance.

Independence: ε_i should be random and independent from itself.

Normality: ε_i is normally distributed.

To obtain the supply elasticity and demand elasticity, which were calculated as $E\_s = \frac{dQs/Qs}{dPx/Px}$, and $E\_d = \frac{dQd/Qd}{dP/P}$, a natural logarithmic transformation was implemented to all the variables within the regression formula. This is because the estimated parameter β will then become elasticity itself after this conversion. This is proven as follows:

After taken the natural logarithmic of the variables, we have

$$\ln(Y) = a + b\ln(X) \tag{3}$$

Differentiating the formula, we have:

$$\frac{DY}{Y} = b\ \frac{DX}{X} \tag{4}$$

We have $b = \frac{DY/Y}{DX/X}$, which is the elasticity definition.

Accordingly, the price elasticity in our regression function would be the reciprocal of coefficient, $\frac{1}{\beta}$. If the independent variable denotes maize supply quantity, then the reciprocal of the parameter of this variable is supply elasticity (E_s). If the independent variable denotes maize demand quantity, then the reciprocal of the parameter of this variable is the demand elasticity (E_d).

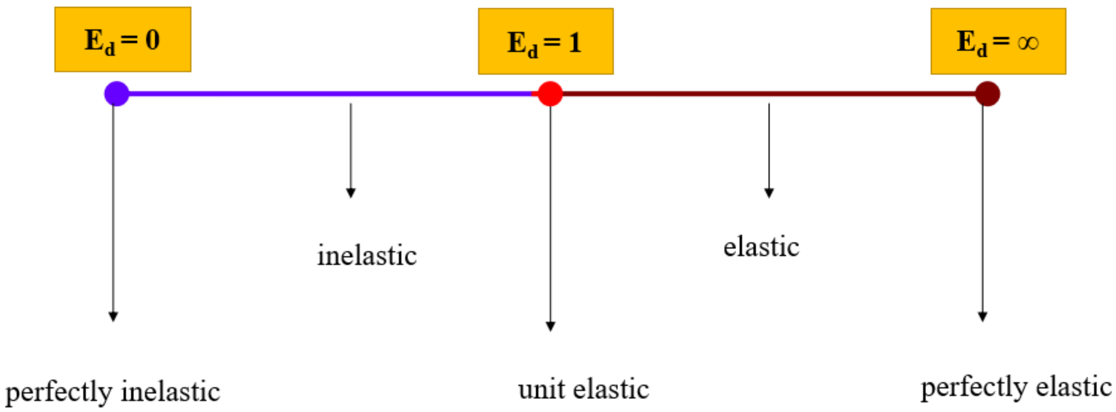

Figure 1. Illustration of three categories of constant demand elasticity. The purple line represents inelastic range from 0 to 1. The red line represents the elastic range from 1 to infinity.

There are three scenarios of demand elasticity. When elasticity equals to 1 or -1, it is unit elastic; When it falls in between 0 to ±1, it is called inelastic; When it equals to infinity, it is called perfectly elastic. Figure 2 exhibits the demand curve when it is perfectly elastic, perfectly inelastic and unit elastic.

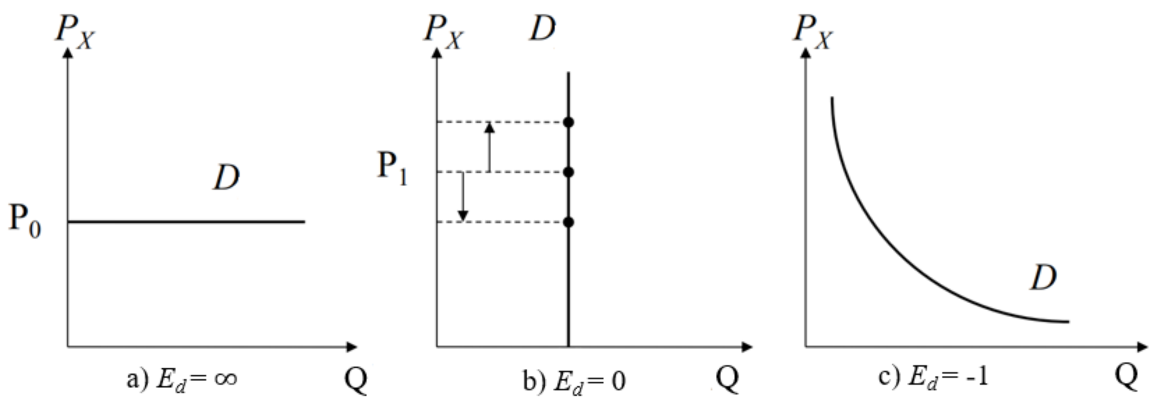

Figure 2. Illustration of three categories of constant demand elasticity. The x-axis represents quantity demanded of a good. The y-axis represents the price of that good. In a) a horizontal line, a minor change of price cause huge change in demand, which means that consumer is hugely sensitive to price. This is commonly seen in the goods of perfectly competitive market. In b) a vertical line denotes that demand is fixed regardless of price change. Necessary products like gas are generally inelastic. In c), the curve represents a unit elastic which implies change in price leads to the same percentage change in demand.

2.2 Data

Maize demand factors are fuel, cereal, alcohol, seeds, livestock feeds and so on. Maize supply factors are limited to maize production, maize storage, and maize imported. This categorization is based on Kenyon (1998). Grains Database and Quick Stats Database provided by the U.S. A. Department of Agriculture (USDA) were used to retrieve factors and maize price at national level and state level. The state level data is annual data which includes 16 independent variables, and producer price over 42 years from 1980 to 2021. Producer price was selected because it reflects the origin price regardless of transportation cost and value added in the supply chained. At the states-level dataset, 8 out of the 49 states are deleted due to substantial missing value of the maize price and maize production. Two factors, which are maize production and stock, were collected from 1949 to 2021 for each state.

For the version of the most current and updated dataset, the data retrieved and categorized shown in table1. Beginning stock was eliminated from the list since this figure is the same as the end stock from previous year. The units of all the variables were changed from million bushels, $/bushels to 1000 tons, USD/tons, respectively.

Table 1. Categorization of datasets factors used in this study. Note there is no data of the demand side found at state level. Only supply elasticity would be calculated at state level.

	National level data(1980-2021)	41 States data(1949-2021)
Supply side(1000 tons)	Begin_stock, End_stock, Imports, Production, Total_supply	Production, Stock
Demand side(1000 tons)	BeverageManuf_use, Fuel_use, Cereal_use, Feed_use, FAI_use, FSI_use, GD_use, HFCS_ use ,Seed_use, Starch_use, Exports, Total_ domestic_use, End_stock, Imports, Production, Total_supply	Na
Maize price(dollors/ton)	price received by farmers	price received by farmers

2.3 Analysis

OLS regression at national level and states level were performed. At national level, there exist 16 variables as predictors. A stepwise regression was conducted to select the predicative variables which could lead to a higher model fit. Stepwise regression approach adopts backward elimination using Akaike Information Criterion (AIC), which is suitable for small data size and collinearity of variables (Heinze et al., 2018; Mantel,1970).

At state level analysis, only two factors from the supply side are available. OLS regression was applied for all the 41 states separately and calculated the reciprocal of coefficients as the price elasticity of production and price elasticity of stock. Recall that corn-belt states are assumed to be less sensitive to price change compared with non-corn-belt states (E_sc < E_sn). A comparison of the price elasticity of factors will be performed between states. Regression equation as follows:

$$log(Price) = \beta_0 + \beta_1 \log(Production) + \beta_2 \log(Stock) + \cdots . + \beta_j x_j \quad (5)$$

With j the number of independent variables.

To measure the significance of coefficients estimation, t-statistics and its p value were calculated for each independent variable (Student,1908). Student t statistic is the coefficient divided by its standard deviation. P value evaluates the null hypothesis there is no association between the independent and dependent variables. A p value of 5% or less is a widely accepted level which indicating the coefficient is statistically significant and can suggest the correlation between itself and dependent variable. The smaller the p, the more significant the correlation coefficient would likely to be at a given significant level.

Regression diagnostics plots are utilized to test the assumptions of model. Linear relationship is tested by 'Residuals versus Fitted' plot. It is a scatter plot that has fitted value as x-axis and residual value as the y-axis. When the points are evenly distributed around the line of zero, it suggests that the relationship of x and y is linear. Scale-Location Plot is used to test homogeneity of the variance of residuals. If there is a horizontal line while points are equally distributed around the line is a good indication of homoscedasticity. Q-Q Plot (Wilk and Gnanadesikan,1968) is used to check whether the residuals follow a normal distribution. It is ideal if residuals points fall along the dashed line. Residuals versus Leverage Plot is used to identify outliers that might impact the regression outcome. Leverage describes how much a certain observation would affect the regression model's coefficients if it were taken out of the dataset. If points fall outside of the Cook's distance (Cook, R. D.,1977) shown as a dashed line, then these observations are seen as influential.

In addition to plots, we also use three statistical tests to investigate the linear regression assumptions. The homoscedasticity of residuals is validated by performing Breusch-Pagan test (Breusch, T. S. and Pagan, A. R. ,1979) which null hypothesis is residual variances are constant. The independency is validated by employing Durbin Watson Test (Durbin, J.;

Watson, G. S.,1950), which null hypothesis is there is no correlation among residuals. The normality is validated by conducting Shapiro-Wilk Test (Shapiro, S. S.; Wilk, M. B.,1965), which null hypothesis the data is normally distributed. We set the significant level to 5%, therefore if these tests showed a p-value greater than 5%, this is a good sign meaning that we do not reject their null hypothesis. We could conclude that our linear regression model is valid at 5% significance.

3 Result

3.1 Interpretation at national level

A full model with all the 16 factors on national level was first fitted by OLS approach and then employed AIC backward elimination to find the most predictive factors. The final model includes Fuel_use, Cereal_use, FAI_use, GD_use, Export and Total_domestic_use as the demand factors, and End_stock as the supply factors.

Table 2. Outcome of national level regression and the elasticity of each factor. Significance was tested with t-statistics.

	Regressors	**Coefficient**	**P value**	**Elasticity(1/Coeff)**
demand side	log(Fuel_use)	-0.289	0.04*	-3.465
	log(Cereal_use)	-0.726	0***	-1.377
	log(FAI_use)	1.546	0***	0.647
	log(GD_use)	-0.461	0.092	-2.170
	log(Export)	-0.109	0***	-9.210
	log(Total_domestic_use)	-0.689	0.103	-1.452
supply side	log(End_stock)	-0.308	0***	-3.251
	Intercept	13.391	***	

*The codes of p value: 0 '***', 0.001 '**', 0.05'*'.*

Recall E_d is assumed to be negative while E_s is assumed to be positive. From the table 1, it is noticeable that maize used for fuel, cereal, GD (Glucose and dextrose) and export showed a negative E_d as presumed. Besides, they are all price elastics, meaning that they are sensitive to change in price. One exception is that FAI (Food, Alcohol, and industrial), which has a positive demand elasticity (0.65) counter to assumption, meaning that an 1% increase in maize price accompanied by 0.65% increase in consumption of maize used for FAI. Even though total domestic use of maize has a negative elasticity, its lack of relevance prevented it from being used as an explanation for price variation. End stock has a negative supply elasticity of -3.251 which is statistically significant and indicates the negative correlation between price and end stock.

Regards to diagnosis, this fitted model shows a R^2 of 0.917, adjusted R^2 of 0.9 which a good indication that more than 90% of the variation of price can be explained by the model. Additionally, the residuals of this model pass three tests (Appendix D.). Moreover, it is further demonstrated that the model is appropriate in terms of its forms and goodness of fit by checking the four diagnostic plots in Figure 3.

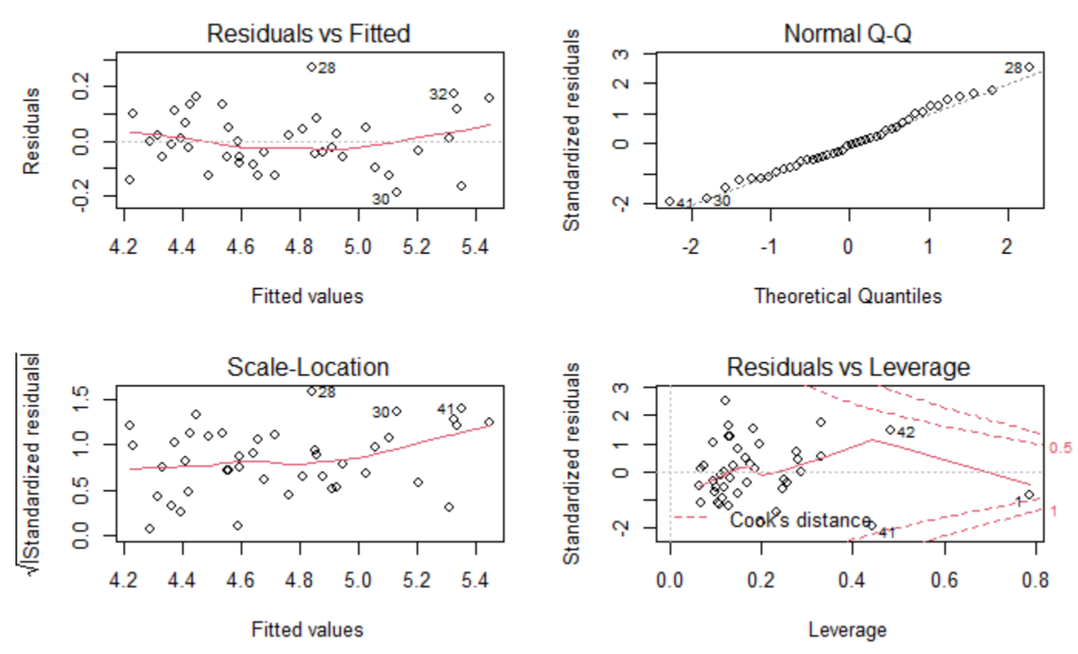

Figure 3. Diagnostic plots at national level. The redline lies at residuals equal to 0 and the points are evenly distributed at both side of the redline, suggesting there is linear relationship between Y and X. Scale-Location denotes a slightly upward line and points are equally distributed around the line, indicating a constant variance of residuals. Most points fall on the diagonal line in Q-Q plot, representing a normality of our residuals. Residuals vs Leverage plot shows that no points fall outside Cook's distance, indicating that no influential outliers in the model.

3.2 Interpretation at state level

At the state level analysis, the result of 41 states regression models were summarized in Appendix C. There are 39 states has a significant estimation of production quantity, only 14 states have a significant estimation of the stock factor. Among the significant states, the maize production has a positive impact on the maize price for all the states. This founding justifies previous assumptions that E_s is positive. Most importantly, the average production elasticity of 10 states (0.444) is much smaller than that of 26 non-corn-belt states (1.218), which justify our assumption that E_sc is smaller than E_sn, implying that maize production in corn-belt states are generally less responsive than that in non-corn belt states.

The regression outcomes of Iowa and Montana are listed in Table 3. Iowa ranked the first one on maize average production from 1949 to 2021 in USA. Montana, on the other side is a typical non-corn belt state. Results showed that production elasticity of Iowa is 1.33 is indeed smaller than Montana 2.97. When price in Iowa increased in 1%, the maize production of Iowa would have an increase of 1.33%. It is obvious that maize production in Montana is more sensitive to price fluctuations. Stock as the other independent variable is not significant in either Iowa or Montana, stock, as a supply factor, cannot be accounted for explaining price.

Table 3. State level regression outcome and calculated elasticity, compared with the assumed direction of supply elasticity.

State	**Corn-belt states**	**Dependent variable**	**Regressors**	**Coefficient**	**Sig.**	**Elasticity**(1/Coeff)
Iowa	Yes	log(Price) of Iowa	log(Production)	0.750	***	1.333
			log(Stock)	-0.081		-12.34
			Intercept	-2.41	*	n/a
Montana	No	log(Price) of Montana	log(Production)	0.336	***	2.976
			log(Stock)	0.031		32.258
			Intercept	3.358	***	n/a

Based on the fitted coefficients, Iowa regression formula could be written as:

$$\log(Price) = -2.41 + 0.75\log(Production) - 0.08\log(Stock) \quad (6)$$

Regards to model diagnosis, Iowa model has a R^2 is 0.528, and adjusted R^2 is 0.514. This is not a good indication since only around 50% of the variation of price can be explained by the model. Additionally, the residuals of this model pass residuals assumptions according to the diagnosis plots in Figure 4.

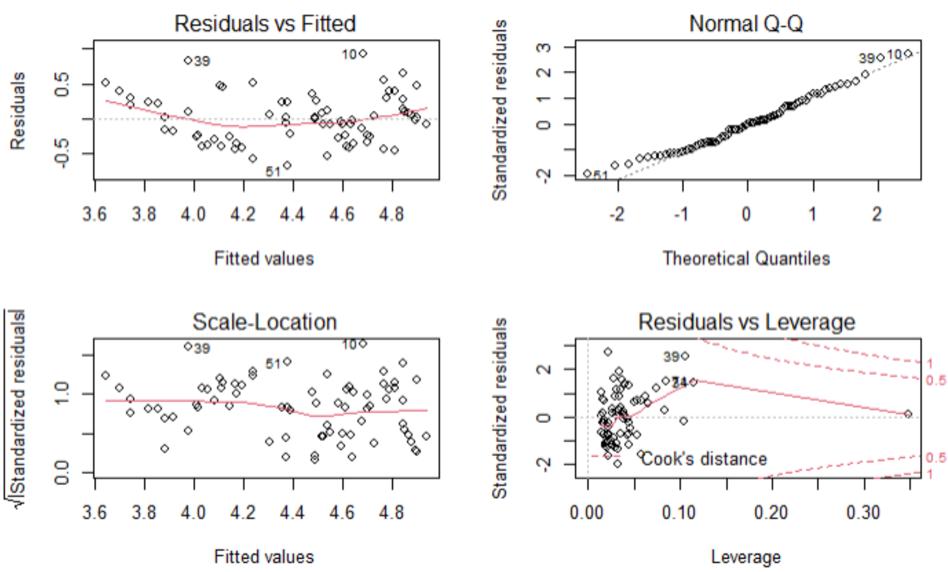

Figure 4. Iowa model residual diagnosis. Residuals vs Fitted implies there is little pattern in the residual plot, suggesting there is linear relationship between Y and X. Q-Q plot showed most points lie at the straight line. Scale-Location denotes a horizontal line while points are equally distributed around the line, which is a good indication of homoscedasticity. Residuals vs Leverage shows no influential points.

Montana regression equation could be written as:

$$\log(Price) = 3.358 + 0.336 \log(Production) + 0.031 \log(Stock) \qquad (7)$$

The model for Montana has a R^2 is 0.706, and the adjusted R^2 is 0.697, indicating that more than have of the variance in price could be explained by production and stock. According to the diagnostic plots in Figure 6, model passed and homoscedasticity of residual test but failed at independence and normality test of residuals (Figure 5).

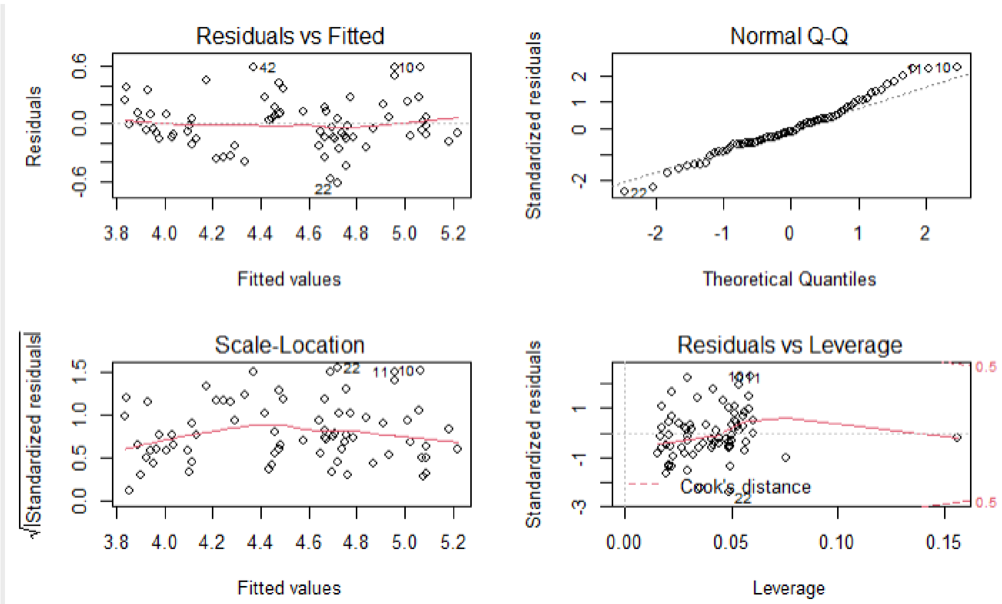

Figure 5. Montana model residual diagnosis. Q-Q plot shows non normal of residuals, whereas that red line is roughly horizontal in Scale-Location, and residuals are random scattered around that line at all fitted values. The assumption of homoscedasticity is satisfied for this model. No points fall outside of cook's distance meaning there are not any influential points in our regression model.

4 Conclusions and Limitations

To analyze the price elasticity of supply and demand of maize, multiple linear regression was used in this study and was conducted at national level and state level in USA.

At national level analysis, 7 out of 16 predictors are selected by conducting a stepwise regression. They are Fuel_use, Cereal_use, FAI_use, GD_use, Export and Total_domestic_use as the demand factors, and End_stock as the supply factors. The model showed a goodness of fit therefore can be used to explain maize price variation by supply and demand factor at a national level.

All the factors except FAI_use showed an elastic negative association of demand quantity and maize price. According to our initial assumption, demand elastics should be negative, and supply should be positive. However, FAI_use showed a positive demand elasticity (0.647). FAI_use is maize used for Food, alcohol, and industrial. One guess would be the maize used for FAI can be seen as Giffen good, meaning that consumption will increase even if the price rise when other factors fixed which is considered as a violation of the law of demand. End stock as the only left supply factors, it has a negative correlation with price (End stock elasticity = -3.251). From a practical perspective, increased end stocks reflect that more maize has been stored. It could be due to an excess of maize been supplied into the local markets and maize price is at a lower level.

At the state level analysis, I conducted regression model for all the 41 states. By comparing the average production elasticity between corn-belt states and non-corn-belt states, our assumption that E_sc should be generally smaller than E_sn is verified (E_sc < E_sn). Also, production has a general positive impact on maize price from the supply side (E_s >0), with production elasticity from 1.23 to 12.77. The production elasticity of Iowa (1.333) is less than Montana (2.976). The stock quantity of the states failed to explain the price because of this factor shows no significancy. This might be a fallacy due to the unfit of the regression model.

State-level analysis can be considered as an addition to national analysis in terms of testing the consistency of the association. Nevertheless, states-level analysis gives us insights on the supply effect difference within con-belt states and non-corn-belt states.

The approach of this study is to analyze the supply and demand effect on price encompasses some limitations. First one, the models employed are all based on OLS regression. Large data is essential to obtain reliable estimation. Our data is small dataset, which could cause the coefficient estimation of some factors may vary with different factor included into the model. Then, this model could be calibrated by adding time lag term which would require more efforts in tuning and testing the function form but could add more practical meaning to the model. Besides, the regression takes all observation as data point which ignored the characteristics temporal effect of my data. Further research could be done on adding time trend into linear regression.

5 Acknowledgement

I would like to thank Dr. Rens van Beek for organizing the structure of this paper and teaching me writing paper, Dr. Marc Bierkens and Dr. Brian Dermody for good measures provided. I acknowledge the help of Danny Redel, Baiju Man and Yan Tan on statistical modeling and technical supports. Besides, I would like to thank Brian Reeds for supporting and motivating me to take the challenge and thank my partner Toby Shi for his accompany through day and night even he is at the other side of the earth. Thank you all for walked me through two months and help me to grow. This paper is here because the support from you all.

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Appendix

Appendix A. Full name of supply factors and demand factors at the national level and their abbreviation.

Full name	Abbreviation
Alcohol for beverage and manufacturing use	BeverageManuf_use
Alcohol for fuel use	Fuel_use
Cereal and other product use	Cereal_use
Feed	Feed_use
Food, alcohol, and industrial use	FAI_use
Food, seed, and industrial use	FSI_use
Glucose and dextrose use	GD_use
High-fructose corn syrup (HFCS) use	HFCS_use
Seed use	Seed_use
Starch use	Starch_use
Export, market year	Exports
Total domestic use	Total_domestic_use
Ending stocks	End_stock
Imports, market year	Imports_mktYr
Production	Production
Total supply	Total_supply
Prices received by farmers	Price

Appendix B. Table of 41 states data used at the state level analysis

States	Corn Production_Avg (1000 tons)	Corn Production _SDV	Corn price_Avg ($/t)	Corn price_SDV	Corn Stock_Avg (1000 tons)	Corn stock_SDV
IOWA	36838.72	16615.81	93.76	49.80	6619824.04	30540.30
ILLINOIS	32815.58	14259.92	96.37	48.98	5009218.48	28167.89
NEBRASKA	21360.53	13067.49	94.25	48.80	3550281.09	21997.84
MINNESOTA	18019.58	10255.34	90.37	48.51	3279381.55	21078.69
INDIANA	15721.82	6288.40	96.85	51.59	1994009.53	10811.48
OHIO	9307.11	3455.47	97.14	51.24	1272967.59	6447.32
SOUTH DAKOTA	7410.46	5920.60	88.54	48.64	1131228.18	9914.68
WISCONSIN	7347.87	3748.67	93.66	47.82	1123997.31	7784.24
MISSOURI	6751.77	3267.68	96.87	51.07	814842.82	4129.65
KANSAS	6488.76	5405.41	96.00	49.37	759673.62	7639.11
MICHIGAN	5037.45	2318.74	94.08	49.60	692588.42	4219.23
TEXAS	3573.28	2312.58	103.96	52.82	338428.37	3030.54
KENTUCKY	3195.59	1408.93	100.59	49.60	323143.85	1681.18
NORTH DAKOTA	2497.59	3442.67	88.25	46.89	333659.09	6060.56
PENNSYLVANIA	2435.12	912.86	108.52	53.85	315872.36	1476.22
NORTH CAROLINA	2249.98	628.06	105.47	54.81	215614.18	855.24
COLORADO	2234.90	1448.76	97.86	48.61	238735.19	2143.11
TENNESSEE	1641.77	792.14	100.86	50.46	103298.67	496.37
GEORGIA	1408.94	543.71	107.05	57.15	99507.39	795.56
NEW YORK	1256.76	704.93	107.69	55.53	67130.69	995.38
MARYLAND	1122.29	435.18	106.09	54.92	88624.70	447.81
MISSISSIPPI	1043.02	949.69	102.09	48.94	53982.32	444.90
VIRGINIA	941.90	297.28	104.12	52.42	68708.55	459.36
LOUISIANA	837.41	829.34	101.08	49.00	79064.77	592.85
ARKANSAS	778.63	1049.65	98.80	49.73	31663.94	432.69
ALABAMA	760.42	323.04	104.64	52.59	54192.77	395.96
SOUTH CAROLINA	689.63	248.44	104.37	53.03	38709.31	293.88
CALIFORNIA	572.41	303.02	116.32	51.66	45747.99	307.14
OKLAHOMA	432.68	358.80	101.68	50.52	26935.10	336.21
DELAWARE	409.64	186.61	106.91	56.37	37765.11	202.54
WASHINGTON	308.25	213.47	112.28	52.35	34855.21	327.87
FLORIDA	227.60	137.59	103.52	54.93	8941.37	120.68
IDAHO	201.36	194.53	111.55	53.84	13026.62	160.33
NEW JERSEY	200.96	66.37	105.97	53.87	9967.74	140.85
NEW MEXICO	161.10	113.69	109.22	52.20	3136.68	70.41
WEST VIRGINIA	119.74	43.69	104.14	50.97	7504.45	111.91
WYOMING	111.78	78.57	98.38	47.72	2979.48	53.94
OREGON	97.74	86.20	113.91	52.47	3658.53	63.04
ARIZONA	74.58	65.28	122.78	58.54	5814.16	79.89
MONTANA	50.17	52.89	102.91	51.55	944.45	19.81
UTAH	49.42	37.69	115.49	53.19	5023.01	108.64

Appendix C. Summary of 41 states regression result by corn-belt states and non-corn-belt states.

Corn-belt State	beta_0	beta1	p-value	Production_Elasticity	beta2	p-value	Stock_Elasti	Rsqr	Rsqr_adj
ILLINOIS	-3.080	0.594	★ 0.029	1.684	0.129	☆ 0.369		0.500	0.486
INDIANA	-3.284	0.575	★ 0.009	1.739	0.220	☆ 0.209		0.502	0.488
IOWA	-2.411	0.745	★ 0.002	1.342	-0.081	☆ 0.583		0.528	0.514
KANSAS	0.723	0.286	★ 0.001	3.498	0.147	☆ 0.351		0.600	0.589
MINNESOTA	-1.344	0.626	★ 0	1.597	-0.028	☆ 0.824		0.583	0.571
MISSOURI	-0.755	0.413	★ 0	2.423	0.174	☆ 0.390		0.251	0.230
NEBRASKA	0.398	0.599	★ 0	1.670	-0.169	☆ 0.145		0.622	0.612
OHIO	-4.104	0.699	★ 0	1.430	0.229	☆ 0.195		0.543	0.530
SOUTH DAKOTA	0.945	0.506	★ 0	1.978	-0.099	☆ 0.464		0.491	0.476
WISCONSIN	-0.759	0.475	★ 0	2.106	0.109	☆ 0.435		0.580	0.568

Non-corn-belt State	beta_0	beta1	p-value	Production_Elasticity	beta2	p-value	Stock_Elasti	Rsqr	Rsqr_adj
ARIZONA	3.550	0.310	★ 0	3.224	-0.006	☆ 0.859		0.553	0.541
DELAWARE	-0.020	0.630	★ 0	1.587	0.138	☆ 0.298		0.542	0.529
IDAHO	2.840	0.435	★ 0	2.301	-0.068	☆ 0.306		0.749	0.742
MARYLAND	0.111	0.809	★ 0	1.236	-0.167	☆ 0.288		0.456	0.440
MICHIGAN	-1.291	0.764	★ 0	1.309	-0.077	☆ 0.598		0.623	0.613
MISSISSIPPI	5.364	0.471	★ 0	2.124	-0.610	★ 0.000	-1.639	0.288	0.268
MONTANA	3.359	0.336	★ 0	2.972	0.031	☆ 0.278		0.706	0.697
NEW JERSEY	2.905	0.383	★ 0	2.610	-0.108	★ 0.000	-9.237	0.590	0.578
NEW MEXICO	3.663	0.233	★ 0	4.287	-0.061	★ 0.001	-16.296	0.603	0.592
NEW YORK	0.821	0.531	★ 0	1.885	0.014	☆ 0.364		0.691	0.682
OREGON	3.945	0.300	★ 0	3.330	-0.154	★ 0.002	-6.489	0.604	0.593
PENNSYLVANIA	-2.395	0.588	★ 0	1.700	0.293	☆ 0.093		0.524	0.510
SOUTH CAROLINA	3.499	0.559	★ 0	1.790	-0.424	★ 0.000	-2.361	0.508	0.494
TENNESSEE	0.913	0.626	★ 0	1.597	-0.137	☆ 0.238		0.343	0.325
UTAH	3.626	0.312	★ 0	3.203	-0.009	☆ 0.811		0.708	0.699
VIRGINIA	2.840	0.583	★ 0	1.716	-0.337	★ 0.001	-2.970	0.253	0.231
WYOMING	3.510	0.268	★ 0	3.738	-0.066	★ 0.003	-15.188	0.592	0.580
ARKANSAS	3.719	0.228	★ 0.001	4.381	-0.099	☆ 0.262		0.267	0.246
KENTUCKY	-2.662	0.522	★ 0.001	1.916	0.360	★ 0.037	2.776	0.556	0.543
WISCONSIN	-0.759	0.475	★ 0.002	2.106	0.109	☆ 0.435		0.580	0.568
TEXAS	0.916	0.285	★ 0.005	3.505	0.169	☆ 0.059		0.707	0.699
WEST VIRGINIA	3.279	0.336	★ 0.007	2.973	-0.124	★ 0.000	-8.092	0.444	0.429
GEORGIA	5.044	0.464	★ 0.008	2.154	-0.544	★ 0.000	-1.839	0.265	0.244
NORTH DAKOTA	2.474	0.271	★ 0.009	3.686	0.003	☆ 0.978		0.624	0.613
ALABAMA	7.624	0.279	★ 0.012	3.590	-0.759	★ 0.000	-1.318	0.490	0.475
LOUISIANA	0.625	0.078	★ 0.025	12.773	0.498	★ 0.000	2.006	0.565	0.553
COLORADO	2.089	0.316	☆ 0.071		0.010	☆ 0.957		0.574	0.562
FLORIDA	3.777	0.230	☆ 0.092		-0.143	★ 0.000	-7.004	0.255	0.234
OKLAHOMA	2.674	0.190	☆ 0.103		0.138	☆ 0.261		0.419	0.403
NORTH CAROLINA	-1.535	0.375	☆ 0.126		0.401	☆ 0.103		0.145	0.120
CALIFORNIA	1.920	-0.038	☆ 0.682		0.471	★ 0.001	2.123	0.297	0.277

Factors whose p value below 0.05 are marked with yellow star, and then the elasticity is calculated and showed in green and red bars.

Appendix D. Diagnostic tests at national level

Tests	P-value	Conclusions
Homoscedasticity - Breusch-Pagan test	0.155 > .05	Residuals have constant variance
Independency - Durbin Watson Test	0.068 > .05	Residuals have no autocorrelation
Normality - Shapiro-Wilk Test	0.83 >.05	Residuals are normally distributed