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Analysis of meat price volatility and volatility spillovers in Finland

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Abstract: Unforeseen important changes in price can present a significant risk in the market. The price fluctuation of agricultural commodities has raised concern for studying the volatility of different agricultural products. A persistent volatility in prices causes continued uncertainty in the market. Higher price volatility is to be mitigated by higher management costs and the higher cost of risk mitigation is often converted into higher producer prices. The aim of this paper is to investigate the price volatility of producer and consumer meat prices and to capture the volatility spillover along the Finnish meat supply chain. The Generalised Autoregressive Conditional Heteroskedasticity – Baba, Engle, Kraft and Kroner (GARCH-BEKK) model is applied to analyse shocks and volatilities of the prices and to estimate whether the price volatility is flowing from the first price level (producer) to the second price level (consumer), using monthly price indices. An asymmetric volatility spillover effect was detected in the poultry meat and a unidirectional, volatility spillover effect, from consumer to producer, is observed for pork prices. The findings of this study could serve as a tool for forecasting meat producer and consumer prices, which could assist the Finnish government with endorsing policy options to alleviate the price volatility impact, to protect both consumers and producers from its negative effects.

Keywords: asymmetric volatility spillovers; consumer price; GARCH-BEKK model; meat products; producer price

Due to different circumstance changes (e.g. political, institutional, environmental), the future of the agricultural market is characterised by uncertainty caused by internal and external forces. Therefore, to preserve the interests of both farmers and consumers, an efficient food supply chain should be established. Thus, a well-functioning supply chain presents a priority for a market to operate efficiently. Since price is the main mechanism which links the different actors of the supply chain and it has experienced many changes, many research studies have investigated these changes.

Price and quantity of agricultural products can change randomly. The sudden change leads to market disruption. It creates difficulty in forecasting price in the market because of high uncertainty (Piot-Lepetit and M'Barek 2011). The European Union agricultural market is monitored by the Common Agricultural Policy (CAP). The market information system of the European Union is an evolving one (Gocht et al. 2017). Its main mission is to provide information on the supply and prices of mass agricultural products, regulated by the common agricultural policy (CAP). In 2016 a specific task force has been formed to upgrade the efficiency of market regulation (Veerman et al. 2016). The suggestions of the task force have highlighted the importance of the introduction of a mandatory price information system and highlighted the importance of modernisation and standardisation of data collection methods, better integrating the industrial input sector as well as wholesale and retail enterprises. Because of disequilibrium between the supply and demand of agricultural products, prices significantly increased during 2007 and 2008. The main role of the CAP is to ensure food stability for the European population (Alexandri 2011). In addition, it has to adjust the market in order to avoid price perturbation (Bórawski et al. 2018).

After joining the European Union (EU) in 1995, Finland experienced a decline in agricultural product

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prices (Toikkanen and Nieni 2014). Despite the decrease in Finnish agricultural products, the lowest agricultural price in the EU remained much lower than the Finnish producer price. Thus, it was difficult for the Finnish economy to adapt rapidly after the transition from a closed market to an open market. The CAP has adopted many changes in order to protect agriculture in the Eurozone. The protection of agricultural producers is a priority of the EU, but the WTO agreement and other bilateral treaties naturally limit the possibilities of defence of interests of producers (Lydgate and Winters 2019). Many policies have been adopted for this purpose. Originally, the Common Agricultural Policy has been developed for boosting of agricultural production and offering a fair income to farmers. Results of the Common Agricultural Policy have been rather mixed: the considerable subsidies caused a hardly manageable overproduction, but the CAP has not been able to considerable slower the migration from rural regions (Sorrentino and Henke 2016). The decreasing of market interventions and increasing direct payments have not been efficient enough to motivate the agricultural producers for more market-oriented behaviour (Bojnec and Fertő 2019). In the future, the CAP should better serve the enhancement of competitiveness of agro-food sphere of the EU, by enhanced supporting innovation and technology change in the era of information technology, increase the market transparency as well as better harmonisation of the CAP with the competition law.

Many policies have been adopted for this purpose. The financial support given to Finnish agriculture helps Finland stay in the European markets (Niemi and Kettunen 2018).

The livestock sector was concerned by the CAP reforms, after the 2003 reform. Decoupling of CAP support, has negatively affected Finnish meat sector. As a result, a decrease in beef production has been detected (Lehtonen 2004).

A significant decrease in meat products will be manifested as the result of removing the import duties (Huan-Niemi et al. 2017).

In Figure 1, we reported the monthly meat price changes of producer and consumer indices. It is clearly shown from the graph that all prices fluctuated significantly throughout the years.

Figure 1 presents consumer price (Cp) and producer price (Pp) of beef, poultry and pork meat. Cp beef, Cp pork and Cp poultry are consumer prices of beef, pork and poultry respectively. Pp poultry, Pp pork and Pp beef are producer prices of poultry, pork and beef respectively.

By examining the price volatility of a product, the unforeseen price change is detected. Unlike price transmission which deals with the mean change, price volatility reveals the conditional variance. Higher price volatility creates disequilibrium between the market actors and as a result, it generates negative effects on their welfare (Rezitis 2003, 2012).

The Finnish meat supply chain has been considered one of the target chains for examining the relationship between different market prices. In line with the number of market prices, we identify two kinds of examinations. Previous researches have involved

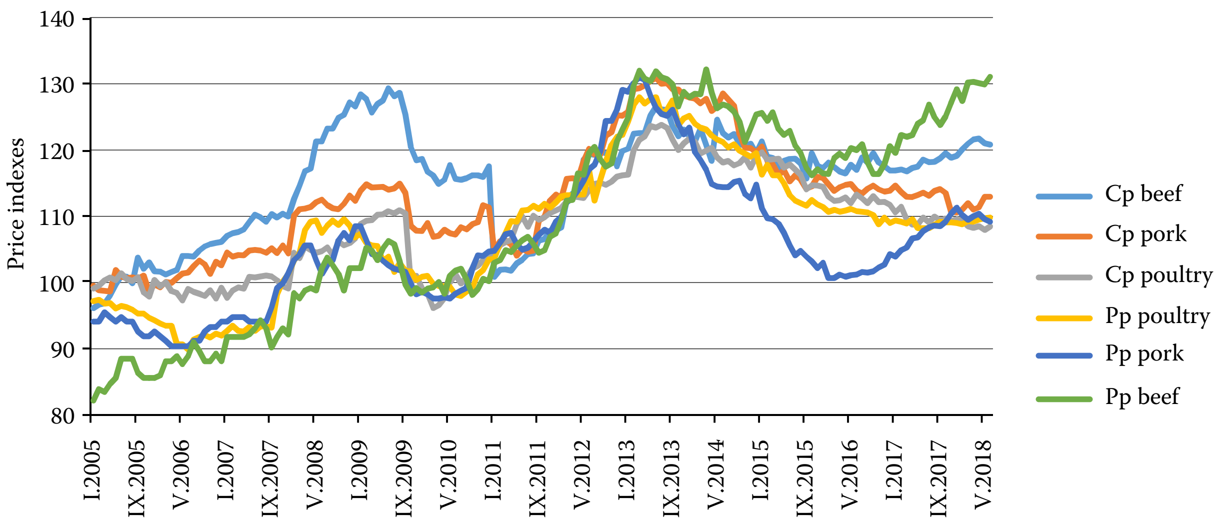

Figure 1. Meat price indexes (2010 = 100) of producer prices and consumer prices (Finland; period 2005:1–2018:06)

Source: Official Statistics of Finland (OSF 2018)

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only two price levels; producer and consumer prices (Luoma et al. 2004; Toikkanen and Niemi 2014). In 2018, Rezitis added another price, the agricultural price, to the other two (Rezitis 2018). Previous studies focus on expanding price transmission, dealing with the mean change, along the Finnish meat supply chain. This paper discusses the conditional variance change, volatility, and its transmission from one market price (producer price) to the other market price (consumer price).

In order to examine price volatility and volatility spillovers, Generalised Autoregressive Conditional Heteroskedasticity (GARCH) models have been adopted by many research studies. GARCH models are capable of capturing the shocks and conditional variance change as well as their persistence. GARCH models are extended from Autoregressive Conditional Heteroskedasticity (ARCH) models. ARCH models are elaborated by Engle (1982), which explains the conditional variance only by using past information (Silvennoinen and Teräsvirta 2009). Bollerslev (1986) defined the generalised ARCH (GARCH), and unlike ARCH models, GARCH introduced the lagged information terms as well as the lagged conditional variances.

This paper aims to examine the volatility and volatility spillover effects from producer to consumer prices of meat. This research uses one of the families of multivariate GARCH (MVGARCH) models; it is called BEKK. The BEKK model is defined by Engle and Kroner (1995). It displays the own shock and volatility spillovers as well as the cross shock and volatility spillovers between two prices.

Many authors have used the GARCH-BEKK model in their research to investigate volatility and volatility transmission (Musunuru 2014; Mohammadi 2015; Emenike 2018). They agreed BEKK is an appropriate model for assessing the volatility and its transmission between time series. It can help in identifying own and cross volatility transmission.

This study attempts to examine the uncertainty (volatility) of producer and consumer prices of meat to find out the extent of price volatility transmission between these two levels, in the interest of supporting of future agricultural policymaking in Finland.

MEAT MARKET IN FINLAND AND MAIN FACTORS INFLUENCING PRICE VOLATILITY

The Finnish retail food industry consists of only four principal components which comprise around 90% of the market (Aalto-Setälä 2002). Retailers deploy their market power over agricultural producers and processors (Rezitis 2018). Food supply chains, such as the meat supply chain, are dominated by retailers. An increasing trend in the effect of market power on retail surplus is induced (Irz and Liu 2016). Retailers are using their power to develop their own private labels, thus enhancing their power (Rezitis 2018).

In Finland, meat expenses present 19.2% of the total food expenditure. Meat consumption has fluctuated. The decrease in Finnish red meat is compensated for by poultry meat and other food products (Lehtonen and Irz 2013). In spite of the variation of poultry meat prices, an increase of 77% has been recorded in poultry meat consumption between 1995 and 2002 (Lehtonen 2004).

METHODOLOGY

Before estimating the BEKK model, some test conditions are required to be satisfied. Two unit root tests are employed to check the stationarity of different time series used in the analysis; the Augmented Dickey Fuller (ADF) test developed by Said and Dickey (1984) and the Phillips-Perron (PP) test, developed by Phillips and Perron (1988). The ARCH test developed by Engle (Engle 1982) is used to test the existence of the heteroskedasticity of the residuals and the autocorrelation of the squared residuals, and then the estimation of BEKK model, as presented in Equation (4), is performed (Engle and Kroner 1995).

BEKK model. In this study, the constant is used to construct the conditional mean of returns. Thus according to BEKK (1, 1) model, we consider the following equations:

$$R_t = \mu + \varepsilon_t \tag{1}$$

$$\varepsilon \backslash \Omega_{t-1} \sim N(0, H_t) \tag{2}$$

The natural logarithms of the data, and then the meat return is defined as:

$$R_t = \ln P_t - \ln P_{t-1} \tag{3}$$

where: R_t – the logarithmic meat price return in month t for each meat type; P_t – the meat price index in month t.

$$H_t = CC' + \sum_{i=1}^{P} A' \left(\sum_{p=1}^{Pi} \varepsilon_{t-i} \varepsilon'_{t-i} \right) A_i + \sum_{j=1}^{q} B'_j H_{t-j} B_j \tag{4}$$

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$$H_t = CC' + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} u_{1,t-1}^2 & u_{1,t-1}u_{2,t-1} \\ u_{2,t-1}u_{1,t-1} & u_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \quad (5)$$

where: A_i (i = 1, ... , p) and B_j (j = 1, ... , q) are unrestricted square matrices; R_t – T by 1 vector of first difference of natural log prices; ε_t – vector of residuals term derived from the Equation (1), Ω_{t-1} – the matrix of conditional information set at t – 1; H_t – the conditional variance-covariance matrix of the error term.

$$CC'\begin{bmatrix} C_{11} & 0 \\ C_{22} & C_{22} \end{bmatrix} \text{ is restricted to be positive.}$$

where: C – lower triangle matrix which presents the intercept matrix; C_{11} and C_{22} coefficients identify the mean conditional variance of producer and consumer prices respectively; C_{21} highlights the mean covariance.

The bivariate BEKK GARCH (1, 1) is shown in Equation (5). Equation (5) presents the matrix form of the conditional variance-covariance equation (H_t). The matrix a_{ij} registers the shock coefficients. a_{11} and a_{22} detect their own shock spillovers. a_{21} and a_{12} coefficients reveal the cross-price interaction of innovations. The matrix b_{ij} deals with volatility and volatility transmission. b_{11} and b_{22} coefficients indicate volatilities emanating from own price series. b_{21} and b_{12} coefficients explain the cross-price volatility transmission between two price series.

The log-likelihood function of the BEKK model is given by:

$$L(\Theta) = \frac{-T_n}{2} + \ln(2\pi) - \frac{1}{2}\sum_{i=1}^{1} \ln|H_t|) + \varepsilon' \,|\, H_t \,|\, \varepsilon_t) \quad (6)$$

where: $L(\Theta)$ – log-likelihood function; n – number of time series used in the model; T – total number of observations; Θ – vector of unknown parameters which should be estimated. In this case for each kind of meat; n = 2; t = 234; Θ = 11.

DATA

The study examines the meat supply chain, considering three commodities (i.e. beef, pork and poultry). Monthly prices indexes (2010 = 100) of producer and consumer prices for beef, pork and poultry in Finland were used. Data were collected from the Official Statistics of Finland (OSF 2018). The sample contains 234 observations for beef poultry and pork prices, running from January 1999 to June 2018.

EMPIRICAL ANALYSIS

Prior to estimating the BEKK model, the stationarity of the prices using the unit root of price series was checked, to ensure their appropriateness. Two different unit-root tests have been applied; the first test is the ADF and the second test is the PP. Both tests supported the evidence of the unit-root presence in the level series. The tests were re-run with the first differences and the unit root non-stationarity is rejected. The results showed that all the differenced series are stationary. The second test, the ARCH test, was applied to check the autocorrelation and the heteroskedasticity of the residuals.

All values of the ARCH test are statistically significant for all prices. The presence of ARCH effect is confirmed for all price series, which indicates the legiti-

Table 1. Descriptive statistics of meat price returns

Prices	Mean	Std. dev.	Min	Max	ARCH test
Pp beef	0.0006	0.0079	–0.3700	0.0284	97***
Pp pork	0.0006	0.0066	–0.0260	0.0196	1 704***
Pp poultry	0.0003	0.0051	–0.0193	0.0230	162***
Cp beef	0.0008	0.0078	–0.0593	0.0622	257***
Cp pork	0.0006	0.0069	–0.0386	0.0469	138***
Cp poultry	0.0011	0.0149	–0.0439	0.1832	5 393***

***significance of the values at 1%; Pp – producer prices; Cp – consumer prices; ARCH – Autoregressive Conditional Heteroskedasticity

Source: Own calculation using R studio

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Table 2. Unit root tests results

Variables	ADF test						PP test					
	type 1 (no drift no trend)		type 2 (with drift no trend)		type 3 (with drift and trend)		type 1 (no drift no trend)		type 2 (with drift no trend)		type 3 (with drift and trend)	
Level prices												
Pp beef	1.03	(0.91)	–0.21	(0.92)	–3.07	(0.125)	0.07	(0.70)	–0.28	(0.93)	–9.61	(0.47)
Cp beef	1.84	(0.98)	–1.47	(0.53)	–2.14	(0.51)	0.09	(0.71)	–2.45	(0.71)	–11.8	(0.37)
Pp pork	0.92	(0.90)	–2.47	(0.14)	–2.34	(0.43)	0.07	(0.70)	–7.07	(0.33)	–8.58	(0.53)
Cp pork	1.55	(0.96)	–1.94	(0.35)	–1.49	(0.78)	0.06	(0.70)	–3.58	(0.58)	–5.93	(0.73)
Pp poultry	0.54	(0.80)	–1.64	(0.46)	–2.23	(0.47)	0.03	(0.69)	–3.03	(0.64)	–5.14	(0.79)
Cp poultry	1.10	(0.92)	–1.99	(0.33)	–1.60	(0.74)	0.12	(0.71)	–5.18	(0.45)	–7.46	(0.62)
First difference of log prices												
Pp beef	–11.13	(0.01)	–11.13	(0.01)	–11.24	(0.01)	–199	(0.01)	–199	(0.01)	–198	(0.01)
Cp beef	–9.89	(0.01)	–10.08	(0.01)	–10.09	(0.01)	–269	(0.01)	–269	(0.01)	–268	(0.01)
Pp pork	–7.18	(0.01)	–7.23	(0.01)	–7.29	(0.01)	–152	(0.01)	–154	(0.01)	–155	(0.01)
Cp pork	–10.44	(0.01)	–10.58	(0.01)	–10.68	(0.01)	–289	(0.01)	–288	(0.01)	–286	(0.01)
Pp poultry	–9.43	(0.01)	–9.46	(0.01)	–9.45	(0.01)	–316	(0.01)	–316	(0.01)	–316	(0.01)
Cp poultry	–10.72	(0.01)	–10.80	(0.01)	–10.89	(0.01)	–272	(0.01)	–272	(0.01)	–272	(0.01)

ADF – Augmented Dickey Fuller; PP – Phillips-Perron; Pp – producer prices; Cp – consumer prices

Source: Own calculation using R studio

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macy of using ARCH/GARCH models. The optimal lag number is chosen based on the Schwarz information criterion (SIC).

Table 1 presents the basic descriptive statistics of the meat price returns over the study period. The diagnostic test (ARCH test) for conditional heteroskedasticity affirmed the strong presence of ARCH structure in all return price series, which further confirms the use of BEKK-GARCH models in explaining the volatility of producer and consumer prices.

Table 2 displays the results of the ADF and PP tests for stationarity. The acceptance of the null hypothesis of the ADF test and the PP test means that all-time series have a unit root. The computed values of the ADF and PP tests statistics demonstrate that the level prices have a unit root at the 1% significance level. This implies that the producer and consumer prices of beef, pork and poultry meat are not stationary but their first differences (returns) are stationary. The ADF and PP stationarity tests are significant at the 99% confidence level, thus indicating that the monthly price series are the first difference stationary.

The results derived from the estimated BEKK model are reported in Table 3. It outlines the own and cross-shock and volatility measures of producer (Pp) and consumer (Cp) prices for each meat category.

Among the estimated BEKK model parameters, registered in Table 3, ($A_{i,j}$) coefficients present the cross-price shock spillover effects and ($B_{i,j}$) coefficients indicate the cross-price volatility spillover effects. The two coefficients A_{11} and A_{22} provide the own shock spillover or the information for each kind of meat. A significant own shock spillover is generated in the producer price of pork and poultry and in the consumer price of pork. In other words, the own shock spillover is generated from its past information.

The estimated diagonal parameters B_{11} and B_{22} detect the own volatility spillover of each price. B_{11} refers to the own volatility spillover of the producer price for each kind of meat and B_{22} refers to the own volatility spillover of the consumer price of meat. B_{11} of pork and beef and B_{22} of beef and poultry are statistically significant, clearly exhibiting volatility in these price series.

A_{12} and A_{21} and B_{12} and B_{21} detect cross-price shock and volatility transmission between the producer and consumer prices for each meat category. A bi-directional shock spillover from producer price to consumer price of pork is highlighted. The price shocks are transmitted from the producer level to the consumer level, and *vice versa*, at the 1% and 5% significance levels, respectively. Past information passes between the producer and the consumer. A uni-directional shock spillover effect, from the producer price to the consumer price of poultry at the 1% significance level, has been identified.

The off-diagonal elements of matrix B show clearly a bi-directional volatility transmission between the producer and the consumer prices. A bi-directional volatility spillover is detected for beef and poultry meat at the 1% significance level. This finding determines that the

Table 3. GARCH-BEKK (1, 1) results

Parameters	Pp Pork/Cp Pork	Pp Beef/Cp Beef	Pp Poultry/Cp Poultry
C_{11}	0.0013**	0.0079	0.0010
C_{21}	0.0005	–0.0012	0.0001
C_{22}	0.0056***	0.0077	0.0029***
A_{11}	0.3159**	0.1000	0.2750***
A_{21}	–0.5000*	0.0200	–0.1065
A_{12}	0.1341**	0.0200	0.1664***
A_{22}	0.2798**	0.1000	0.0000
B_{11}	0.9108***	0.8000***	0.9217
B_{21}	0.1613*	0.1000***	0.4400***
B_{12}	0.0249	0.1000***	–0.0720***
B_{22}	0.0000	0.8000***	0.9037***
LB	4.23 (0.93)	1.88 (0.99)	1.24 (0.99)
PM	33.03 (0.77)	40.13 (0.46)	31.66 (0.82)

***, ** and *significance at the 0.1, 1 and 5% respectively; GARCH-BEKK – Generalised Autoregressive Conditional Heteroskedasticity; Pp – producer prices; Cp – consumer prices; LB – Ljung-Box test; PM – multivariate Portmanteau test

Source: Own calculation using R studio

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past volatility of the beef producer price affects the current volatility of the beef consumer price and *vice versa*. However, from Table 3 there is no evidence of price volatility spillover effect from the pork producer price to the pork consumer price; only uni-directional price volatility has been detected (from consumer to producer). It shows that volatility spillover takes place only from consumer to producer and not conversely as indicated by the B_{21} (0.1613) significance. Dealing with the volatility, a bidirectional volatility transmission was found within the beef supply chain, $B_{12} = B_{21} = 0.10$; the response from both levels (consumer and producer) is equal. The coefficient B_{21} is significant for three types of meat (poultry, beef and pork). Volatility transmission from consumer poultry meat to producer poultry meat is 0.44 which implies that an increase of 1% in the consumer price transmits 44% volatility to producer price of poultry meat. On the other hand, from producer to the consumer for poultry meat, only 7% of the volatility is transmitted This finding of higher volatility persistence in both price level consumer and producer meat prices calls for sustained efforts aimed at mitigating this uncertainty.

Table 3 shows the values of applied diagnostic tests to confirm the adequacy of the BEKK model. Ljung-Box (LB) and multivariate Portmanteau (PM) tests were implemented to test the serial correlation of the BEKK model residuals. We failed to reject the null hypothesis of both tests; no serial correlation and homoscedasticity have been confirmed. The insignificant LB and PM statistics further supported previous findings and the BEKK model is suitable for explaining the conditional heteroscedasticity of the data and it is powerful in capturing the volatility interconnections.

CONCLUSION

The BEKK model allowed us to detect and describe the degree of volatility for each type of meat as well as the level of transmission of this volatility between the two prices (producer and consumer) for each type of meat (beef, poultry and pork) by modelling the variance and covariance. The diagnostic tests of the model residuals affirmed that BEKK is an adequate model for investigating our data. Significant own price volatilities have been underlined in the producer price of pork and beef and the consumer price of beef and poultry. The significant cross-price shock effects imply a strong interaction between the two pork prices (producer and consumer); the advent of news in one market would have a strong influence on the other price. A strong significant volatility transmission between producer and consumer prices for poultry meat signifies the presence of price uncertainty for both prices. Poultry consumer price dominates the cross-price volatility spillover effects. The magnitude of volatility spillover effects exported from consumer to producer poultry and pork prices are much higher than the opposite direction which means the existence of an asymmetric relationship between producer and consumer, implying the presence of meat retail concentration and retail market power. Understanding the magnitude of volatility spillover effect between prices allows the government to be aware of the uncertainty price and to take the necessary measurements in order to protect farm and retail markets. The highly significant own cross-price volatility spillover effects for poultry, beef and pork meat could be explained or influenced by other factors or variables. Further research might be conducted by including agricultural policy, which captures policy implications.

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