The Great Recession and Vertical Price Transmission in the U.S Beef Market

Elham Darbandi
PhD student
Agricultural Economics
University of Kentucky
438 Charles E. Barnhart Bldg.
Lexington, KY 40546
Elham.Darbandi@Uky.edu
Sayed Saghaian
Associate Professor
Agricultural Economics
University of Kentucky
314 Charles E. Barnhart Bldg.
Lexington, KY 40546
ssaghaian@uky.edu

Selected Paper prepared for presentation for the 2016 Agricultural & Applied Economics Association, Boston, MA, July 31-August 2

Abstract

This study analyses the price adjustment of the U.S beef sector using monthly prices of the farm, wholesale and retail levels for the period of 1970-2014. The objectives are to investigate both speed and magnitude of price adjustment. To this purpose, the Vector Error Correction Model (VECM) and historical decomposition graphs are applied. The results indicate that retail prices have lower speed of adjustment than wholesale prices. Also, the magnitude of price adjustment in the presence of the Great Recession shock, as an exogenous shock, is different for each level of the U.S. beef marketing chain such that wholesale prices show a higher magnitude of price adjustment toward the long-run equilibrium. Finally, it is concluded that with respect to both speed and magnitude of the price adjustment, the U.S. beef sector has asymmetric price adjustment, pointing to inefficiency of the U.S. beef supply chain. These results have welfare implications for the U.S. beef consumers and producers.

Keywords: Price Transmission, Beef Market, VECM, Historical Decomposition

JEL: Q11, Q13

Introduction

Studying price interaction is beneficial because it would lead to better recognition of a market. As Goodwin and Holt (1999) asserted, price is the principal mechanism by which various levels of a market are connected. The vertical transmission of a shock in different stages of a market such as farm, wholesale and retail level is a significant attribute explaining the operation of a market. The price adjustment in response to a market shock has important policy implications such as marketing margins and mark-up prices practices. In other words, in the absence of complete pass-through, price information is not available to all economic agents and this may lead to inefficient outcomes because of distorted decisions. (Sarris, et al. (2007))

One of the economic shocks that have changed the social and economic life of Americans is the Great Recession which began officially in December 2007 and ended June 2009, which was called the longest economic downturn since the Great Depression of the 1930s (Grusky, et al. (2011)), and caused incomparable monetary and fiscal policy reactions (Hanson and Essenburg (2014)). The postwar history as the most severe phenomenon during the Recession from 1981 to 1982, lasted only sixteen months and did not bring about labor-market disruptions as profound as those occurred during the Great Recession(Grusky, et al. (2011).

The Great Recession has three different features compared to previous Recession. First, the decline in consumption per capita was Greater than 3 percent from the last quarter of 2007 to the second quarter of 2009 (Figure 1). Second, it was the longest economic downturn since the Great Depression. Third, consumption inequality declined among different age, race, education and wealth groups because of the varying effect (Grusky, et al. (2011).

<Insert figure 1 here>

Noticeably, personal consumption expenditure decreased during the Great Recession. However, disposable income showed a different trend due to a significant increase in the government transfers to the household. These transfers were in forms of unemployment insurance and food stamp. While wages and financial income declined as a result of Recession by 6.6 percent and 15.1 percent respectively, government transfers grew 18.8 percent from 2007 to 2009 (Grusky, et al. (2011).

This study investigates how different stages of a market adjust in response to an exogenous shock; the focus will be on the U.S beef market. There are two main objectives in this study; first the speed of adjustment will be studied, using Vector Error Correction Model (VECM). Second, the magnitude of adjustment during the Great Recession will be discussed, using the historical decomposing graph. The innovation of this research is using historical decomposition technique which is usually applied to macroeconomic shocks. There are only a few number of study which applied this approach to agricultural prices (Saghaian (2007), Saghaian, et al. (2008), Chopra and Bessler (2005)), all investigating food safety issues.

Generally, the consumption of meat is significant in the U.S., and about 4% of consumer disposable income and 30% of their food expenditure are allocated to meat and poultry products. Per capita meat consumption (red meat and poultry) increased over the past two decades until 2007 (Darko and Eales (2013). The importance of meat and beef as a food ingredient in the Unites States can be reflected by per capita consumption. Table 1 provides summary statistics of quarterly retail weight per capita disappearance (pounds)[1]. The average per capita disappearance is 62.2, 49.3, and 1.03 lbs., respectively for beef, pork and lamb. Beef has the highest per capita consumption (pounds) among other kinds of red meat from 2000-2014.

1- Disappearance is a proxy that United States Department of Agriculture (USDA) used as consumption level

<Insert table1 here>

Furthermore, beef has a higher price than, lamb, pork and broiler composite[2]. Studying the price relationship will help policy makers to be aware of the effects of a policy on different stages of this market. For example, if a policy to support beef producers is set at the farm level, how will consumer's welfare be affected by that policy through retailers? The livestock compensation program and the emergency livestock feed assistance are examples of such support policies that USDA provides to producers.

As mentioned before, the second objective of this study is to investigate the magnitude of price adjustment in the presence of the Great Recession as a real exogenous shock that affects the prices and consumption patterns. Figure (2) depicts the monthly nominal prices for beef at retail level of the U.S. beef market during Dec 2007 to June 2009 that includes the period of the Great Recession. Retail prices have had an increasing trend that reached its maximum by August, 2008. In the mean while, per capita food expenditure in the U.S has dropped (Figure 3).

<Insert figure 2 here>

<Insert figure 3 here>

In the following section a review of the literature on the price transmission is provided. Then, the conceptual framework, econometrics model and data are explained respectively. The empirical result section reports the result of the VECM model and historical decomposition of price series. The discussion section discusses the related diagnostic test and robustness of the result, and finally, summary and concluding remarks are presented.

2-- The retail values are based on Bureau of Labor Statistics (BLS) retail price data

Literature Review

In a competitive market, it is expected that the effects of a policy are transferred fully to the consumers. However, the results of some empirical studies in the U.S meat market (e.g. Hahn (1990); Goodwin and Holt (1999); Pozo, et al. (2013); Vavra and Goodwin (2005)), reported that the price transmission was faster when there was an increase in the upstream market prices compared to when there was a decrease. Numerous studies have addressed the price transmission along vertically linked market for agricultural products. Most of the earlier studies (e.g. Kinnucan and Forker 1987; Pick, Karrenbrock, and Carman 1990; Zahng, Fletcher, and Carley 1995) used a model based on the Wolffram-Houck specification to investigate the pass-through among different markets. This specification was criticized by Goodwin and Holt (1999) because of ignoring important properties of the time series data. Goodwin and Holt (1999) studied the price transmission in the U.S. beef sector, using weekly data and Threshold Vector Error Correction Model (TVECM). Also Carmon-Taubadel (1998) addressed the limitation of standard models of asymmetry and discussed the inconsistency of those models with cointegration between prices by modifying the standard Wolffram specification with including an error correction term. This modification allowed looking at the long-run relationship among price series. Application of this proposed model resulted that the transmission between the producer and wholesale pork prices in Germany is not symmetric.

Recently, Pozo, et al. (2013) compared the vertical price transmission in the U.S. beef market using two sources of retail prices which differ in the collection procedure. They used a threshold cointegration approach and monthly prices for 2001-2012. One of the retail price series is collected using electronic scanner at the point of sale, and the other one is collected by the bureau of labor statistics (BLS). They tested how the use of different retail prices will affect the result of price transmission.

Retail prices based on scanner data are available from 1999 in Economic Research Service (ERS) database. As Hahn, et al. (2009) argued, scanner data are reported with a 7-8 week lag and contributed little to the price analysis due to timing issues, while BLS data are available after 12-20 days of each month. Therefore, to takes advantage of a long period data (the period of 1970-2014) this study used BLS data. With a few exceptions (e.g. Saghaian (2007); Saghaian, et al. (2008)) previous studies did not discuss any specific real shock, and merely looked at the speed of adjustment. This study refers to the Great Recession as a real exogenous shock, and discusses the magnitude of adjustment in the presence of this shock.

Conceptual framework

The basic model to study vertical price transmission was introduced by Wolffram (1971) and modified by Houck (1977). This model has been used in numerous studies in agricultural economics. However, Von Cramon-Taubadel (1998) argued that this specification is not appropriate to test asymmetric transmission, because of its inconsistency with cointegration between prices at various levels of a market. Mathematically, based on the Wolffram-Houck specification, the relation between two levels of prices, P_i and P_j can be estimated by the following equation:

$$\sum_{t=1}^{\tau} \Delta P_{i,t} = \beta_0 + \beta^{+} \sum_{t=1}^{\tau} \Delta P_{j,t}^{+} + \beta^{-} \sum_{t=1}^{\tau} \Delta P_{j,t}^{-} + \varepsilon_t \qquad \text{Equ (1)}$$

where $\Delta P^{+}$and ΔP^{-} show the positive and negative changes in prices respectively, β_0, $\beta^{+}$and β^{-} are coefficients and τ is the time period. If $\beta^{+}$and β^{-} are equal, then the price transmission is symmetry.

Although, many empirical studies (e.g. Zhang, et al. (1995), Pick, et al. (1990), Kinnucan and Forker (1987)) used the above specification to test the symmetry, this model has been criticized because it ignores the nature of the time series data. In other words, in all of the above mentioned studies, the problem of first-order autocorrelation exists. This problem arises from non-stationary time series data, and leads to spurious regression (Von Cramon-Taubadel (1998)).

In order to avoid the problem of spurious regression in this study, first stationary tests are applied and then an appropriate model is used to check the price relationship. Augmented Dickey-Fuller test which is widely used in empirical studies is used in this study to check the stationary of variables. In order to assure the validity of the result of stationary test, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test has been applied as a complementary test to check stationary, as suggested by Kwiatkowski, et al. (1992). Both tests are explained in the next section.

Empirical Model

As mentioned earlier ADF test is used to prevent the problem of spurious regression. The basic unit root test starts with considering a simple Auto Regressive, AR (1) process:

$$Y_t = \rho Y_{t-1} + X_t \delta + \varepsilon_t \qquad \text{Equ (2)}$$

where, Y_t is the variable of interest (price series in this study), t is the time index, X_t represents the constant term and trend, and ε_t is the error term. After estimating ρ and δ, the null hypothesis $H_0\colon \rho = 1$ is tested against the alternative hypothesis $H_1\colon \rho < 1$. The standard t-distribution provides the critical value for this test. In the case that null hypothesis is accepted, a unit root is present and the series would be non-stationary. In other words, the variance of Y increases with time and approaches infinity, while if a series is stationary, its mean and variance are constant over time.

The above mentioned process is the basic of Dickey-Fuller (DF) test; there is an augmented version of the Dickey-Fuller test for a larger and more complicated set of time series model, called the Augmented Dickey-Fuller test (ADF). The advantage of The ADF test is that, it considers the possibility of higher order correlation by assuming that Y series follow an AR(P) process. The testing process is the same as for the DF test, but it is applied to the following model:

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \delta_1 \Delta Y_{t-1} + \cdots + \delta_{\rho-1} \Delta Y_{t-\pi+1} + \varepsilon_t \qquad \text{Equ (3)}$$

where, α is constant, β is the coefficient on a time trend and π is the lag order of the autoregressive process. The null hypothesis $\gamma = 0$ is tested against the alternative hypothesis of $\gamma < 0$. If the corresponding value for the test statistics in equation (4) is less than the relevant critical value, the null hypothesis is rejected and the series is stationary (Dickey and Fuller (1979)).

$$t_{\hat{\gamma}} = \frac{\hat{\gamma}}{SE\ (\hat{\gamma})} \qquad \text{Equ (4)}$$

The KPSS test is the other stationary test that this study uses. As a complementary to the DF test, KPSS is used for testing that a series is stationary around a deterministic trend. This test is based on the residual from the Ordinary Least Squares (OLS) regression of Y_t on the exogenous variableX_t. The test is the Lagrange Multiplier (LM) test and the null hypothesis is that the random walk has zero variance. In other words, the series is stationary. While in ADF test, the null hypothesis is that a variable has a unit root, and is not stationary. In econometrics, when a series is stationary in level, it is shown by I(0) that means integrated of order zero. Otherwise, if the first difference of a series is stationary, it is shown by I(1), and means it is integrated of order one (Charemza and Syczewska (1998)). This study first applies stationary test to the original prices, and then the first difference of each series.

After stationary test, the second step will be using Johansen's cointegration test to determine if a long run relationship exists among the price series. Based on the result of stationary and cointegration test, it can be decided if VECM is an appropriate model to fit the data. Cointegration techniques are useful to test the extent of price transmission along the market levels (Saghaian (2007)). The Johansen and Jeselius technique is very popular for estimating a group of cointegration relationships (Johansen (1991); Johansen and Jeselius (1992)). This technique begins with a Vector Error Correction (VEC) model, as follows:

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-1} + \Pi X_{t-k} + \varepsilon_t \qquad \text{Equ (5)}$$

where, X is a p-element vector of observations on all variables in the system at the time t, α_0 is a vector of intercept terms, $\Gamma_i \Delta X_{t-1}$ term accounts for stationary variation related to the history of variables, and Π matrix contains the cointegration relationship. In this study, X is a 3×1 matrix, since there are three price series. All variables must be non-stationary in levels, and it is hypothesized that $\Pi = \alpha\beta'$ where "β" is a matrix combining the cointegration vectors. This cointegration, requires that the β matrix contain parameters such as Z_t, where $Z_t = \beta' X_t$ is stationary. In other words, the β matrix contains the cointegration vector that represents the underlying long-run relation. Also, the α matrix represents the speed at which each variable changes to return to their respective long-run equilibrium after a temporary shock. (Johansen and Juselius (1992, Schmidt (2000); Saghaian 2007).

Data Description

This study utilizes monthly time series nominal beef price spreads, assembled for the period from January 1970 to December 2014 for the farm, wholesale and retail levels. These data are retrieved from the United Stated Department of Agriculture (USDA), Economic Research Service (ERS). USDA data for farm and wholesale are based on Agricultural Marketing Service (AMS) data, and the retail values are based on Bureau of Labor Statistics (BLS) retail price data. Using this long period and updated data is an advantage for this study. Descriptive statistics of the price series are provided in Table 2.

<Insert table 2 here>

The beef prices in this study are related to the choice grade beef. The grades are decided based on measurements of beef tenderness, juiciness and flavor by USDA meat graders' subjective assessment, and by electronic instruments. Prime, choice and select are the three quality grades awarded. Most of the graded beef sold in the supermarket is either USDA Choice or USDA select (USDA, 2012;Surathkal, et al. (2014)). The wholesale cutout beef data from USDA- Agricultural Marketing Service (AMS) (2013) show that the shares of Choice, Select and prime in the total graded and branded beef products are about 47%, 36% and 1% respectively. Hence, this study relies on the Choice grade beef that has the highest production level. However, prime is considered the highest quality grade based on marbling and is generally sold in restaurants and hotels. The choice grade is considered to be superior in quality to the select grade. (Surathkal et al. 2014).

Empirical Results and Discussion

As discussed earlier, it is important to check the stationary before running the pass-through regressions. Both Augmented Dickey-Fuller (ADF) test and KPSS test are used for this purpose; results are reported in table 3. Based on ADF test, the null hypothesis of a unit root for the price series cannot be rejected. First difference of each series is also tested. The null hypothesis of a unit root at the 1% level of significance is rejected in each series. For the ADF, the lag lengths are chosen based on Schwarz Info Criterion (SIC). These results are closely consistent with the previous studies such as, Saghaian et al (2007); Vavra and Goodwin (2005). Also, the KPSS test, confirms that the price series are stationary at their first difference.

<Insert table 3 here>

Since it is proved that all the series are integrated of order one, next step is to check for the long-run equilibrium or cointegration, and the results are provided in table 4.

<Insert table 4 here>

Johansen's test is a likelihood ratio (LR) test designed to determine the number of cointegration vectors in the system, or the cointegration rank *r*. Theoretically, "*r*" can be at most one less than the number of endogenous variables in the model (Saghaian, 2007). The results reject the null hypothesis r=0 and r<=1, but the null hypothesis r,=<2 is not rejected (table 4). This indicates that there are two vectors of long-run relationships.

As mentioned earlier, the all variables are stationary at the first difference, and a long run relationship exists between them. Therefore VECM is an appropriate model. Before estimating the final model, the appropriate number of lags should be chosen. There are some criteria to do that, including Akaike Information Criterion (AIC), Schwarz information criterion (SIC) and Bayesian Information Criterion (BIC). Koehler and Murphree (1988) have compared the Akaike information criterion (AIC) and the Schwarz information criterion (SIC) in the time series analysis. The results of this comparison shows that it is preferable to apply the SIC, which leads to lower order models for predicting. Therefore, this study used SIC as the lag length criteria.

Table 5 provides the empirical estimates of the speed of adjustment for three price series, whereΔP_{ft}, ΔP_{wt} and ΔP_{rt} are the dependent variables of the models, which are related to the farm, wholesale and retail prices respectively.

<Insert table 5 here>

The coefficient of the lagged error correction term is interpreted as the short term adjustment coefficient, and represents the proportion by which the prices adjust in response to the long run disequilibrium. The R-squared values indicate the goodness of fit of the models which are 12%, 17% and 39% for the farm, wholesale and retail levels respectively. The R-squared values are low, and only the coefficients for retail and wholesale are statistically significant. These results are supported by Saghaian (2007) who used weekly beef price spreads during the period of January 5, 1991 to July 2,2005 for the feedlot, wholesale and retail prices. He found the speed of adjustment is only significant for wholesale and retail level and R-squared value were 0.14, 0.39, and 0.13 for three above mentioned level of the U.S beef market.

In this study, the speeds of adjustment for retail and wholesale prices are statistically significant at the one percent level with estimated values of 0.23 and -0.11, respectively. The speed of adjustment for farm prices was 0.034, but statistically insignificant. The dynamic speed of adjustment for wholesale prices (0.223) in absolute value, that is larger than the retail prices (0.115), this is an indication of asymmetric price transmission with respect to speed. This important result indicates that in the U.S beef sector, wholesale prices adjust much more rapidly, and are more flexible than the retail prices in response to a shock. In other words, it took more time for the retail prices to come back to the longrun equilibrium after the Great Recession had elevated the prices. It implies that the burden of a positive price shock is more on the retailers and consumers than the producers.

The asymmetric price transmission might be because of non-competitive market condition; however, this hypothesis must be checked for the U.S beef sector using appropriate modeling that is not the purpose of this study. Some of the previous studies listed some reasons as the cause of asymmetric adjustment. Luoma, et al. (2004) emphasized that the market power could be a good explanation for asymmetric adjustment. Conforti (2004) summarized six groups of factors affecting the price transmission for agricultural markets: transport and transaction costs, market power, increasing returns to scale in production, product heterogeneity and differentiation, exchange rates, and border and domestic policies. All of these factors are related to both vertical and spatial price transmission.

According to the result of VEC model, the wholesale beef market is more competitive and operates more efficiently than the retail market with respect to speed of adjustment. This result in this step is consistent with what other researchers found for the U.S beef market. For example, Saghaian (2007) found out that the prices in wholesale market adjusted more than six times faster than the prices in retail market in response to the BSE shock. The author argued there have been concerns regarding the high degree of packer concentration at the wholesale level.

It is important to mention that in table 5, the negative sign of the retail and positive sign of the wholesale price coefficients imply that when the cointegration equation is out of equilibrium, the wholesale prices tend to rise whereas the retail prices tend to fall, resulting in a wider price margin. This point is elaborated in more details using the historical decomposition graph in the next section.

Historical Decomposition Graphs:

As discussed in the previous section, the speed of price adjustment along the U.S. beef sector varied from stage to stage. The other important aspect of the price transmission is the magnitude of adjustment. In this study, the historical decomposition graph is used to measure this magnitude. The Historical decomposition traces the short-run dynamic effects of the beef market shock on the prices, which is helpful to develop a visual explanation of the impact of a shock in the neighborhood of the event (Saghaian (2007)). These graphs are based upon partitioning of the moving average series into two parts, (Fackler and McMillin (2002); RATS - (2004)) as follows in equation 6:

$$P_{t+j} = \sum_{s=0}^{j-1} \gamma_s U_{t+j-s} + \left[\beta X_{t+j} + \sum_{S=j}^{\infty} \gamma_s U_{t+j-s}\right] \qquad \text{Equ(6)}$$

where P_{t+j} is the multivariate stochastic process, U is multivariate noise process, X is the deterministic part of P_{t+j}, and S is the counter for the number of time periods. This study used the RATS[3] software to extract the graphs. The solid lines represent the actual prices, and predicted price are shown by the dashed lines. It is noteworthy that only actual prices are influenced by the Great Recession shock. Although the dynamic impacts of any shock can last over a long time, the scope of this study is limited to the period of the Great Recession (i.e., Dec 2007 to June 2009). The results are shown at figure 4.

<Insert figure 4 here>

Before the start date of the Great Recession, the actual farm, wholesale and retail price (solid lines in figure 4) represent less volatility. But after this date sharp increases and decreases is obvious in all the three series of prices. Also, the retail prices in contrast to the wholesale and

[3] Regression Analysis of Time Series

farm levels never returned to the original level (i.e., the beginning of recession), while both the wholesale and farm levels experienced lower prices at the end versus start date of the recession.

The historical decomposition for the all three market prices (i.e. farm, wholesale and retail) indicate that they have started to sharply increase at some date, peaked, and then decreased. Interestingly, the actual and predicted prices are equal at two dates (points A and B) in this period. However, the markets are different in terms of the dates of points A and B, and the length of the period between them (Table 6), where the actual price is higher than the predicted price (figure 4).

<Insert Table 6 here>

According to Table 6, the period that the actual price is higher than the predicted is longer in the retail market than the wholesale and farm markets. On the other hand, inside the Great Recession period, such as august 2008, the highest difference between actual and predicted price is related to retail level followed by wholesale and farm level. The intuition behind this point is that, in the short run an exogenous shock affected retailers much more severely than other stages of the Beef market.

In August 2008, the estimated magnitude of the actual farm prices was 3.6 % higher than the predicted prices without the shock. Also, at the maximum point, the estimated magnitude of the actual wholesale prices with the impact of the Great Recession was 9% higher than the predicted prices without the shock. However, a huge drop in the wholesale prices occurred in March 2009 (one month after huge reduction in farm price), at that time the difference between the actual and predicted wholesale price was about 13% (exactly the same as the farm level). This indicates that the farm and wholesale prices mimicked each other very closely in reduction with one month lag. In August 2008, the estimated magnitude of the actual retail prices with the impact of the Great Recession was. 6.7% higher than the predicted prices without the shock. The historical decomposition graph indicates that the wide departure between the actual and predicted retail price is in May 2008, and lasted until March 2009 (10 months). In contrast to the farm and wholesale level, no sharp reduction has been observed in the retail prices. Therefore, the burden of price increase was on the retailers and consumers for a longer period than the producers. This is in agreement with another study by Saghaian, et al. (2008), which investigated the effects of food safety scare on the Turkish poultry sector. However, the results are in disagreement with Saghaian (2007), who reported that an exogenous beef safety scare on the U.S. beef sector impacted producers and packers much more severely than beef retailers in terms of the magnitude of adjustment. The difference could arise from the nature of the shocks. In the latter study, the BSE[4] shock was investigated. This shock was discovered in December 2003, and had a negative impact on the U.S. beef market, while in this study, the Great Recession had a positive effect on the prices (figure 2), and the trend of nominal retrial beef price was increasing over the period of Great Recession.

In summary, the historical decomposition analysis confirmed that the emerge of Great Recession had affected all the prices positively as expected, but the effects had been substantially different between levels of the market (i.e., 3.6 %, 9% and 6.7% in the farm, wholesale and retail levels respectively). This confirms the results of VECM model regarding the differential speeds of adjustment. Both approaches addressed the asymmetry price transmission in the U.S. beef marketing channel.

4 -BSE, Bovine Spongiform Encephalopathy, is a fatal neurological disease that can occur in adult animals aged five years or older.

Robustness tests:

As the results of estimated VECM in table 5 showed, the relevant coefficients for the speed of adjustment at the retail level and wholesale level were statistically significant. However, if the error terms are serially correlated, the estimated standard errors are invalid and the estimated coefficients will be biased. This issue can be investigated using an appropriate serial correlation test. Portmanteau and Lagrange Multiplier (LM) test are two examples of common tests to check the autocorrelation in residuals (Bruggemann, et al. (2006)). In this study, the Breusch- Godfrey (BG) test that is based on the idea of Lagrange Multiplier is applied. The BG test is sometimes referred to as LM test for serial correlation. Even though, the Durbin-Watson (DW) test is a very common test for serial correlation, it is not appropriate in this study because DW is valid only if these assumptions are satisfied:

(a)The model has a constant term.

(b) The serial correlation is of order one.

(C) The lagged dependent variable is not included in the model as an independent variable. Mathematically, if the model has the form of equation (7), the DW is not valid.

$$\mathrm{Y_t} = \beta_1 + \beta_2\mathrm{X_{2t}} + \beta_3\mathrm{X_{3t}} + \cdots + \beta_k\mathrm{X_{kt}} + \gamma\mathrm{Y_{t-1}} + \varepsilon_t \qquad \text{Equ (7)}$$

In the vector error correction model, the lagged of both dependent and independent variables appear in the model as explanatory variables. Therefore, the results of DW test are not reliable. In this case, the LM test, developed by Breusch (1978) and Godfrey (1978), is an alternative way to check the serial correlation. The procedure is as follows:

$$\mathrm{Y_t} = \beta_1 + \beta_2\mathrm{X_{2t}} + \beta_3\mathrm{X_{3t}} + \cdots + \beta_k\mathrm{X_{kt}} + \mathrm{U_t} \qquad \text{Equ (8)}$$

where Y and X are independent and dependent variables respectively, and $\mathrm{U_t}$ is the residual term, which is expanded as:

$$\mathrm{U_t} = \rho_1 \mathrm{U_{t-1}} + \rho_2 \mathrm{U_{t-2}} + \cdots + \rho_p \mathrm{U_{t-p}} + \varepsilon_t \qquad \text{Equ (9)}$$

Combining these two equations, $\mathrm{Y_t}$ can be written as:

$$\mathrm{Y_t} = \beta_1 + \beta_2 \mathrm{X_{2t}} + \beta_3 \mathrm{X_{3t}} + \cdots + \beta_k \mathrm{X_{kt}} + \rho_1 \mathrm{U_{t-1}} + \rho_2 \mathrm{U_{t-2}} + \cdots + \rho_p \mathrm{U_{t-p}} + \varepsilon_t \qquad \text{Equ (10)}$$

Then, the null hypothesis is there is no autocorrelation, such that $\rho_1 = \rho_2 = \cdots = \rho_p$. The alternative hypothesis is that at least one of the residual coefficients is non-zero, and there is a serial correlation between the residual terms. In this test, LM statistic will be compared with χ^2 critical value (Asteriou and Hall (2011)).

The results of the serial correlation test between the residuals are reported in table 7.

<Insert table 7 here>

In the above table, "Obs*R-squared" is the number of observation times the R-square statistic, and has an asymptotic chi-squared distribution. The result of this test proves that the null hypothesis cannot be rejected. Therefore, there is no serial correlation between the error terms, and thus, the standard errors are reliable.

In order to evaluate the robustness of the results of estimated model, a subset of data has been chosen and the model is re-estimated. Table 8 displays the VECM model for the period of 2000-2014, including 180 monthly observation of each price series.

<Insert table 8 here>

Using a subset of data in re-estimating the VECM, results of table 8 support the previous results. The speed of adjustment that is reflected by the lagged error correction term is different between each price series. Hence, it addresses the asymmetric price transmission. Again, the relevant coefficients for both the wholesale and retail levels are significant and the negative sign for the retail prices implies that the retail prices tend to fall out of equilibrium.

Summary and Conclusion

This study analyzed the price adjustment in the vertical market channel, using monthly prices for the farm, wholesale and retail level for the period of 1970- 2014. To address the dynamic of price adjustment along the U.S. beef marketing channel, time series analysis including cointegration and Vector Error Correction (VEC) model have been applied to address the of speed of price transmission. The estimation process can be summarized as follows. First, standard Dickey-Fuller unit root tests and KPSS test were used to evaluate the times series properties of the data. To prove the longrun relation between variables Johansen cointegration approach was applied and finally VEC model was used to estimate the speed of price adjustments. Also, to analyze the magnitude of price adjustment in the presence of an exogenous shock the period of the Great Recession is discussed. The Great Recession that is the deepest economic crisis in the U.S economy started at December 2007 and remained until June 2009, for an eighteen months' time-period. To compute the magnitude of prices adjustment, the historical decomposition graph is applied that provides a visual explanation of the shock.

Findings revealed that the retail level had the lower speed of adjustment (0.115) than wholesale level (0.223), for the farm level the speed of adjustment was not significant statistically. Therefore, there is an asymmetric price transmission along the supply chain. The wholesale market is more competitive and operates more efficiently than the retail market with respect to both speed and magnitude of the price adjustment. Also, this study concludes the burden of a positive price shock is more severe for the consumer than the producers. One explanation can be the presence of the market power. The American Meat Institute, the National Meat Association, and the National Cattlemen's Beef Association are some examples of the powerful meat trade and lobbying organizations in the U.S. Also government intervention can impact the efficiency of the markets. The previous studies suggested many reasons as the cause of differential price adjustment in the agricultural markets including, transport and transaction costs, market power, increasing returns to scale in production, product heterogeneity and differentiation, exchange rates, border and domestic policies. From the above mentioned reasons, market power in the wholesale market seems to be more relevant to the U.S beef market. Future study to investigate this hypothesis is encouraged.

Refrences

- (2004) "RATS User's Guide." In Estima ed. USA.

Asteriou, D., and S.G. Hall. 2011. *Applied Econometrics*. New York: Palgrave Macmillan. pp 159–61.

Bruggemann, R., H. Lutkepohl, and P. Saikkonen. 2006. "Residual autocorrelation testing for vector error correction models." *Journal of Econometrics* 134:579-604.

Charemza, W.W., and E.M. Syczewska. 1998. "Joint application of the Dickey-Fuller and KPSS tests." *Economics Letters* 61:17-21.

Chopra, A., and D.A. Bessler. 2005. "Impact of BSE and FMD on Beef Industry in U.K." Paper presented at NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, Missouri, April 18-19.

Conforti, P. 2004. "Price transmission in selected agricultural markets." *working paper, Fao commodity and trade policy research* No.7.

Darko, F.A., and J.S. Eales. 2013. "Meat Demand in the US During and After the Great Recession." Paper presented at AAEA & CAES Joint Annual Meeting. Washington, DC, August 4-6.

Dickey, D.A., and W.A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time-Series with a Unit Root." *Journal of the American Statistical Association* 74:427-431.

Fackler, J.S., and W.D. McMillin. 2002. "Evaluating monetary policy options." *Southern Economic Journal* 68:794-810.

Goodwin, B.K., and M.T. Holt. 1999. "Price transmission and asymmetric adjustment in the US beef sector." *American Journal of Agricultural Economics* 81:630-637.

Grusky, D.B., B. Western, and C. Wimer. 2011. *The great recession*. New York: Russell Sage Foundation.

Hahn, W., J. Perry, and L. Southard. 2009. "Comparing Two Sources of Retail Meat Price Data." *Economic Research Report* Number 88.

Hahn, W.F. 1990. "Price Transmission Asymmetry in Pork and Beef Markets." *Journal of Agricultural Economics Research* 42:21-30.

Hanson, L.K., and T.J. Essenburg. 2014. *The new faces of American poverty : a reference guide to the great recession*.

Johansen, S. 1991. "Estimation and Hypothesis-Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometrica* 59:1551-1580.

Johansen, S., and K. Juselius. 1992. "Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the Ppp and the Uip for Uk." *Journal of Econometrics* 53:211-244.

Kinnucan, H.W., and O.D. Forker. 1987. "Asymmetry in Farm-Retail Price Transmission for Major Dairy-Products." *American Journal of Agricultural Economics* 69:285-292.

Koehler, A.B., and E.S. Murphree. 1988. "A Comparison of the Akaike and Schwarz Criteria for Selecting Model Order." *Applied Statistics-Journal of the Royal Statistical Society Series C* 37:187-195.

Kwiatkowski, D., et al. 1992. "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit-Root - How Sure Are We That Economic Time-Series Have a Unit-Root." *Journal of Econometrics* 54:159-178.

Luoma, A., J. Luoto, and M. Taipale. 2004. "Threshold Cointegration and Asymmetric Price Transmission in Finnish Beef and Pork Markets." *working paper, Pellervo Economic Research Institute*.

Pick, D.H., J. Karrenbrock, and H.F. Carman. 1990. "Price asymmetry and marketing margin behavior: An example for California-Arizona citrus." *Agribusiness* 6: 75-84.

Pozo, V.F., T.C. Schroeder, and L.J. Bachmeier. 2013. "Asymmetric Price Transmission in the U.S. Beef Market: New Evidence from New Data." Paper presented at 134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. St. Louis, MO, April 22-23.

Saghaian, S.H. 2007. "Beef safety shocks and dynamics of vertical price adjustment: The case of BSE discovery in the US beef sector." *Agribusiness* 23:333-348.

Saghaian, S.H., G. Ozertan, and A.D. Spaulding. 2008. "Dynamics of Price Transmission in the Presence of a Major Food Safety Shock: Impact of H5N1 Avian Influenza on the Turkish Poultry Sector." *Journal of Agricultural and Applied Economics* 40:1015–1031.

Sarris, A., D. Hallam, and J. Rude. 2007. "Agricultural commodity markets and trade: New approaches to analyzing market structure and instability." *European Review of Agricultural Economics* 34:287-290.

Schmidt, M.B. 2000. "The dynamic behavior of wages and prices: Cointegration tests within a large macroeconomic system." *Southern Economic Journal* 67:123-138.

Surathkal, P., C. Chung, and S. Han. 2014. "Asymmetric Adjustments in Vertical Price Transmission in the US Beef Sector: Testing for Differences among Product Cuts and Quality Grade." Paper presented at AAEA Annual Meeting. Minneapolis, MN, July 27-29.

Vavra, P., and B.K. Goodwin. 2005. "Analysis of Price Transmission Along the Food Chain." *Working Papers, OECD Food Agriculture and Fisheries* No. 3.

Von Cramon-Taubadel, S. 1998. "Estimating asymmetric price transmission with the error correction representation: An application to the German pork market." *European Review of Agricultural Economics* 25:1-18.

Zhang, P., S.M. Fletcher, and D.H. Carley. 1995. "Peanut price transmission asymmetry in peanut butter." *Agribusiness* 11: 13-20.

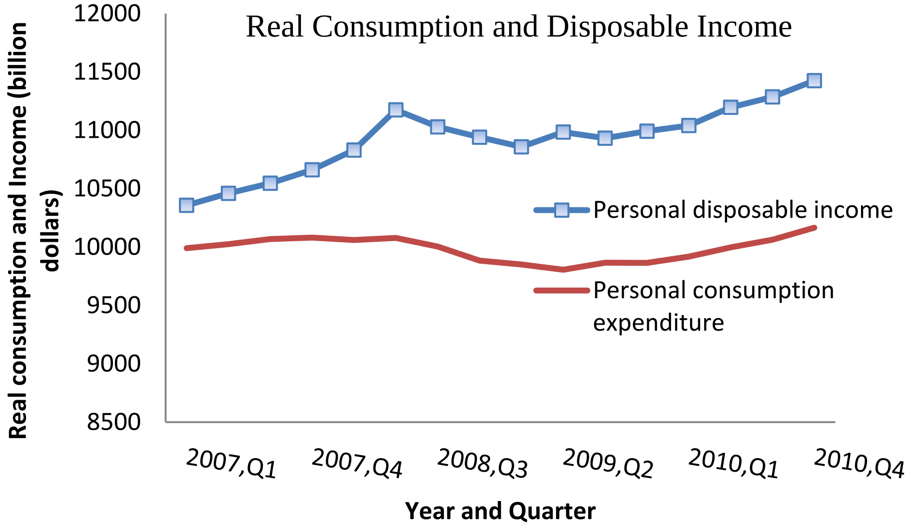


Figure 1- Real Per Capita Consumptions and Disposable Income
Source**:** The U.S. Department of Commerce, Bureau of Economic Analysis

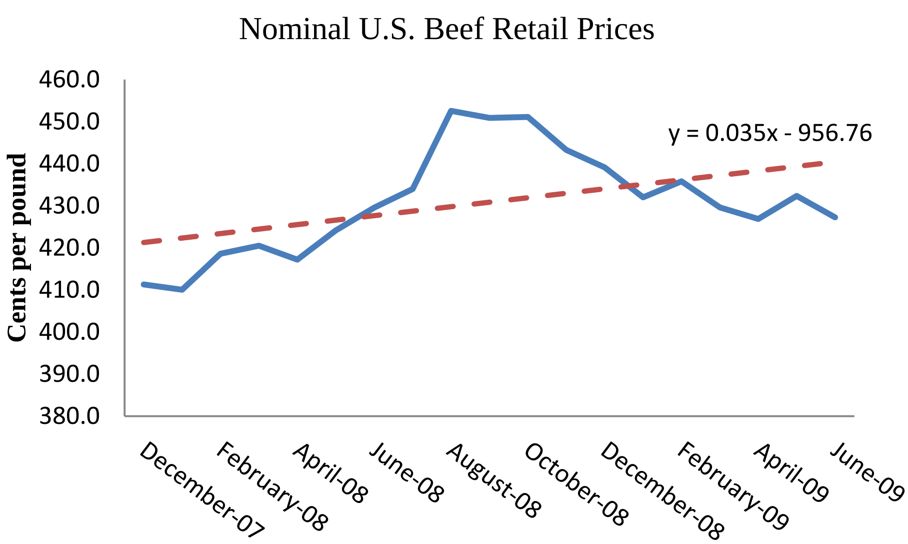


Figure 2: Trend in retail beef prices in the U.S. during the Great Recession
Source: Bureau of Labor Statistics (BLS) retail price data
Note: Dashed line is the estimated trend line by author

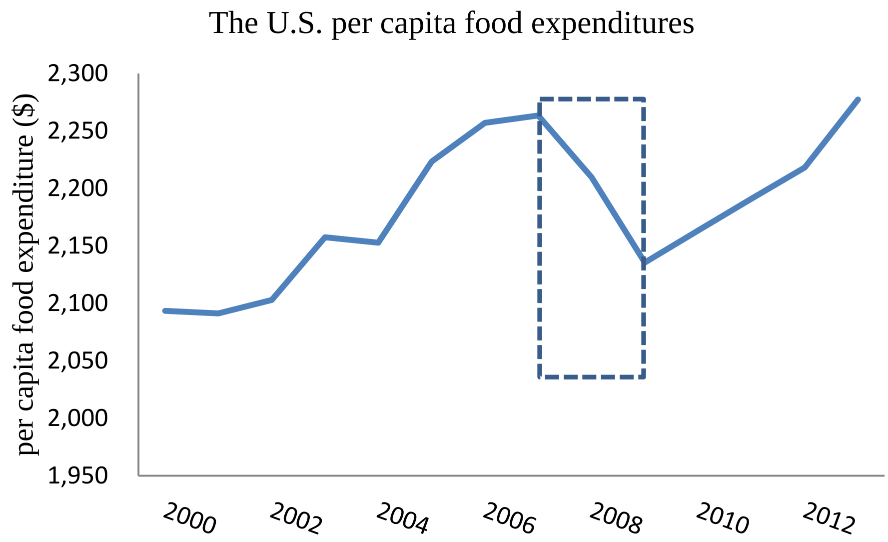
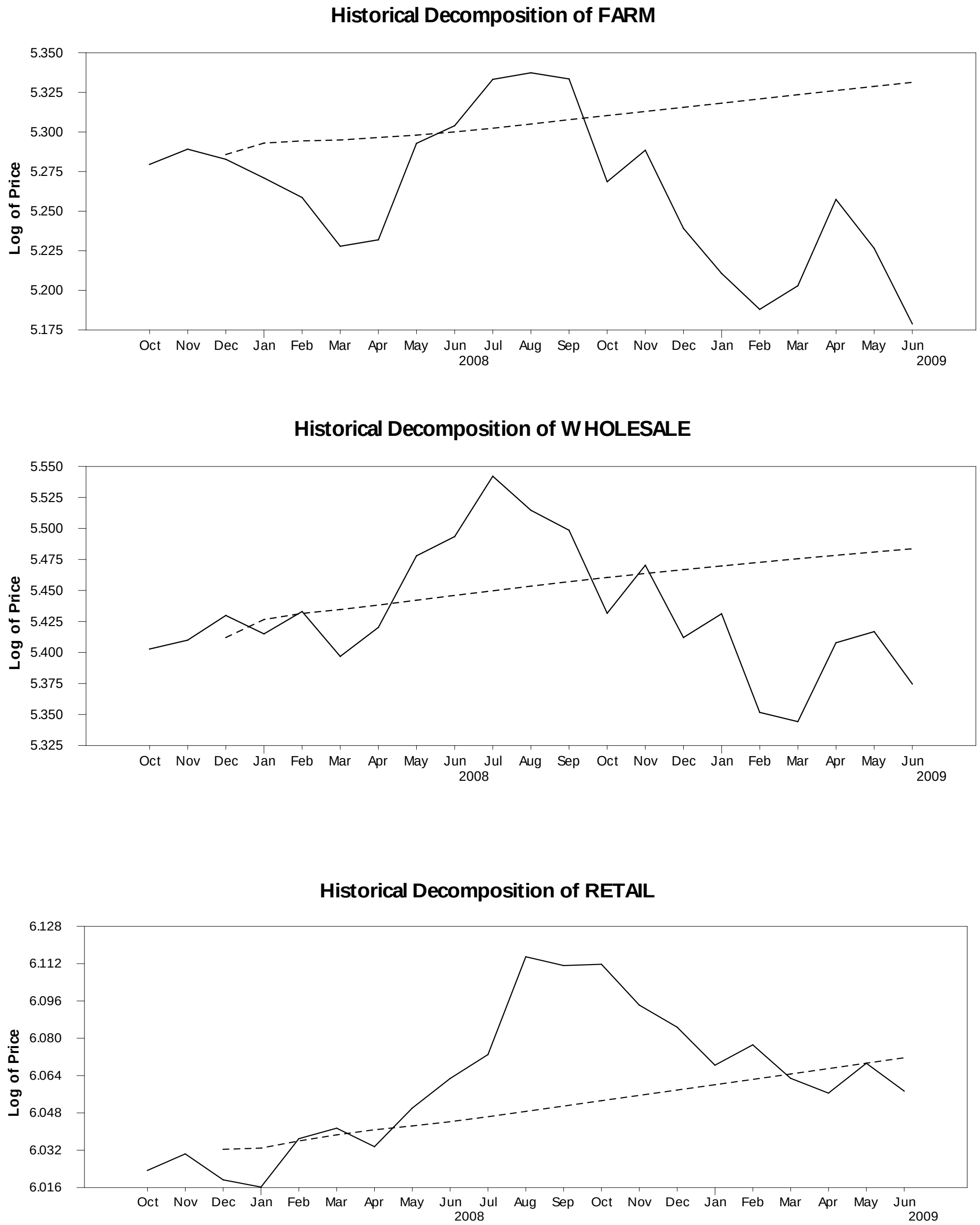


Figure 3: Trend in per capita food expenditure in the U.S. during 2000-2013
Source: Economic Research Service data
Note: the dashed line covers the period of the Great Recession



Note: Solid line and dashed line show actual and predicted price, respectively

Figure 4- The Great Recession impact on the U.S beef sector, in log form

Table 1- Summary Statistics of Per Capita Consumption (pounds), 2000 (1) - 2014 (4)

Variable	Average	Std.Dev	Minimum	Maximum
Beef	62.55	4.57	54.14	67.8
Pork	49.28	2.19	45.69	51.91
lamb	1.03	0.11	0.84	1.18

Source: Author's calculation based on USDA Economic Research Service

TABLE 2. Descriptive Statistics of Continuous Price Series (1970-2014)

	Farm	Wholesale	Retail
Mean	152.70	178.44	290.16
Median	145.45	171.45	279.05
Maximum	367.00	388.20	631.00
Minimum	58.80	71.50	98.00
Std. Dev.	52.61	58.51	116.70
Skewness	1.02	0.82	0.54
Kurtosis	4.93	4.21	2.87
Observations	540	540	540

Source: Research calculations

All nominal prices are in cents per pound

TABLE 3. Stationary Test Results

Test in	Level		First Difference	
Variables	ADF	KPSS	ADF	KPSS
Farm prices	-0.421	0.307	-14.59***	0.164**
Wholesale prices	-1.154	0.317	-17.195***	0.145*
Retail prices	0.274	0.389	-16.00***	0.169**

[a]: Mackinnon (1996) one-side P-value.

Critical values level are -3.975, -3418, and -3.131 respectively at 1%, 5% and 10% for ADF.

Asymptotic critical values are 0.216, 0.149, and 0.119 respectively at 1%, 5% and 10% for KPSS.

***, **, * indicates significance level at 1%, 5% and 10% respectively

TABLE 4. Johansen Cointegration Test Results

Unrestricted cointegration Rank Test (Trace)

Null Hypothesis [a]	Eigenvalue	Trace statistics	0.05 critical value	Prob**
r = 0**	0.157	112.90	29.797	0.000
r <= 1**	0.034	20.80	15.494	0.007
r <= 2	0.003	1.921	3.841	0.165

Unrestricted cointegration Rank Test (Maximum Eigen value)

Null Hypothesis [a]	Eigenvalue	Trace statistics	0.05 critical value	Prob**
r = 0**	0.157	92.097	21.131	0.000
r <= 1**	0.034	18.882	14.264	0.008
r <= 2	0.003	1.921	3.841	0.165

[a] r is the cointegration rank .

*denotes rejection of the hypothesis at the 5% level.

Source: Research findings

TABLE 5. The empirical Estimates of Speed of Adjustment

Variable	ΔP_{ft}	ΔP_{wt}	ΔP_{rt}
Error correction term	0.034	0.223***	-0.115***
	(0.926)	(5.325)	(-4.618)
Model diagnostics			
R-squared	0.12	0.17	0.39
Akaike AIC	6.458	6.715	5.680
Schwarz SC	6.489	6.754	5.720

*** indicates significance level at 1% - Numbers in parenthesis are t- Statistics

Source: Research findings

Table 6- Comparison of stages of the beef market in two points

Market	**Peak**	**Point A**	**Point B**	**Length of the period AB (month)**
Farm	Aug 08	Jun 08	Sep 08	4
Wholesale	Jul 08	Apr 08	Oct 08	6
Retail	Aug 08	Apr 08	Mar 09	11

Source: research finding based on the historical decomposition graphs

TABLE 7- Serial correlation test Results

Breusch-Godfrey serial correlation LM test			
Null Hypothesis: there is no serial correlation			
F-Statistic	2.078	Prob. F	0.126
Obs*R-squared	4.081	Prob. Chi-squared	0.129

Source: research finding

TABLE 8. The empirical Estimates of Speed of Adjustment

Variable	ΔP_{ft}	ΔP_{wt}	ΔP_{rt}
Error correction term	0.036	0.368***	-0.185***
	(0.549)	(4.484)	(-3.532)
Model diagnostics			
R-squared	0.14	0.23	0.40
Akaike AIC	6.901	7.309	6.420
Schwarz SC	6.990	7.398	6.508

*** indicates significance level at 1% - Numbers in parenthesis are t- Statistics

Source: Research findings