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Hog Price Transmission in Global Markets: China, EU and U.S.

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Abstract: This paper analyzes the twelve years monthly hog price data from the Chinese, U.S, and EU markets. The study's methodology includes cointegration tests and VECM, followed by tests for Granger Causality. The analysis provides a broad view of international hog markets price linkage and price transmission mechanism. There are several results: first, rather weak price linkages are found among the three markets; second, China is the least price responsive and the EU is the most price responsive market; third, the hypothesis of Granger causality is confirmed between the Chinese and the EU market prices but not in both directions. Fourth, U.S. hog prices responds noticeably to a shock in the EU price but mildly to the shocks in the Chinese hog price.

Key words: price transmission; hog industrial; VECM
JEL codes: F47, C32, Q17

1. Introduction

China is the largest consumer and producer of pork and it accounts for nearly half of the world's pork production and consumption. In 2011, its annual pork output was 50 million tons, nearly 4.5 times that of the United States and 2.3 times that of the European Union (EU) (USDA, 2013). The EU is the second largest producer of pork and the largest exporter of pork in the world. The United States (U.S) is the third producer of pork and the second exporter of pork in the world. These three markets are the main hog producers in the world and hold about 80 percent of the world production. While these markets dominate world production and consumption, they are characterized by differences in size, history, production systems and trading time (hours).

Historically, China has been a mostly self-sufficient pork economy. Hog imports are about 4.68 million tons which constitutes approximately 1.3% of its domestic slaught in 2012 (USDA, 2013). However, there are constraints inhibiting hog production increase in China (Zhang & Nie, 2010). First, land resources are limited. According to Food and Agriculture Organization (FAO, 2006) data, China must feed 13 persons for each hectare of arable land. By comparison, the EU must feed 4.1 persons and the US only 1.4 persons. Second, China's cost of production continues to increase, particularly feeding-costs relative to the U.S and the EU. Third, environmental problems caused by farm size are larger in China relative to other countries. Fourth, there are a number of policy interventions that impact market prices and dynamics. Galan et al. (2012) point out that while the expansion of China's domestic pork industry is limited by these and other factors such as animal disease epidemics, animal waste disposal challenges, and food safety, China's potential as a major pork importer presents opportunities for exporting countries.

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The illustrated demand and supply relationships suggests that the greater demand for hogs in China results in a larger p_c than in p_a (p_c is the Chinese hog price and p_a is the U.S hog price) (Figure 1). When demand in China increases, the U.S hog price increases to p'_a. Because of China's natural resources constraints, the supply is unchanged, so the price will increase to the p'_c. And the China hog price will be much higher than US price for given increases in demand.

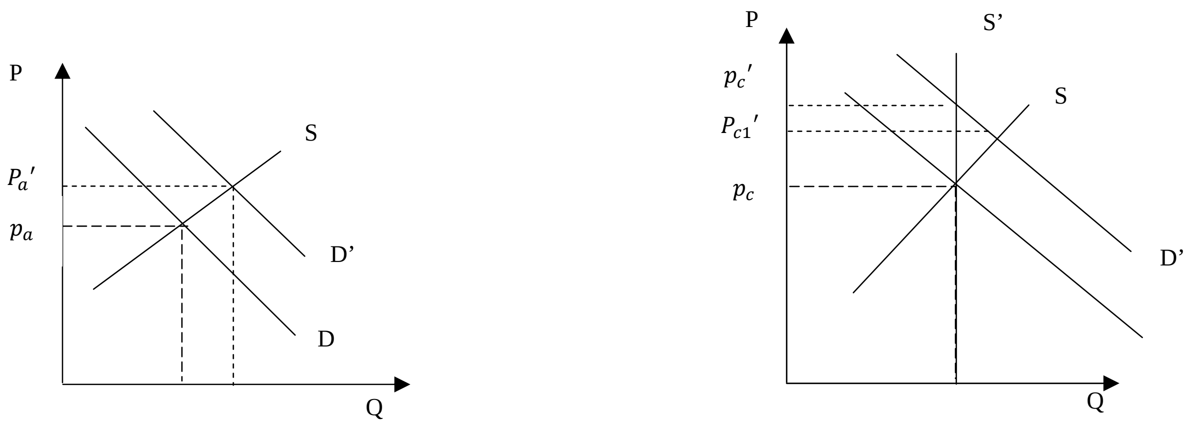


Figure 1 The Chinese and the US Hog Demand

The recent acquisition of Smithfield Foods, Inc. by a Chinese food producer Shuanghui International has been a cause of surprise to many in the U.S. industry. This business transaction served to exemplify the growing importance of the pork market to China. The underlying price relationships and sets of mutual interdependencies will influence the trends regarding the world's hog prices and production levels.

The interest of this study is to study price transmission in the dominant pork markets: China, the EU and the U.S. There are reasons for studying cross market price linkages and price transmission mechanism for the hog market. First, correlations between the world's hog markets affect the volatility of hog production and hog price, and therefore it can assist hog and grain farmers, hog processing companies and other value-adding entities in formulating better trading and asset allocation strategies. Second, information transmission mechanisms reveal the level of market price efficiency. Third, hog prices reflect the entire market dynamics and such information is useful to the commercial trade. Finally, the cross-market analysis reveals a long-term price leadership (i.e., which market is leading in price formation).

Thus, the main purpose of this study is to investigate the price relationships across world's three largest hog markets. It creates information on cross-market correlation, information transmission mechanisms within and between the three markets, and identifies the price discovery processes within each market. The long-term price relationship among the three markets is analyzed using cointegration methods. We examine the extent to which each market is influenced by the other two, and which market is most efficient. Additionally, we examine the issue of which market is the price determining market (i.e., the market that has the greatest influence over the other two in the price discovery process).

The paper is structured as follows. First, this study examines the long-term equilibrium relationship among hog prices in Chinese, EU and US hog prices. Second, it uses cointegration and vector error-correction models (VECM) to analyze the transmission mechanism. Third, it uses Granger causality test to make sure which market is the price leading market. Fourth, impulse response functions and variance decomposition analysis are used to investigate dynamic interactions among prices.

2. Review of Literature

The literature on price transmission across markets is extensive and is an issue of recurrent interest to price analysts. At the most basic micro-theory level, two markets for the same commodity that are spatially separated are expected to determine prices whose differences reflect transfer costs. Others have expanded this theoretical framework in the context of the law of one price (LOP) and transaction costs of trading the good between these locations and the role of arbitrage in as rule that operates to keep this markets true to the LOP. In the context of international markets and cointegration theory, Ravallion (1986) and Ardeni (1989) were probably the first agricultural economists to study such price transmissions. Others followed this lead and expanded the specification of such models in a variety of ways (e.g., Abdulai, 2000; Goodwin & Piggott, 2001; among others). The above literature generated a large body of additional work on the subject of asymmetric price transmission (e.g., Greb et al., 2013). It is plausible that such models may have relevance for studying price transmissions as done in this study and is a topic that we may pursue in future research. A purpose of this paper is to provide initial insight to international hog price transmission in these three markets. Nonetheless, the Greb et al.'s paper contains a comprehensive list of published work on price transmission (symmetric and asymmetric) thus we refer the reader to this up-to-date paper on the subject.

3. Methodology

3.1 Data Collection

This study uses hog market price data from the three major hog markets: China hog market price (P_c), European hog market price (P_e) and the U.S. hog market price (P_a). The China price was obtained from China National bureau of statistic website; the EU price was obtained from the European Union public data and the U.S. price was obtained from USDA. The data period was from January, 2000 to December, 2012; a total of 156 monthly for each market. The return of the three series, R_t is calculated as the difference between the month price and the previous month price by taking natural logs:

$$\begin{aligned} Rlp_c &= lpc_t - lpc_{t-1} \\ Rlpe &= lpe_t - lpe_{t-1} \\ Rlpa &= lpa_t - lpa_{t-1} \end{aligned} \tag{1}$$

Each price has been transformed to real prices using the CPI from various sources for each country (i.e., The Chinese CPI was obtained from the National bureau of statistic, The CPI for the EU was obtained from the European Union (Eurostat website), and the U.S CPI is from the Bureau of Labor Statistic). Historical monthly exchange rate information was obtained from DataStream maintained by the International Monetary Fund (IMF 2012). The U.S. dollar equivalent of the U.S. domestic prices and U.S. dollar world prices were converted to real U.S. dollars (1980 = 100) using the U.S. consumer price index (CPI).

3.2 Research Design

We first start with a simple description of the three prices P_c, P_e, and P_a with the intent of highlighting similarities and differences in price and inter-market correlations between each of the three markets. While such descriptive statistical relationships do not imply causality, they provide a basic understanding of the contemporaneous correlations.

The second step is to use the cointegration analysis. If the three markets are cointegrated, then this would imply causality in at least one direction. The Johansen (1988) cointegration test is used in this analysis. Also the VECM model is used for empirical analysis to discover the potential long-term equilibrium in the three markets.

Impulse response functions and error-variance decompositions are used to analyze dynamic price responses these markets. If the difference of the price is conintegration, then it could use the impulse and variance decomposition to see the short-time price impulse. It could show that the cause of short fluctuation to each of the price. Granger tests are to test non-causality in prices.

3.3 Model Specification

We use standard cointegration and VECM methods to test for unit-roots and cointegration. The Augmented Dickey Fuller test is used to test for unit roots and the VEC to build a dynamic model. The Akaike Information Criterion (AIC) is used to identify the lag length in both the ADF model and in the VEC.

We represent the VECM as follows:

$$dX_t = \mu + A_1 dX_{t-1} + \sum_{i=1}^{k-1} A_i \, dX_{t-i} + \varepsilon_t \tag{2}$$

Where dX_t equals (X_t-X_{t-1}), μ is a deterministic component ε_t is a vector white noise.

3.4 Short-run Dynamic Analysis

Short-run dynamic interactions between Chinese, EU prices, U.S. prices could be visually identified through the impulse response analysis based on VECM models. The impulse response refers to the reaction of any dynamic system in response to some external shock. The variance decomposition indicates the amount of information each variable contributes to the other variables in the autoregression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables.

3.5 The Granger Causality

Lead-lag relationship is tested using standard Granger non-causality tests; these results should highlight which market leads or lags in the transmission of price information.

4. Results and Discussion

4.1 Descriptive Statistics and Correlations

As discussed above, 156 monthly market price observations were collected for each of the three primary hog markets (Chinese, EU, U.S.) for the twelve-year period from January, 2000 to December, 2012. Figure 1 is the price trend of the three markets. It shows that Chinese hog price has an increasing trend in long time and especially there is a very acute and fluctuate trend since 2006. The sharp increases in china hog price were catalyzed by various factors including the rising cost of the feed, labor and the land. However, it appears that there are relative gentle fluctuations in the U.S. and EU markets. And the hog price in the EU is a bit higher than that of the U.S. The hog prices in U.S. and EU were steady because the cost is lower and productivity is higher.

Table 1 offers sets of descriptive statistics for each of the three major hog markets in the world. The range from high to low in the hog prices is China, EU and U.S. However the smallest rate of changes occurred in U.S. A total of six data series are obtained three markets (Chinese, EU and U.S.) times two variables (price and return). Table 1 provides descriptive statistics for the EU and U.S. market about the same mean prices (\$0.6589 and \$0.6204). The Chinese hog prices have a significantly larger standard deviation (\$0.3254) than the EU and the U.S (\$0.087 and \$0.062, respectively). This may partially be explained by a significantly higher average price in the Chinese hog market. The standard deviation in month returns (\$0.0434) of the Chinese market is high than the standard deviation of EU and US ($0.0335 and 0.026). Additionally, the Chinese market has the higher media than EU and US.

Table 2 provides price correlation results between the Chinese, EU and U.S hog markets. There are a moderate high relationship between p_c and p_e. However the p_a has rather low relationship with p_c and p_e. Panel B shows the EU and U.S. are related together. However, Chinese have the extremely low relationship both with EU and U.S. In summary it appears from the data in Table 1 and 2 that EU and US share more consistency in both price and return, and the Chinese market is less integrated and features more independency in pricing and returns.

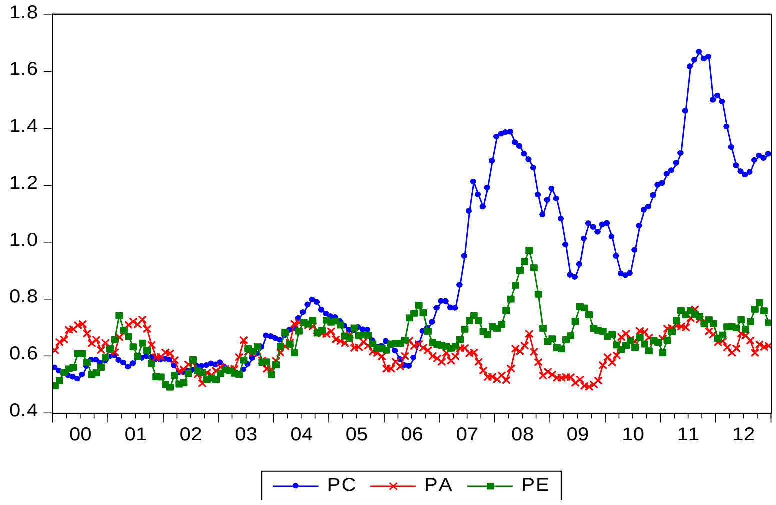


Figure 2 Trend of Hog Prices Over the World's Major Production Areas

Table 1 Descriptive Statistic (in US Dollars per Pound) Markets *p*

	p_c	p_e	p_a	R_c	R_e	R_a
Mean	0.8823	0.6589	0.6204	0.0048	0.0014	0.0001
Media	0.7492	0.6573	0.6258	0.0018	0.0007	-0.0019
Standard deviate	0.3254	0.087	0.062	0.0434	0.0335	0.0263
Skewness	0.6688	0.4767	-0.1256	0.4148	-0.257	0.2556
Kurtosis	2.162	3.9706	2.185	5.9879	3.3505	2.9244
Observations	156	156	156	155	155	155

Table 2 Provides Price and Return Correlation Results between the Chinese, EU, and U.S. Hog

PanelA				Panel B			
Market price	p_c	p_e	p_a	Market price	rp_c	rp_e	rp_a
p_c	1			rp_c	1		
p_e	0.6447	1		rp_e	0.1506	1	
p_a	0.0838	0.1673	1	rp_a	0.0105	0.3552	1

4.2 Spatial Market Information Transmission—Cointegration

ADF test results are show in Table 3. All variables were transformed into natural logs before estimation and testing for unit roots using the Augmented Dickey-Fuller (ADF) and phillps-perron (PP) test. And we find that the null hypothesis is not rejected under test ($p < 0.01$), and therefore the price of Chinese, EU and U.S. have a unit-root. However, the first differences are stationary, thus concluding that there is one unit-root.

Table 3 Unit Root Test (ADF)

	lpc	lpe	lpa	rpc	rpe	rpa
Without linear tread						
ADF	-1.477	-1.328	-0.58	-7.47 ***	-9.49***	-10.814***
PP	-1.381	-1.396	-0.626	-5.39 ***	-9.21***	-10.82***
With linear tread						
ADF	-2.535	-4.23***	3.121	-7.40 ***	-9.44 ***	-10.74***
PP	2.416	-3.716 ***	-3.03	-5.18***	-9.157***	-10.75***

Cointegration is used to describe this stationary relationship, and to investigate the international information transmission in the hog price markets. Assuming $p \equiv (p_c p_e p_a)$ is cointegrated, then the following VECM can be estimated:

$$dlp_t = \mu + \pi dlp_{t-1} + \sum_{i=1}^{k-1} \tau_k \, dlp_{t-k} + \varepsilon_t \tag{3}$$

The appropriate lag length k, is determined prior to the cointegration test. In this study, Akaike information criterion (AIC) and the final prediction error (FPE) (AKaike, 1969) to determine the lag term in a simple vector autoregressive model. As shown in the Table 4, the lag length k in the VECM chosen by the AIC and FPE is 2.

Table 4 Lag Order Selection Criteria

Lag	AIC	FPE
0	-10.21	7.35e-9
1	-10.66	4.67-09
2	-10.7*	4.50e-09*
3	-10.61	5.95e-09
4	-10.57	5.13e-09
5	-10.51	5.47e-09
6	-10.47	5.70e-09
7	-10.47	5.68e-09
8	-10.48	5.69e-09

Then, we perform the Johansen cointegration test. Both trace and maximum eigenvalue test statistics are calculated in this study. As Table 5 indicates, the null hypothesis is rejected as both trace value and max eigenvalue exceed the 0.01 level critical value. This shows that all the three markets are highly cointegrated, and have a high level of information transmission with synchronized moves in the long run. In this case, a vector error correction model (VECM) is appropriated to deal with the problems of dynamic effects and nonstationarity.

Table 5 Johansen Cointegration Test

Number of Cointegating Equations	Trace	Max. Eigenvalue
None	99.63***	52.68***
At most 1	49.94***	30.52***
At most 2	16.42***	16.42***

The VECM model was estimated to examine the price transmission mechanism between hog markets. Long-term price equilibrium is the basis for studying cross-market information transmission. We perform the Johansen (1991) cointegration test. Both trace and maximum eigenvalue test methods are applied in this study. Vector error correction functions as a short-term force that helps to bring price deviations back to their equilibrium relationship.

The results from the estimation of the VECM are presented in Table 6. The results are good generally. The F-statistics for each regression are significant (They exceed a 1% statistical significance level) and the R^2 value are high for the overall fitting of the VECM. This provides some evidence of spatial-market information transmission efficiency in returns.

Table 6 Estimation of VECM Model

Error correction	dlpc	T-statistic	dlpe	T-statistic	dlpa	T-statistic
β_0	-0.0051	-0.7225	0.0446	4.548***	0.021	2.253**
β_1	0.7847	9.859***	0.1708	1.559*	0.0559	0.537
β_2	-0.3099	-3.911***	0.2769	-2.539**	0.1545	-1.491*
β_3	-0.0083	-0.1407	0.2147	2.606**	-0.0169	-0.2164
β_4	0.0443	0.739	0.0476	0.576	0.1361	1.7353*
β_5	0.0689	1.0489*	0.2833	3.131***	0.1739	2.022**
β_6	-0.047	-0.705	0.0718	0.774*	-0.0778	-0.882
$\propto$	0.003	1.143*	0.0017	0.4788	-4.73E-06	-0.00137
R^2	0.4329		0.2475		0.076	
F	15.81***		6.8152***		1.712*	

Note: *** Statistical significance at the 1% level; ** Statistical significance at the 5% level; *Statistical significance at the 10% level. α_i and β_i refer to the correlation coefficients in Equations (8); where β_1 to β_2 are "lagged dlpc" coefficients; where β_3 to β_4 are "lagged dlpe"; where β_6 to β_6 are "lagged dlpa" coefficients.

The results illustrate the following. Although each market has an influence on the other markets, however, the results are not very significant (t value is not very large). And the U.S. and EU market has no significant relationships with the Chinese hog market (t value is very small). The strongest influence comes from Chinese hog market prices and U.S market prices to the EU prices (the t-statistics of 2.606, 3.13) and the reverse is not true. It shows that the China price is influence very little by other market prices but that the EU price is the most influenced by other prices.

The influence of information flow between the three markets is not always consistent in direction. It indicates that the U.S. market and EU markets share price information transmission and move together (the total error correction coefficients are positive in both direction of information flow). However, the price information power of the Chinese hog market on the other two markets is reversed in direction (the total error correction coefficient is negative in both directions of information flow). This inverse relationship may contribute to a higher volatility in the Chinese hog market prices.

4.3 Granger Causality Test

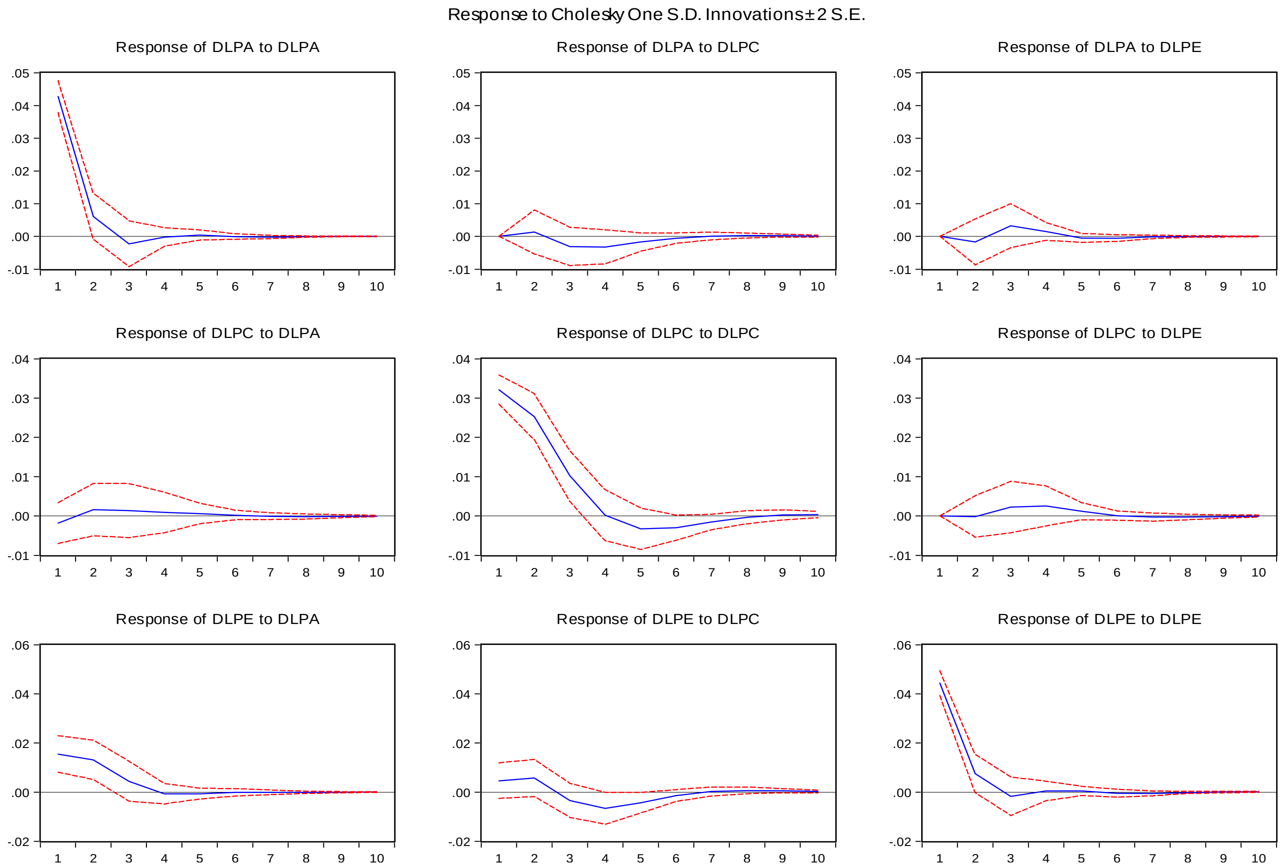
Granger casualty test are used to identify the price discovering market. Table 7 provides the VECM for the Granger casualty tests. Granger causality can be used to test the influence of the three hog markets on each other since all three data series are found to be stationary without difference. The results indicate that the US price does not cause the China price and the reverse is also true at the p = 0.05 level. The causal relationship between the US and EU prices is different. Note that the EU price does not Granger cause the US price but that the reverse is true. A similar causal relationship is found for the EU and Chinese hog prices. That is, the EU price does not Granger cause the Chinese price but the Chinese price Granger causes the EU price.

Table 7 The Granger Cause Test

Null Hypothesis:	Obs	F-Statistic	Prob.
p_c does not Granger Cause p_a	148	0.0102	0.7688
p_a does not Granger Cause p_c		0.878	0.3248
p_e does not Granger Cause p_a	148	0.1918	0.8257
p_a Granger Causes p_e		4.25**	0.0153
p_e does not Granger Cause p_c	148	0.549	0.5781
p_cGranger Causes p_e		3.427**	0.0351

4.4 Impulse Response Analysis

The study uses the impulse response functions (IRF) to evaluate the impact of a one-standard deviation shock on the system. Figure 3 illustrates the IRF for the three market prices. It is observed from these functions that the IRF of p_a and p_e to p_c settle back to equilibrium after 6-8 months. A shock to the EU price results in a higher response in the Chinese price than that of the US price. All price changes respond more to a shock in the own series than to shocks in other series.



Figures 4 The Impuse Response Functions to Price Shock in Chinese, EU and US Market

The IRF analysis is corroborated by the EVD analysis. The estimates in Table 8 show most of the EVD is attributed to the series itself and that this holds true more for Chinese prices and US prices relative to the EU prices. For example, over 95% of the variation in the Chinese price is explained by the Chinese price itself regardless of the decomposition horizon.

Table 8 Generalized Forecast Error Variance Decomposion

Month ahead	Chinese	EU	US
	Variance of Chinese price (percentage) explained by shock to prices		
1	1.0000	0.0000	0.0000
5	0.9848	0.0109	0.0041
10	0.9752	0.0187	0.006
20	0.9551	0.0189	0.00603
30	0.9749	0.0189	0.00604
40	0.9749	0.0191	0.00604
50	0.9749	0.019	0.00604
	Variance of EU price(percentage)explained by shock to prices		
1	0.0116	0.9883	0.0000
5	0.0316	0.9305	0.0378
10	0.0818	0.8645	0.0535
20	0.2468	0.6538	0.0992
30	0.3418	0.5335	0.1246
40	0.4053	0.4531	0.1415
50	0.4506	0.3956	0.1536
	Variance of US price (percentage)explained by shock to prices		
1	0.0022	0.0858	0.9119
5	0.0069	0.0469	0.9461
10	0.0071	0.0359	0.9569
20	0.0041	0.0368	0.9590
30	0.0028	0.0364	0.9606
40	0.0022	0.0362	0.9615
50	0.0017	0.0361	0.9620

5. Summary and Conclusions

This study investigates price and volatility transmission for the three most import players in the international hog market. The period study period was January 2000 to December 2012. There are some findings in this paper that should be synthesized. First, the relationships among the three markets hog prices are rather weak. Chinese market are much more close relationship with EU than U.S. American hog market prices show a weak linkage to the EU and Chinese hog market price. Second, china is the least easily influenced and EU is the most influenced by other country prices. The US and the EU seem to share more price information. Third, the hypothesis of Granger causality is confirmed between the Chinese hog price and the EU but not in both directions, that is, we find Granger causality from Chinese price to EU price but not the reverse. And the same between US and EU hog price, we find Granger causality from the US price to the EU price but not vice versa. But the hypothesis of Granger causality is not confirmed between Chinese and U.S. hog prices. Fourth, according to the impulse response function, the hog price of the U.S. market responds noticeably to the shock in the EU but mildly to the shocks in the Chinese price. A variance decomposition analysis shows that the own-series contributes to most of the variation, and this is particularly more true for the Chinese price.

Though the commercial volume of trade in Hogs is low and the price transmission linkage is weak among the three markets, China is becoming an important export market for the U.S. and the EU. Time will tell whether the acquisition of Smithfield’s Foods and the flow of commercial trade will strengthen price relationships in these markets. The evidence here shows that this may not be case for the US-China price linkage which should appeal the argument that U.S. consumers may end up paying a higher price for hogs in the next few years.

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