The Impacts of Foot and Mouth Disease Outbreaks on the Brazilian Meat Market

by

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Abstract

This study uses unrestricted vector autoregression method and historical decomposition with directed acyclic graphs to quantity the impacts of the foot and mouth disease outbreak on the Brazilian meat market for different levels of the industry (export, wholesale and farm). The imposition of an import ban by Russia on Brazilian meat exports is also analyzed. Results show that beef, pork, and chicken export prices all decreased after the FMD outbreak. More importantly, our findings indicate that all prices ended up recovering after the removal of the import ban by Russia in December 2007. As for the price margins in both beef and pork meat supply chains, the export-to-farm and export-to-wholesale margins were found to be very close to each other. On the other hand, the chicken price margin at the export level relative to the farm and wholesale levels had opposing directions trend movements. Finally, the historical decomposition of analysis of the export beef price revealed that the removal of the Russian ban on Brazilian meat imports had a very drastic positive influence on the beef industry supply chain in general.

Keywords: foot and mouth disease, Brazilian meat market, vector autoregression model, historical decomposition, directed acyclic graphs.

1. Introduction

In Brazil, foot and mouth disease (FMD) outbreaks have been present in the meat industry for more than one century. In 1895, the first FMD outbreak was reported and, since then, Brazilian authorities have struggled to contain this disease, which was considered endemic until the 1970's. In the mid-1980's, Brazilian livestock producers invested in both more sophisticated production methods and animal vaccination with the purpose of eradicating FMD (Lima et al, 2005). Since 1998, the Brazilian government has actively implemented efforts to eradicate FMD via the Programa Nacional de Erradicação da Febre Aftosa (PNEFA). The main purpose of this program was to eradicate the disease by the end of 2005 with the implementation of the Brazilian System of Identification and Certification of Origin for Cattle (SISBOV), which is tracks and documents all animals (Haley, 2005).

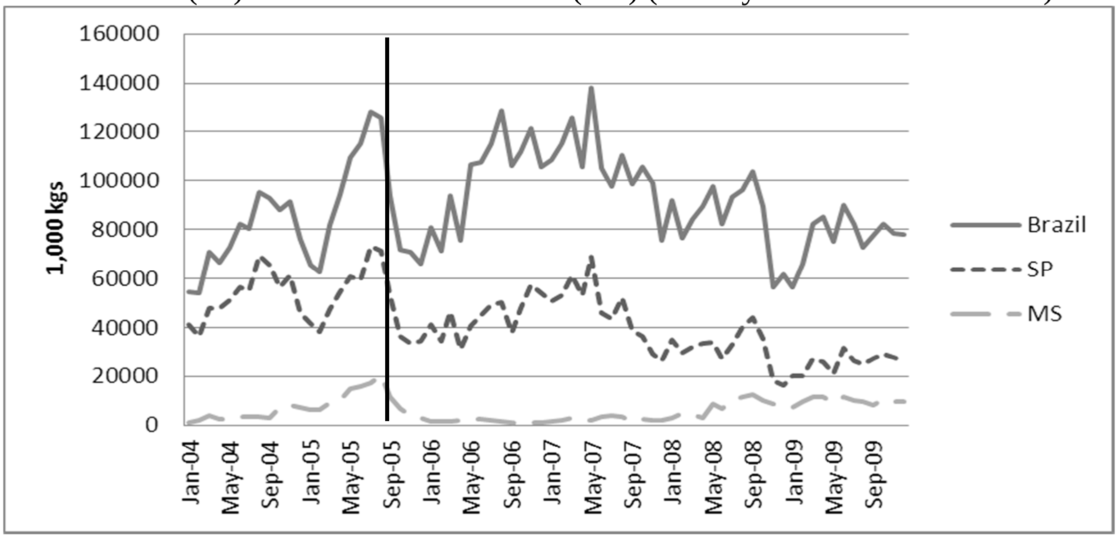
As the number of FMD outbreaks decreased partly due to the program mentioned above, the Brazilian government decided to follow the sanitary and phytosanitary guidelines of the World Organization for Animal Health (OIE) and World Trade Organization (WTO) by dividing its territory into five regional markets with the purpose of managing sanitary controls more efficiently. By agreeing with the guidelines and regionalizing its livestock, the competitiveness of Brazilian meat improved significantly in the world meat trade. In 2000, Brazil became the fourth largest beef and pork exporter and the second largest chicken exporter. Five years later, Brazil became the largest world beef and chicken exporter and, although stayed as the fourth largest exporter of pork meat, more than quadrupled its pork exports. Currently, the Brazilian meat export industry has kept the same positions as before in the rankings of the top meat suppliers in the global market (USDAa, 2011).

However, Brazilian meats are still affected by FMD outbreaks. In the last ten years, two major FMD outbreaks occurred in Brazil. The most detrimental and recent outbreak occurred in September, 2005. According to the OIE (2006), the FMD outbreak took place initially in the state of Mato Grosso do Sul. Three months later, an outbreak was spotted in the neighboring state of Paraná. The announcement of the FMD outbreak had negative impacts on Brazilian meat exports, especially for beef and pork. Several beef and pork importing countries initiated an import ban, including Russia[1], the number one importer of Brazilian meat. The Russian import ban originally was only on meat originating from the infected states of Mato Grosso do Sul and Paraná. Eventually, the Russian authorities expanded the ban to the states which were contiguous to the infected states. This expansion of the import ban accounted for eight meat producing states in Brazil. After the destruction of 33,741 FMD-susceptible animals (32,549 cattle, 566 pigs, 626 sheep and goats) (OIE, 2006) and several rounds of meetings between Brazilian and Russian authorities, the import ban was lifted in December 2007, 28 months after the FMD outbreak occurred.

As a consequence, the FMD outbreaks caused immense uncertainty and economic damage to the Brazilian meet industry, particularly for exports. One to two months after the import ban by Russia and other countries, Brazilian beef exports decreased from 93.8 thousand tons in September 2005 to 66.1 thousand tons in December 2005 (a decrease of 30 percent) (Figure 1). Furthermore, according to the SECEX (2011) database, Brazilian beef exports to Russia decreased from 21.3 thousand tons in September 2005 to 12.5 thousand tons in December 2005 (down 41 percent).

[1] According to the Secretária de Comércio Exterior (SECEX, 2011), for the last ten years, the Russian market is a major destination of Brazilian meat exports, representing 40 percent of Brazilian total beef exports.

Figure 1. Monthly exports of Brazilian beef at the national level and for the states of São Paulo (SP) and Mato Grosso do Sul (MS) (January 2004-December 2009)



Note: the vertical black line represents the time period of the FMD outbreak (September, 2005).
Source: compiled from SECEX (2011)

The purpose of this study is to analyze the impacts of the FMD outbreak on the Brazilian meat market for different levels of the industry (export, wholesale and farm). The imposition of an import ban by Russia on Brazilian meat exports is also investigated. We employ time series methods, mainly using an unrestricted vector autoregression (VAR) model and historical decomposition of price innovations, accompanied by directed acyclic graphs (DAGs). This approach quantifies the impacts of the 2005 FMD outbreak in Brazil on prices of different meat types (beef, pork, and chicken) at different levels of the marketing channel (export, wholesale, and farm levels), price margin along the supply chain, and price interdependence in the system.

This work is an important contribution to the literature of animal disease impacts on meat markets for the following reasons: (i) we simultaneously investigate the impacts of animal disease outbreaks on export price levels as well as domestic price levels (wholesale and farm) and (ii) to our knowledge, there is no study that analyzes the

Brazilian meat market to this detailed extent. This study fills these gaps and provides evidences from a major player in the global meat industry and trade.

The following section presents a brief literature review on animal disease outbreaks on different types of meat markets. This is followed by a discussion of the method of analysis, data section, empirical results, and conclusions.

2. Literature Review

Several studies have analyzed the impacts of animal disease outbreaks and their effects on the livestock sector for different countries. Burton and Young (1996) measured the impacts of the bovine spongiform encephalopathy (BSE) on the British domestic beef market. Their findings indicated the BSE outbreak led to significant negative impacts for the beef industry in Great Britain. Piggott and Marsh (2004) estimated the impacts of publicized food safety information (media index construction) on meat demand for the U.S. Their results indicated that major food scares induced large demand responses, but these responses were rapidly dampened. Park et al (2008) quantified the impacts of domestic and overseas animal disease crises on the Korean meat market. Their findings concluded that the Korean market recovered after approximately one year for different animal diseases and the impacts were somewhat different across different levels of the supply chain.

Most recently, Attavanich et al (2011) estimated the impacts of media coverage related to the H1N1 (swine flu) on the U.S. meat and related product prices, and quantified the revenue losses across the meat and related markets. Their findings indicate that the media coverage was associated with a significant but momentary negative impact on the nearby lean hog futures price. An important contribution of their work was to analyze the trade bans imposed by several countries to U.S. pork meat. Their estimates showed that the trade ban negatively affected the pork industry.

Regarding animal disease outbreaks and the impacts on the Brazilian meat industry, there are few studies in the literature. Teixeira and Maia (2008) used Box-Jenkins time series method to estimate the impacts of the 2004 FMD outbreak on the live cattle farm price. Their findings indicate that the FMD outbreak caused a structural break in the live cattle farm price series. The authors suggest that the import ban by Russia on Brazilian meat exports (originated from the states of Amazonas and Pará) due to the outbreak possibly triggered the structural break. Otuki et al (2009) analyzed the impacts of the FMD outbreaks in 2004 and 2005 on the price volatility of two series of farm pork prices: national price and the state of Santa Catarina price. The authors employed the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models to perform their analysis. Their findings were that the FMD outbreaks caused high pork price volatility for both series.

3. Methods of analysis

To quantify and identify the potential impacts of FMD outbreaks on the Brazilian meat industry, time series methods, mainly VAR, are employed as well as historical decomposition of price innovations. The most important contribution of the VAR method is to allow a comparison between the actual price that is affected by the FMD outbreak and the forecasted price that uses only information before the outbreak occurred. The comparison allow us to quantify the impacts on meat prices in different manners: (i) price levels for different types of meat and (ii) price margins along the supply chain (i.e. export, wholesale, and farm levels). The historical decomposition of price innovations is utilized to identify the dynamic interdependence within meat prices for different levels along the supply chain and to measure the participation of each price series on the net change of a certain meat price following the FMD outbreak.

3.1. Vector Autoregression Model

The empirical method used in this study to analyze a set of interrelated variables is a VAR model. An unrestricted VAR model with k lags of *M* variables is written:

$$X_t = \sum_{i=1}^{n} \alpha_i X_{t-i} + \gamma + e_t \ (t = 1, \dots, T) \qquad (1)$$

where X is a ($M \times 1$) vector of series at time *t*, α_i is a ($M \times M$) matrix of coefficients relating series changes at lagged *i* period to current changes in series, γ is a ($M \times 1$) vector of constants, and e_t is a ($M \times 1$) vector of independent and identically distributed (i.i.d.) innovations (error terms). Equation (1) indicates that each of the *M* variables is a function of *n* lags of all *M* variables, including itself, a constant and a present innovation term. If some series in the set of evaluated variables are nonstationary and cointegrated, the error correction model, developed by Johansen (Johansen, 1988), has to be utilized to study both short-run discrepancies and long-run equilibrium. However, for simplicity reasons, the method to be utilized in this study is the VAR time series technique.

To determine the optimal lag length of the VAR representation, we use two different loss metrics methods: (i) the Schwarz-loss criterion (SIC) and (ii) the Hannan and Quinn Φ (HQ). The first optimal lag length search criteria is argued to be inefficient in the sense that it has a tendency to over-penalize additional regressors in contrast to other metrics (Geweke and Meese, 1981). Therefore, the HQ loss metric criteria is also performed to determine the optimal length of the VAR representation. Further, Hannan and Quinn (1979) suggest that the HQ information criteria outperforms the SIC by giving more consistent results in large samples.

3.2. Historical Decomposition

The dynamic response coefficients of a VAR are difficult to interpret (Sims, 1980; Swanson and Granger, 1997). Instead, the dynamic price relationship can be best summarized through the historical decomposition. Similarly to previous studies (Yang and Bessler, 2008; Park et al, 2008; Attanavich et al, 2011), the historical decomposition method is applied to investigate abnormal market events from the unanticipated exogenous (demand or supply) shocks. The historical decomposition is derived from the moving average representation of equation (1), where the vector X_t is written as a function of the infinite sum of past innovations

$$X_t = \sum_{i=0}^{\infty} H_i\, \varepsilon_{t-i} \qquad (2)$$

where H_0 is a *MxM* matrix of moving average parameters which map historical innovations at lag i into the current position of the vector X. In other words, H_0 matrix represents the contemporaneous causal patterns between orthogonal innovations ε_t. Since e_t estimated from the VAR may exhibit off-orthogonal contemporaneous correlations, we need to transform e_t to orthogonal price innovations (ε_t), such that

$$\varepsilon_t = \mathbf{A} e_{t.} \qquad (3)$$

The most used method to account for the orthogonal price innovations is the Choleski factorization. However, the Choleski factorization is recursive in its nature and may not reflect the “true” causal patterns among a set of contemporaneous innovations (Yang and Bessler, 2008). Therefore, this study utilizes the Bernanke structural factorization (Bernanke, 1986) based on the directed acyclic graphs (DAGs) which has been used in previous studies (Yu et al, 2007; Yang and Bessler, 2008; Park et al, 2008; Attavanich et al, 2011) and will be discussed in the next section.

Based on the orthoganized price innovations generated by the DAG method, equation (2) can be written in terms of orthoganized innovations as

$$X_t = \sum_{i=0}^{\infty} G_i \, v_{t-i} \quad (4)$$

where the matrix G_0 is not diagonal, but summarizes the causal pattern in contemporaneous time between innovations in each price series.

From equation (4), we can estimate the historical partition of the vector X at any date T+i into information available at time t=T and information which is revealed at period t=T+1,T+2,…,T+i. Specifically, we can write the vector X at period T+i as

$$X_{t+i} = \sum_{s=0}^{i-1} G_s \, v_{T+i-s} + [\sum_{s=i}^{\infty} G_s \, v_{T+i-s}] \quad (5)$$

where the first part of equation (5) is the difference between the actual price and the base projection which is the second part. The base projection utilizes information available up to time period T. Through the partition, historical decomposition allows us to examine the behavior of each price series in the neighborhood of historical events (FMD outbreaks) and to infer how much each innovation contributes to the unexpected variation of X_{t+i}.

3.3. Directed Acyclic Graphs (DAG)

The DAG methodology uses algorithms of inductive causation to best represent the causal flows among variables that have been suggested by prior study or related theory. Causal relationships are represented among a set of variables using an arrow graph or picture. Arrows are a representation of the direction of the causation between variables. No arrows or sequence of arrows is allowed to represent a direct information flow from one variable back to itself.

There are many search algorithms in the machine learning literature which try to represent the causation between variables. Spirtes et al (2000) developed the PC algorithm which has structures and outputs for inference on DAGs based on observational data. A short description of the PC algorithm is as follow: by using the notion of sepset, one starts with forming a complete undirected graph G on the vertex set V[2]. The full undirected graph shows an undirected edge between every variable of the system (every variable in the vertex set V). Edges between variables are removed successively based on zero unconditional correlation or zero partial correlation. Then, Fisher's z statistic is used to test whether conditional correlations are significantly different from zero. The conditioning variable(s) on removed edges between two variables is defined as the sepset of the variables whose edges have been removed (for disappearing zero order conditioning information). The remaining edges are then directed by considering triples X–Y–Z, such that X and Y are adjacent as are Y and Z, but X and Z are not adjacent. Direct the (remaining) edges between triples X–Y–Z as X → Y ← Z if Y is not in the sepset of X and Z. Furthermore, if X → Y, Y and Z are adjacent, X and Z are not adjacent, and there is no arrowhead at Y, then Y–Z should be positioned as Y → Z. Finally, if there is a directed path from X to Y, and an edge between X and Y, then X–Y should be positioned as X → Y. Please see Spirtes et al (2000) for more information on the PC algorithm. The software TETRAD IV has programmed the PC algorithm as well as others machine learning algorithms (Spirtes et al., 2005). This work utilized TETRAD IV to conduct DAG analysis.

[2] This part of the DAG explanation was based on Bessler and Akleman (1998).

4. Data

The data used in this work are monthly Brazilian meat prices of beef, pork, and chicken at the export, wholesale, and farm levels from January 1996 to February 2011. All price series at the wholesale and farm levels are provided by the Instituto de Economia Agrícola (IEL, 2011) and they represent price quotes from farmers located in different producing regions within the state of São Paulo. In the original dataset, the farm level prices for beef, pork, and chicken are live animals of slaughter weight. Both the beef and pork prices were transformed to R$/kgs by dividing the value of the animal by the common unit of 15 kgs. There was no need to transform the farm chicken prices since they were in R$/kgs. The wholesale price for chicken is the equivalent to the fresh chicken and was in R$/kgs. As for the wholesale pork prices, quotes were in half carcass and was also in R$/kgs. The wholesale beef prices were also in R$/kg and was assumed to be equal to the part of the animal which has the most value: the hindquarter (rear portion).

Export price data are from the Secretária de Comércio Exterior (SECEX, 2011) and is in U.S. dollars. Therefore, the nominal exchange rate of the R$ to the U.S. dollar was calculated using data available from USDA (2011). It is important to mention that the export price was calculated as a proxy from the unit value of the Brazilian exports (total value of exports divided by the quantity). The data were transformed into logarithmic form to reduce the magnitude of the variations without changing the overall appearance and characteristics of the data.

The descriptive statistics for these nine price series are presented in Table 1. The highest meat price is found in the beef market with export price having the greatest mean

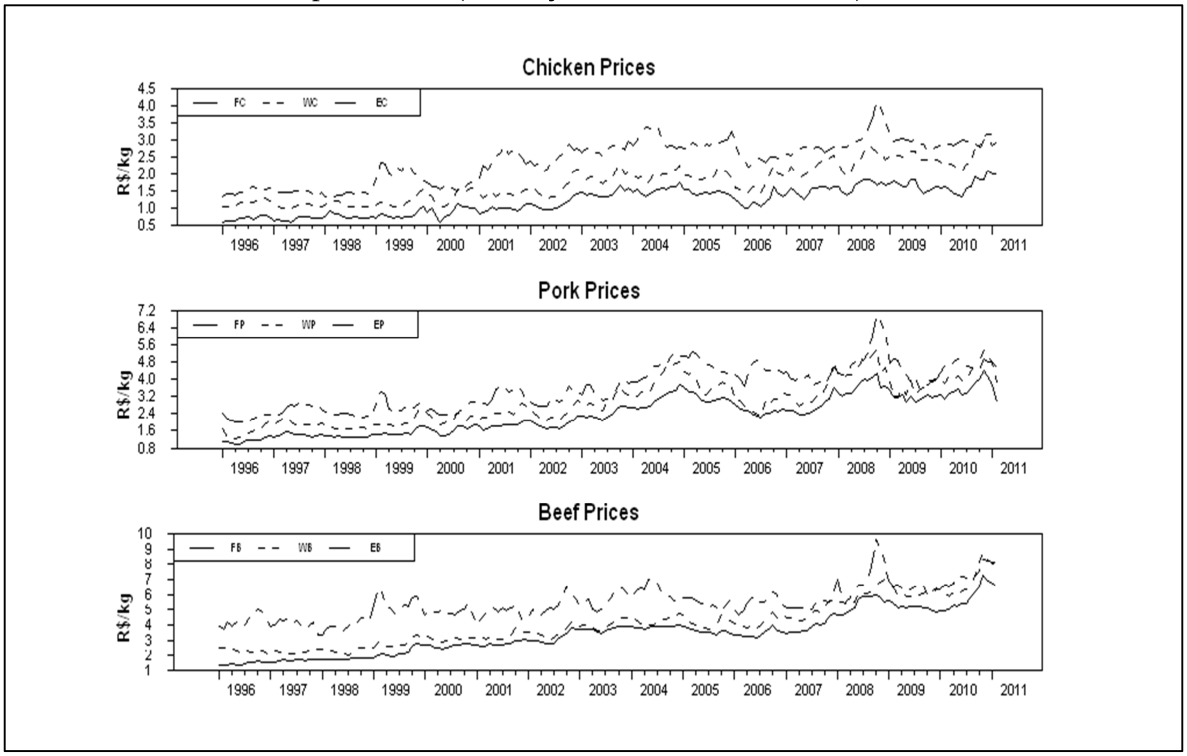
(R$5.47/kg). As expected, the mean of the export prices for all the analyzed meats was greater than the both wholesale and farm prices. The largest standard deviation was found in the wholesale beef price (R$1.53/kg) and lowest in the farm chicken price (R$0.39/kg).

Table 1. Descriptive Statistics on Brazilian Meat Prices in Different Levels of the Industry, Monthly Data: January 1996–February 2011

Series	Mean	SD	Minimum	Maximum
Chicken (R$/kg)				
Farm	1.21	0.39	0.58	2.07
Wholesale	1.74	0.55	0.96	3.09
Export	2.40	0.65	1.27	4.12
Pork				
Farm	2.36	0.88	0.98	4.42
Wholesale	2.96	1.04	1.23	5.44
Export	3.64	1.06	2.02	7.04
Beef				
Farm	3.41	1.39	1.40	7.28
Wholesale	4.05	1.53	2.07	8.80
Export	5.47	1.16	3.31	9.60

Nine monthly price series are plotted in Figure 2. The export chicken prices are shown to increase the gap with respect to the wholesale and farm prices after the beginning of 2001 until the end of 2006. On the other hand, the beef export prices seem to reduce the gap with respect to the wholesale and farm prices, especially after the end of 2005. The gap between the different levels of the pork supply chain seems to be very narrow along the entire period of the data series. Overall, with the exception of the farm chicken prices series, all series seem to have a modest upward trend especially after the beginning of 2007.

Figure 2. Monthly prices of Brazilian beef, pork, and chicken at the farm, wholesale, and export levels (January 1996–December 2011).



Note: Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC), Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP), Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB)

5. Empirical results

We first determine the optimal lag length for the unrestricted VAR representation in Equation (1). Table 2 lists the outcome of Schwarz and Hannan and Quinn loss metrics on various lag lengths, with and without monthly (seasonal) dummy variables, associated with fit unrestricted VAR on the 9 logged price series. The measures in Table 2 summarize fit on the 9 different models. Half of the models incorporate 11 seasonal variables, with the remaining half having no seasonal variables. Both groups of models use a constant with zero through 12 lags (we analyzed up to 12 lags but only reported results on up to 6 lags in Table 2). The model with the lowest Schwarz and Hannan and Quinn loss metrics had no seasonal variables, a constant, and prices lagged a single time period.

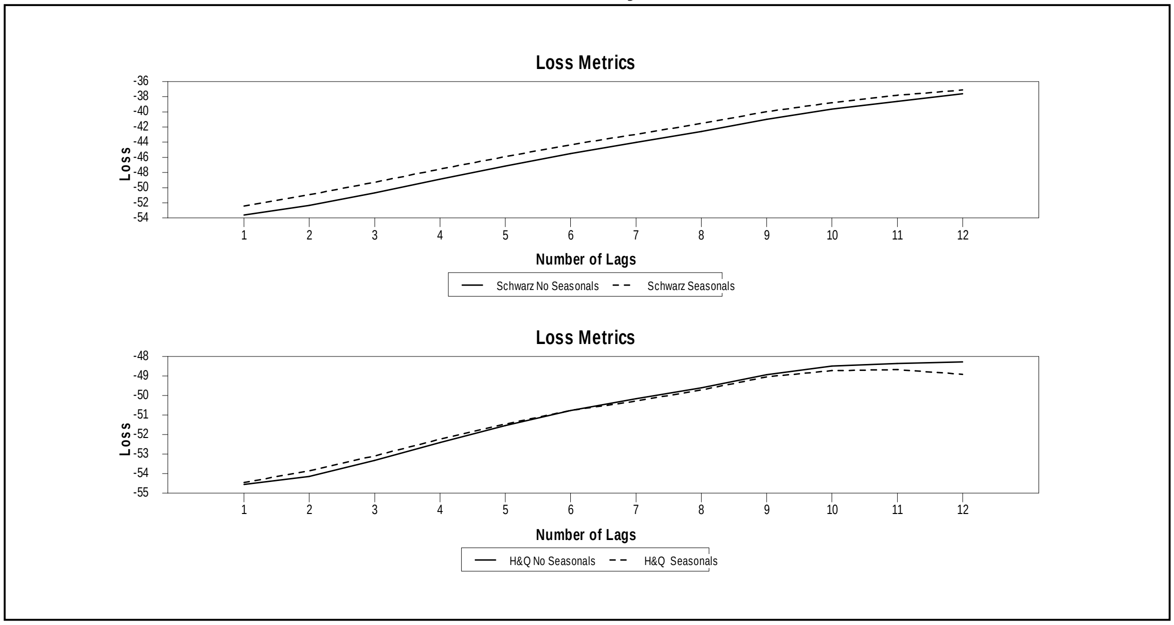
Table 2. Loss Metrics on the Order of Lags (k) in a Levels Vector Autoregression on Log Prices for the Brazilian Livestock and Meat and 11 Seasonal Dummy Variables, Monthly Data: January 1996 –February 2011

Lags = k	Schwarz-loss	Hannan and Quinn's Φ
	Constant, k lags of Prices and No Seasonals	
1	-53.61*	-54.55*
2	-52.35	-54.14
3	-50.69	-53.33
4	-48.89	-52.39
5	-47.16	-51.53
6	-45.50	-50.75
	Constant, k lags of Prices and 11 Seasonals	
1	-52.41	-54.45
2	-50.93	-53.84
3	-49.29	-53.08
4	-47.56	-52.23
5	-45.90	-51.45
6	-44.33	-50.76

Notes: The models considered are vector autoregressions of the logarithms of the nine meat prices with lags of 0 (no lags) through 12, each equation in the panel has either no, or 11 seasonal monthly variables. Metrics considered are Schwarz- loss (SL) and Hannan, and Quinn's Φ measure on lag length (k) of a levels vector autoregression: SL=log(|∑|)+(9k+2n+1)x(logT)/T, Φ =log(|∑|)+(2.00)(9k+2n+1)□(log(logT))/T where ∑ is the error covariance matrix estimated with 9k+11+1 (the ''11'' represents the 11 seasonal dummy variables, the ''1'' represents the constant) regressors in each equation, T is the total number of observations on each series, the symbol ''| |'' denotes the determinant operator, and log is the natural logarithm. We select that model that minimizes the loss metric. The asterisk (''*'') indicates minimum of each column. We report only results on lags of prices for lags 1 to 6. Results on other lags of prices, up to 12, are available from the authors.

In Figure 3 below, we plot Schwarz and Hannan and Quinn loss metrics for specification from one to 12 lag length, both with and without the seasonal dummy indicator variables. The metrics calculated without seasonal dummy variables lie below those calculated with seasonal variables. Both the Schwarz and Hannan and Quinn loss metrics are minimized at one lag. Therefore, we assume that the optimal lag length for the nine price series unrestricted VAR representation is equal to one and has a constant and no seasonal dummy variables.

Figure 3. Schwarz Loss and Hannan and Quinn (H&Q) Loss on Alternative Lags with and without Seasonal for Brazilian Livestock and Meat Prices Monthly Data: January 1996 –February 2011



5.1. The impacts of the FMD outbreak on Brazilian meat prices

To analyze the impacts of the FMD outbreak in Brazil that occurred in September 2005, we first estimate a unrestricted VAR using the data from January 1996 to August 2006, a month before the FMD outbreak in the state of Mato Grosso do Sul and two months before the beginning of the Russian import ban, and then we conduct out-of-sample forecasting of meat prices of 35 months after the event and 6 months after the end of the Russian import ban on Brazilian meat (which was December, 2007). We use the following formula to estimate the percentage change of the actual price relative to the forecasted price for the analyzed period (August 2006 to June 2008):

$$\Delta P_{ij} = \frac{X_{ij} - F_{ij}}{F_{ij}} \times 100 \qquad (6)$$

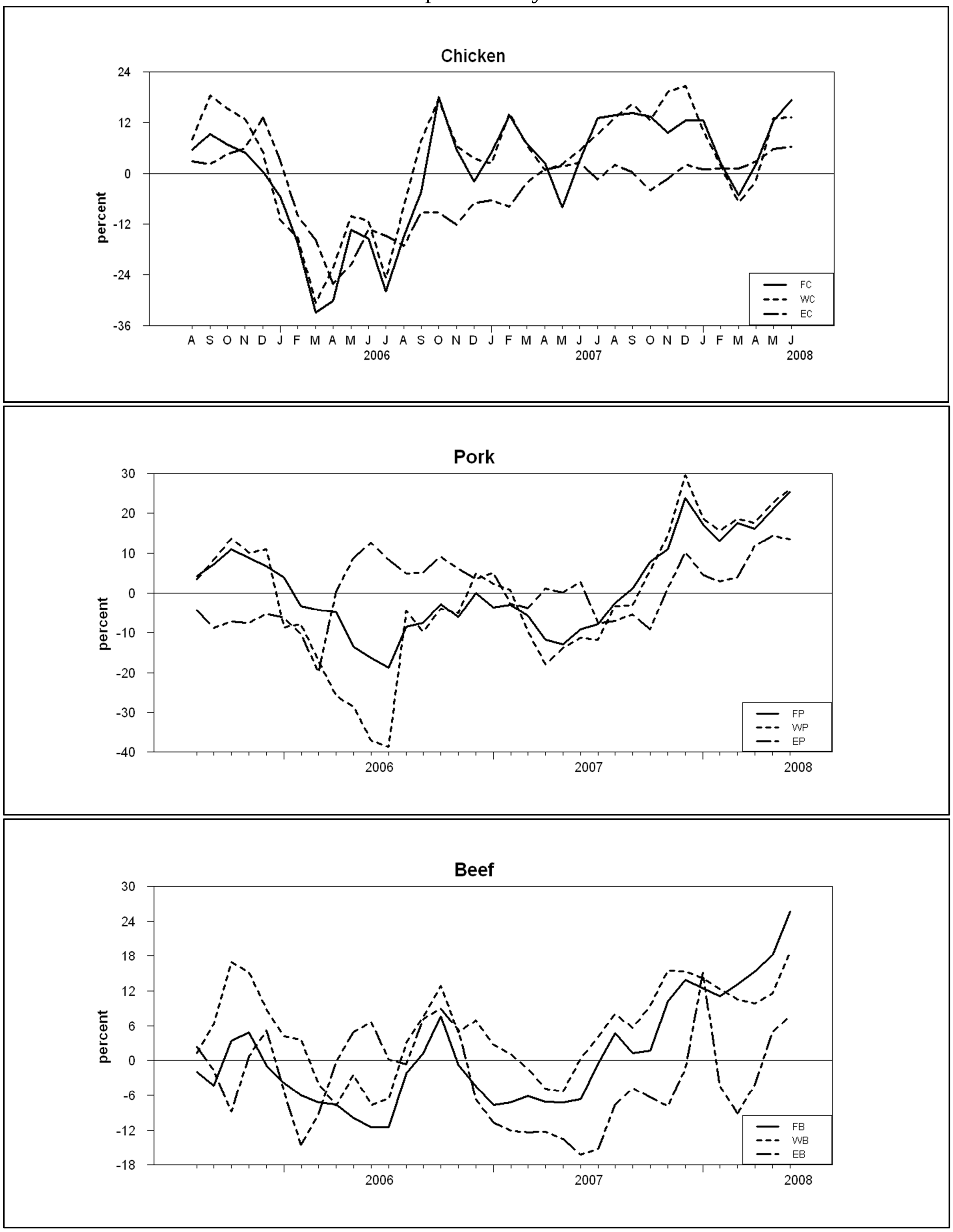
where x_{ij} and F_{ij} are the actual and forecasted prices, respectively, of the meat type *i* (c = chicken, p = pork, b = beef) in the *j* market level (f = farm, w = wholesale, e = export).

Figure 4 illustrates ΔP_{ij} over time for beef, pork, and chicken following the FMD outbreak in September 2005 and, sequentially, the beginning of the Russian import ban in October 2005 through the lift of the import ban by Russia in December 2007. We start the discussion on the impacts of the FMD outbreak on the meat prices by analyzing each type of meat.

5.1.1. Beef Prices

As we can see on the lower graph of Figure 4, in the first six months after the outbreak and five months after the Russian import ban (i.e. by February 2006), the export beef price decreased approximately 12 percent. The export price recovered four months later (around May 2006) up to 6 percent and stayed positive until November 2006. After November 2006, the export price dropped below zero and stayed negative for 13 months, with the largest decrease in price (nearly 18 percent) in mid-2007, until the lift of the import ban by Russia in December 2007. In January 2008, one month after the removal of the import ban by Russia, the export price rose 15 percent relative to the forecasted price.

Figure 4. Percentage change of the actual price relative to the forecasted price following the FMD outbreak (and Russian import ban) in September 2005 (in October 2005) and before the removal of the import ban by Russia in December 2007



Note: See Figure 2 for definition of variables.

As for the wholesale beef price, the impacts of the FMD outbreak were positive in the short run (up almost 18 percent in the first two months) until dropping below zero in March 2006. The wholesale price rebounded five months later and stayed above the forecasted price for most part of the period. Similarly to the wholesale price, the effects of the FMD outbreak on the farm beef price were ambiguous for most part of the period. It seems that the farm and wholesale price were tied to each other with the farm price always below the wholesale price.

5.1.2. Pork Prices

The graph in the middle of Figure 4 represents the percentage change of the actual price relative to the forecasted price for the pork market. Likewise the export beef price, the FMD outbreak had negative effects on the export price for pork. The export pork price reached the lowest percentage decrease six months after the occurrence of the FMD outbreak in September 2005 (down approximately 20 percent), such decrease was the largest in the short run for all the export price series. However, the recovery of the export pork price occurred less than two months later and eventually reached its highest increase in price in June 2006. The positive percentage change stayed until February 2007 when it dropped below zero and eventually only rebounded one month before the removal of the import ban by Russia. Overall, the percentage change of the actual price relative to the forecasted for the export pork price was positive for thirteen months, the most of all export prices series.

The wholesale pork price had severe negative effects due to the FMD outbreak in the first twelve months. In July 2006, the decrease in wholesale price reached nearly 40 percent, which is the lowest decrease when compared to other wholesale prices. The wholesale price rebounded rapidly getting very close to the forecasted price one month later (in August 2006). The actual price went above the forecasted price finally in February 2007 and eventually went down 20 percent four months later. The final recovery of the wholesale price came in October 2007, two months before the lift of the Russian import ban. Regarding the farm pork price, similarly to the wholesale price, the lowest decrease occurred in July 2006 (down 20 percent). The recovery of the farm pork price only happened twenty months later in October 2007. Of all the farm price series, the actual price for pork spent the longest period under the forecasted price, totaling 20 months before the recovery two months the lift of the import ban by Russia.

5.1.3. Chicken Prices

The graph in the top of Figure 4 presents the percentage change of the actual price to the forecasted price for the chicken market. This market is interesting to analyze since the chicken meat is considered to be a substitute of both beef and pork. In addition, since chickens cannot be infected by the FMD, one would expect that the Russian government would not include chicken meat as part of the ban. In the first four months, the export chicken price increased 12 percent. Eventually, the Russian authorities included chicken meat in their import ban of Brazilian meats. As the ban on chicken meats was incorporated, the export chicken price decreased 24 percent in April 2006. The recovery of the export chicken price only occurred one year later (April 2007) and stayed stable around zero for the rest of the import ban.

The wholesale and farm chicken prices were affected in a similar manner to the export price. After increases in the first three months, both prices had drastic decreases three months later (March 2006). However, both prices rebounded faster than the export price (in September 2006). For most part of the analyzed period, the wholesale and farm prices for chicken were both above their respective forecasted prices.

5.2. The impacts of the FMD outbreak on price margins of the Brazilian meat supply chain

To analyze the impacts of the FMD outbreak along the supply chain, we estimate the changes in the price margin for the export, wholesale, and farm levels within each market. The changes in the price margins along the supply chain due to the FMD outbreak are

$$PM_{i,ef} = (x_{ie} - x_{if}) - (F_{ie} - F_{if}) \text{ export-to-farm} \quad (7)$$

$$PM_{i,wf} = (x_{iw} - x_{if}) - (F_{iw} - F_{if}) \text{ wholesale-to-farm} \quad (8)$$

$$PM_{i,ew} = (x_{ie} - x_{iw}) - (F_{ie} - F_{iw}) \text{ export-to-wholesale} \quad (9)$$

where PM is the price margin at level *l* relative to level *m* and can be widen by the FMD outbreak ($PM_{i,lm} > 0$), narrowed ($PM_{i,lm} < 0$), or has no effect on the price margin ($PM_{i,lm} = 0$). Figure 5 shows the changes in the price margins resulting from FMD outbreak in September 2005 and, sequentially, the beginning of the Russian import ban in October 2005 through the lift of the import ban by Russia in December 2007.

5.2.1. Beef Prices

The lower graph in Figure 5 shows the changes in the price margins resulting from the FMD outbreak along the beef supply chain. The price margin at the export level relative to the farm and wholesale levels decreased in the first month after the FMD outbreak (down R$0.50/kg and R$1.20/kg, respectively) and only recovered two months later (December 2005). This recovery only lasted one more month then decreased again approximately for both farm and wholesale levels (R$0.50/kg and R$0.80/kg, respectively) in February 2006. After eight months of positive outcomes, the price margin at the export level relative to the farm and wholesale levels decreased to negative points until rebounding after the removal of the import ban by Russia. The wholesale-to-farm price margin was positive for the entire period of the analysis.

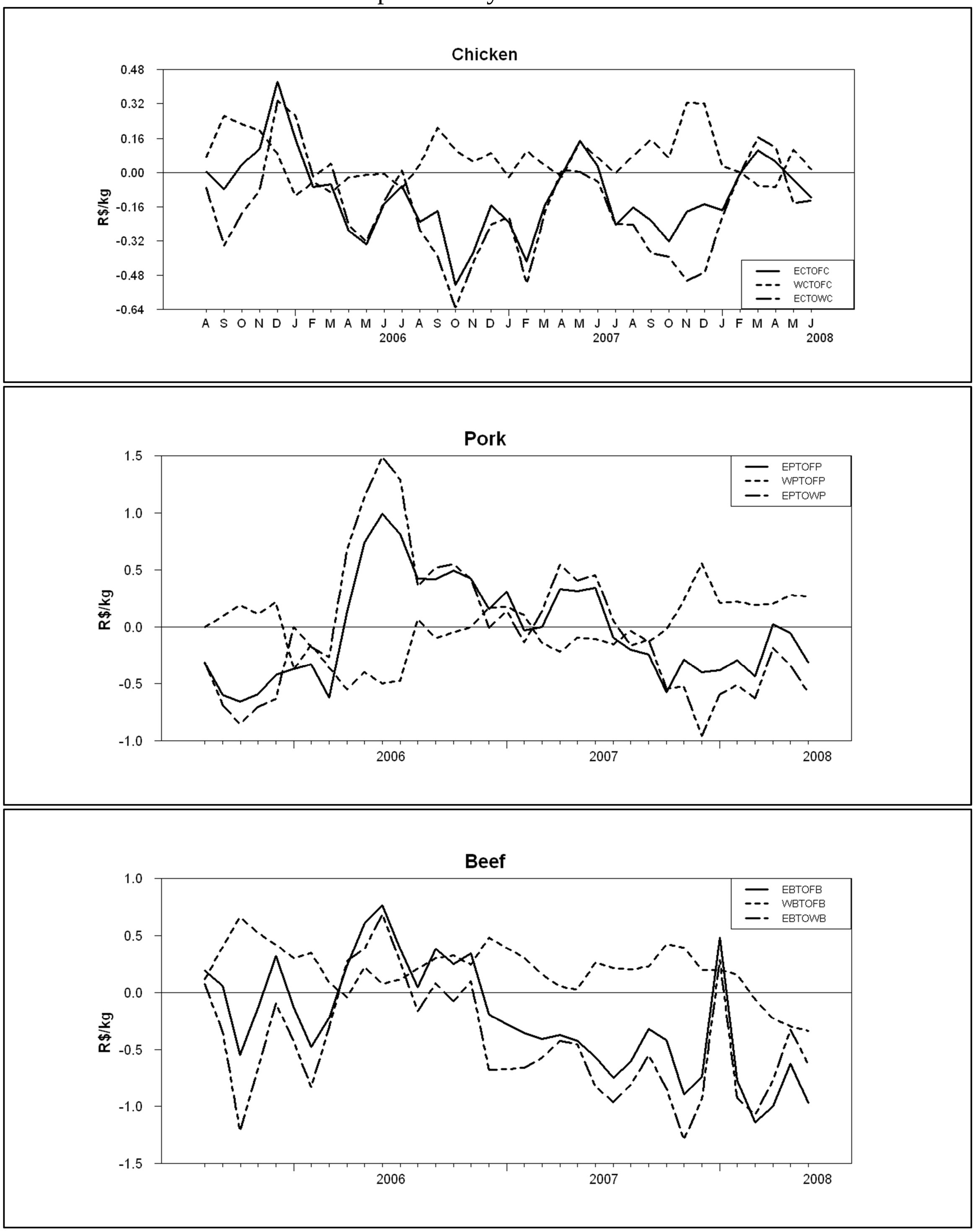
5.2.2. Pork Prices

The middle graph in Figure 5 shows the changes in the price margins resulting from the FMD outbreak along the pork supply chain. The results for the price margin at the export level relative to farm and wholesale levels for the pork are similar to the results from the beef market. The major difference between the results of these two markets is that, at the end of the analyzed period (after the removal of the Russian import ban), both the export-to-farm and export-to-wholesale margins never recovered completely, staying negative for the following three months (from December 2007 to April 2008). For the whole period of the analysis, the wholesale-to-farm price margin was stationary in the range of –R$0.50/kg and R$0.50/kg .

5.2.3. Chicken Prices

The top graph in Figure 5 illustrates the changes in the price margins resulting from the FMD outbreak along the chicken supply chain. In this market, the price margin at the export level relative to the farm and wholesale levels had an upward trend in the first four months after the outbreak, then downward trend between month five (January 2006) and nine (May 2006), stayed negative for most part until recovering in April 2007 which lasted just one month, then decreased again and stayed negative until February 2008 (two months after end of the import ban by Russia). Likewise the beef market, the wholesale-to-farm price margin was positive for the entire period, with the exception of five months (from January 2006 to May 2006).

Figure 5. Changes in the price margin along the supply chain following the FMD outbreak (and Russian import ban) in September 2005 (in October 2005) and before the removal of the import ban by Russia in December 2007



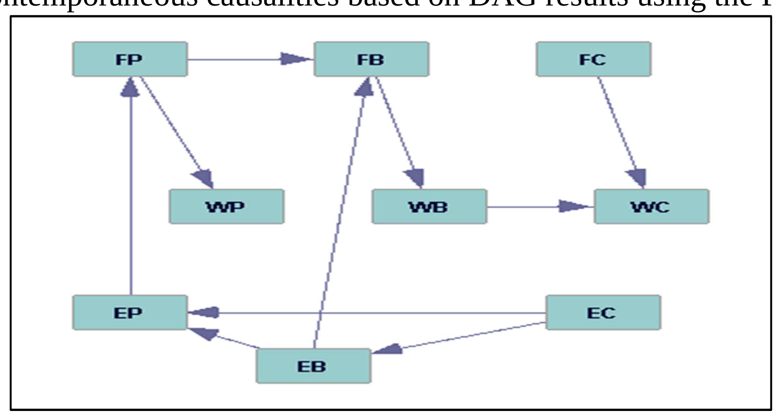
Note: See Figure 2 for definition of variables.

5.3. The impacts of the FMD outbreak on dynamic price interdependence

In this section, we use historical decomposition to address the potential changes in interdependence among prices due to the FMD outbreak. Analysis is performed to evaluate how much each price innovation accounts for the atypical variation of a certain price due to the FMD outbreak.

By using the correlation matrix of price innovations estimated from the unrestricted VAR estimated, we employ the TETRAD IV software with the PC algorithm to determine the contemporaneous causal flows between price innovations. The results in Figure 6 indicate that the innovations in the farm prices directly affected the wholesale prices in all the meat markets. The innovation of the farm pork price also directly affected the farm beef price which is an interesting result since in the literature the opposite holds (Bessler and Akleman, 1998). The beef and pork export prices directly caused the farm level prices for both meats which was expected since the Brazilian meat industry is very export oriented and plays a major role in the global meat trade. Interesting to note was the result of export chicken price directly causing both the beef and pork export prices.

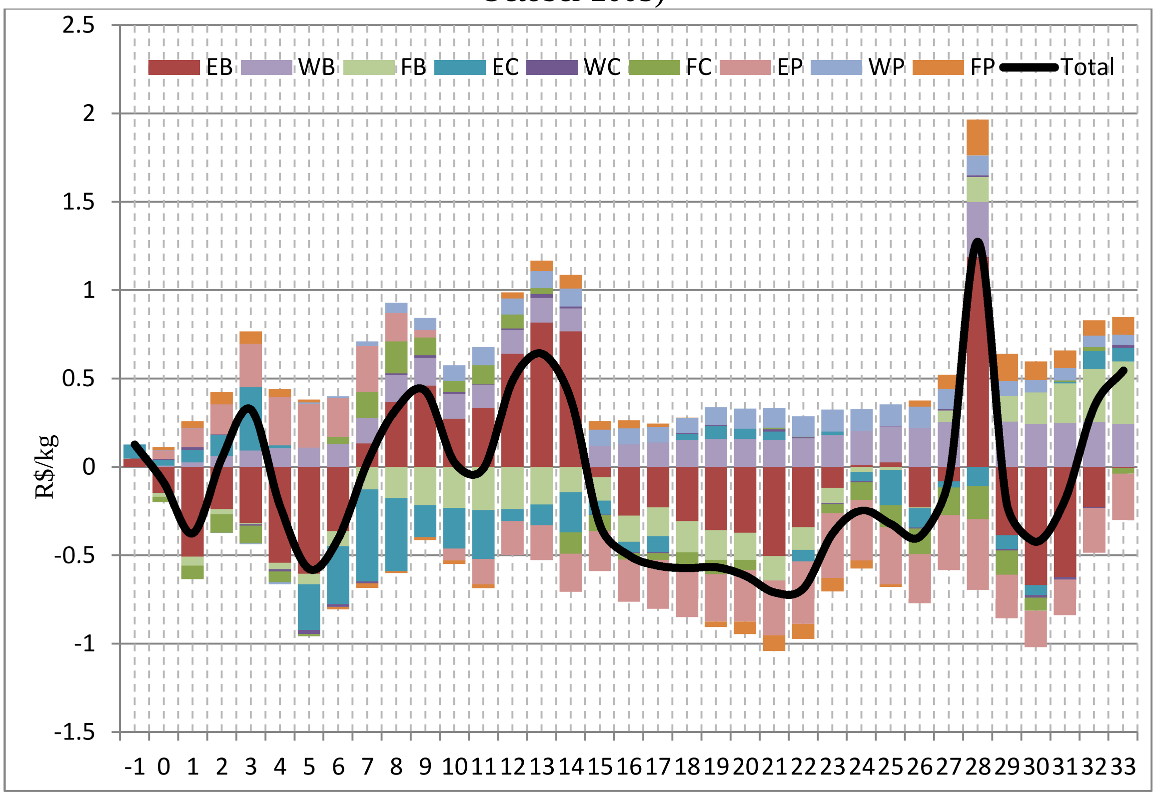
Figure 6. Contemporaneous causalities based on DAG results using the PC algorithm.



Note: See Figure 1 for definition of variables.

After implementing the contemporaneous relationship identified by the PC algorithm (figure 6) in the unrestricted VAR representation, we evaluate the historical decomposition for export price beef. The contribution of each price to historical decomposition is implemented over 35 months: one month before the event and 34 months following the event. The bar chart in figure 7 illustrates the contribution of each price series, either negative or positive, to the atypical change in the export beef price responding to the FMD outbreak in September 2005 and the Russian import ban in October 2005[3].

Figure 7. Contribution of each price series on the innovation of the export beef price when responding to the FMD outbreak (and Russian import ban) in September 2005 (in October 2005)*



*Each stacked bar represents positive or negative contribution of nine price series to innovation of export beef price. The solid line represents the deviation of the actual export beef price from the base projection. The x-axis is the number of months before and after the event while the event occurred in month zero.

[3] Historical decomposition figures for the other price series are available upon request.

The deviation of the actual export beef price relative to the base projection, which is represented by the solid line, indicates that the FMD outbreak in September 2005 had an immediate negative impact on the export beef price. The introduction of the Russian import ban (month 1) further decreased the export beef price by R$0.35/kg, where most of the variation was mainly due to its own price innovation. In the following two months, the deviation of the actual price relative to the base price increases by R$0.35/kg, where, unexpectedly, the positive variation was attributed to the price innovations of the pork and chicken export prices while the negative price innovation was most due to the own price innovation. Conversely, in the following three months (from months 4 to 6), the price innovations of the export pork and chicken series played a major role in the downward movement of the export beef price. For the most part of the next seven months (from months 7 to 14), the deviation of the actual export beef price relative to the base projection was positive, where the positive deviation was most explained by own price and wholesale beef price innovations. For the same period, the deviation of the export beef price to the forecasted price was not larger due to the negative contribution of the pork and chicken export price innovations.

From months 15 to 27, the deviation of the actual export beef price relative to the forecasted projection was negative for the entire period. In this period we also found the lowest negative variation of the deviation for the 34 months (approximately -R$0.70/kg), which occurred in month 22. It is interesting to mention that, in this 12 month period, the export pork price innovations played a major role in the negative deviation. Most of the positive export beef price variation was mainly attributed to its own series and the wholesale beef price innovation contributions.

The most important result of the historical decomposition of the export beef price series is revealed in month 28 (January 2008), which is exactly one month after the removal of the import ban by the Russian government. As we can see on figure 6, the deviation of the actual export beef price relative to the forecasted price reached its peak (approximately R$1.30/kg) of the entire studied period in month 28. The variation of the export beef price for that month was mainly due to the shocks of its own price followed by the wholesale and farm beef prices innovations. If the negative contributions of the beef substitutes (pork and chicken) had not been significant (total of approximately R$0.70/kg), the positive variation would have the potential of reaching nearly R$2.00/kg. One can conclude that the removal of the Russian ban on Brazilian meat imports had a very drastic positive influence on the beef industry supply chain in general, especially at the export level.

6. Conclusions

This study estimates the market impact associated with the 2005 FMD outbreak in Brazil, along with the consequences of the meat import ban by Russia, and its effects on the Brazilian meat supply chain. By using time series methods, mainly unrestricted VAR and historical decomposition of price innovation, complemented by DAGs, we found that the 2005 FMD outbreak caused a temporary price shock to the Brazilian meat market.

Beef, pork, and chicken export prices all decreased after the FMD outbreak. However, certain prices had different recovery dates than others. For example, export chicken price only rebounded 15 months later after the import ban imposed by Russia. On the other hand, the changes in export pork prices due to the FMD outbreak varied in the same range over the analyzed period (between +10 percent and -15 percent). Of all the analyzed export prices, the beef price was the one which spent most of the period below zero. To be more precise, the percentage change of the actual beef price relative to the base was positive in only 8 months out of the analyzed 35 months. As for the wholesale and farm prices for the different type of meats, all price series underwent a negative impact due to the FMD outbreak only rebounding 7 months later, with the exception of the pork prices which took 10 months to recover. The most important change in the price analysis is that all prices ended up recovering after the removal of the import ban by Russia in December 2007.

The impacts of the FMD outbreak on price margins of the Brazilian meat supply chain were different for the three different types of meat. For the beef market, the price margin at the export level relative to the farm and wholesale levels decreased in the first month after the FMD outbreak and only recovered two months later (December 2005). This recovery only lasted one more month then decreased again in February 2006. After eight months of positive outcomes, the price margin at the export level relative to the farm and wholesale levels decreased to negative points until rebounding after the removal of the import ban by Russia. As for the pork supply chain, the results for the price margin at the export level relative to farm and wholesale levels for the pork are similar to the results from the beef market. The major difference between the results of these two markets is that, at the end of the analyzed period (after the removal of the Russian import ban), both the export-to-farm and export-to-wholesale margins never recovered completely. In the chicken market, the price margin at the export level relative to the farm and wholesale levels had both upward and downward movements along the period of the analysis, which made it difficult to form any precise conclusion. For the whole period of the analysis, the wholesale-to-farm price margin for the three types of meat was stationary in the range of –R$0.50/kg and R$0.50/kg .

The interdependence among the price series and its change under the FMD outbreak is identified using historical decomposition of price innovations. The results suggest that the farm level price innovation has played a major role in explaining the innovations of the wholesale prices in all the meat markets. The innovation of the beef and pork export prices directly caused the farm level prices for both meats which was expected since the Brazilian meat industry is very export oriented and plays a major role in the global meat trade. Interesting to note was the result of export chicken price innovations directly causing both the beef and pork export prices. This can be explained by a possible substitution effect which perhaps is present in the data series.

The historical decomposition of the export beef price is evaluated based on the contemporaneous relationship identified by the DAGs method. For most part of the period analyzed, the positive deviation of the actual export beef price to the base projection was mainly explained by the price innovations of its own price series and the wholesale beef price series. Conversely, the price innovations of the export pork and chicken series along with the farm beef price series played a major role in the downward movement of the export beef price. The most important result of the historical decomposition analysis was the possibility to show that the removal of the Russian ban on Brazilian meat imports had a very drastic positive influence on the beef industry supply chain in general, especially at the export level.

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