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

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Abstract

This paper elucidates the impacts of the September 2005 foot and mouth disease outbreak on the Brazilian meat market for different levels of the industry (export, wholesale, and farm). The associated import ban by Russia on Brazilian meat exports is also analyzed. Results suggest that the increase in domestic supply due to the import ban generated downward pressure on prices at all levels for pork and chicken. Meanwhile, export beef and wholesale beef prices underwent ambiguous and positive changes, respectively, while farm level prices only recovered after the removal of the import ban.

Keywords: animal disease outbreaks, Brazilian meat market, international trade

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Introduction

In Brazil, foot and mouth disease (FMD) outbreaks have been present in the meat industry for more than a century. In 1895, the first FMD outbreak was reported, since then, Brazilian authorities have struggled to contain the 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 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 regions with the purpose of managing animal health controls more efficiently. Regionalization involves declaring one or more areas of a country FMD-free, even if other areas are responding to an outbreak. Under a regionalization policy, if one state or area is infected, the nation as a whole may not lose its FMD-free status, and trade restrictions might not be forced on all of the FMD-susceptible products. In 2000, Brazil became the fourth largest beef and pork exporter and the second largest chicken exporter. Five years later, Brazil became the largest beef and chicken exporter in the world and more than quadrupled pork exports. Currently, the Brazilian meat export industry has maintained its position as a leading meat supplier in the global market (FAS/USDA 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 (2011), the FMD outbreak took place initially in the state of Mato Grosso do Sul, which is historically the state with the third largest cattle herd in Brazil (IBGE 2014). Three months later, an outbreak was reported 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 covered eight meat producing states in Brazil, which from 2008 to 2012 these states accounted for more than half of the country's cattle herd (IBGE, 2014). After the destruction of 33,741 FMD-susceptible animals (32,549 cattle, 566 pigs, 626 sheep and goats) (OIE 2011) 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.

[1] According to the Secretaria de Comércio Exterior (SECEX/MDIC, 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.

As a consequence, the FMD outbreaks caused immense uncertainty and economic losses to the Brazilian meat industry, particularly for exports. One to two months after the import ban by Russia and other countries, Brazilian beef exports decreased from 93,800 tons in September 2005 to 66,100 tons in December 2005, a decline of 30 percent. Furthermore, according to the SECEX/MDIC (2011) database, Brazilian beef exports to Russia decreased from 21,300 thousand tons in September 2005 to 12,500 thousand tons in December 2005 (a reduction of 41 percent).

The purpose of this study is to analyze the impacts of the FMD outbreak on the Brazilian meat prices for three different levels of the industry: export, wholesale and farm. The imposition of an import ban by Russia is also investigated. A vector error correction model (VECM) is used for this analysis. This approach quantifies the effects of the 2005 FMD outbreak in Brazil on prices of different meats at different levels of the marketing system.

This work is a contribution to the literature on the impacts of animal disease on meat markets for two reasons. First, it simultaneously investigates the effects of animal disease outbreaks on export prices, as well as domestic prices (wholesale and farm). Second, Brazil is a major player in the global meat industry. To our knowledge there is no study in the literature that has analyzed this important market at our level of detail.

This study begins with a literature review on the impacts of animal disease outbreaks on meat markets. This is followed by a presentation of a conceptual model that depicts the impacts of animal disease outbreaks followed by trade bans. The third section contains a discussion of the method of analysis. A description of the data used for analysis follows. The empirical results section presents the most important findings of the study. A conclusion completes the paper.

Literature Review

Several studies have analyzed the impacts of animal disease outbreaks and their effects on the meat prices for different countries. Burton and Young (1996) measured the impacts of bovine spongiform encephalopathy (BSE) on the British domestic beef market. Their findings indicate the BSE outbreak led to significant negative impacts for the beef industry in Great Britain. By using a food publicity index related to BSE, Lloyd et al. (2001) found that beef prices at the retail, wholesale and producer levels in the United Kingdom fell considerably. The authors argue this drop in prices was consistent with an inward shift in the demand for beef function. Sanjuán and Dawson (2003) also investigated the impacts of BSE on the UK meat sector (beef, pork, and lamb). The authors used a cointegration procedure which allowed structural breaks (BSE crisis) in the cointegrating space. Their findings indicated that the BSE crisis increased the retail-producer margin for the beef sector but no evidence of BSE-related breaks were found in the lamb or pork relationships. Lloyd et al. (2006) showed that the negative impact of the UK BSE outbreak on farm prices was more than double the impact on retail prices. They also showed that the retail-to-farm price margin became larger due to the 1996 UK BSE discovery. Piggott and Marsh (2004) estimated the impacts of publicized food safety information (media index construction) on meat demand for the United States. These authors showed that major food scares induced large demand responses, but these responses were rapidly dampened.

A stream of literature has focused on the impact of animal disease outbreaks coupled with trade bans on meat prices. Rich and Winter-Nelson (2007) developed a multimarket model with a dynamic and spatial epidemiological model to investigate FMD outbreaks in the Southern Cone region of South America. Six FMD mitigation strategies which included export restrictions were analyzed. Their results indicated that product prices and export volumes would decrease for all countries in the region. Paarlberg et al. (2008) assessed hypothetical FMD outbreaks on aggregate supply, demand, and trade in the U.S. They used an economic-epidemiological model to show that export embargoes caused by the FMD outbreaks would lead to increase in domestic supplies and lower prices. Park et al. (2008) quantified the impacts of domestic and overseas animal disease crises on the Korean meat market. One of the findings of their study is that the Korean import ban on U.S. beef meat, due to the 2003 BSE discovery, caused an overall concern in the population. This concern had negative impacts on the demand side and led to substantial decreases in prices of domestically produced beef.

More recently, Attavanich et al. (2011) estimated the impacts of media coverage related to H1N1 (swine flu) on U.S. meat and related product prices, and quantified the revenue losses across the meat and related markets. A trade ban by U.S. pork meat importing countries was also examined and was shown to negatively affect the industry by reducing lean hog prices considerably. A study by Tozer and Marsh (2012) analyzed hypothetical FMD outbreaks impacts on the second largest exporter of beef meat in the world, Australia. Scenarios with closure of export markets were evaluated. In all scenarios, domestic supply increased and domestic prices fell significantly. Furthermore, after the FMD mitigation measures, their work showed that it would take approximately one year for the Australian beef price to return to base scenario levels.

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 methods 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 (originating in 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) model to perform their analysis. Results from this study suggest that the FMD outbreaks caused high pork price volatility for both series.

Conceptual Model

As discussed in the literature review section, animal disease outbreaks, followed by meat trade bans, affect both exporting and importing countries. In this section a conceptual model depicts the occurrence of an import ban by a large importing country (Russia) and its impacts on the exporting country (Brazil). To illustrate this event, Figure 1 below presents the effects of a trade ban by Russia on the Brazilian beef market (this also applies for the pork and chicken). The Brazilian domestic beef supply and demand are shown in the left panel. The Russian beef market is located in the right panel. Domestic beef supplies in both countries are assumed to be perfectly inelastic (beef production is derived from the Brazilian cattle market). The panel in the middle represents the world beef market. Excess supply is derived by measuring the horizontal distance between the supply and demand schedules in Brazil. Excess demand in the world market for simplicity is assumed to be equal to the demand schedule for Russia.

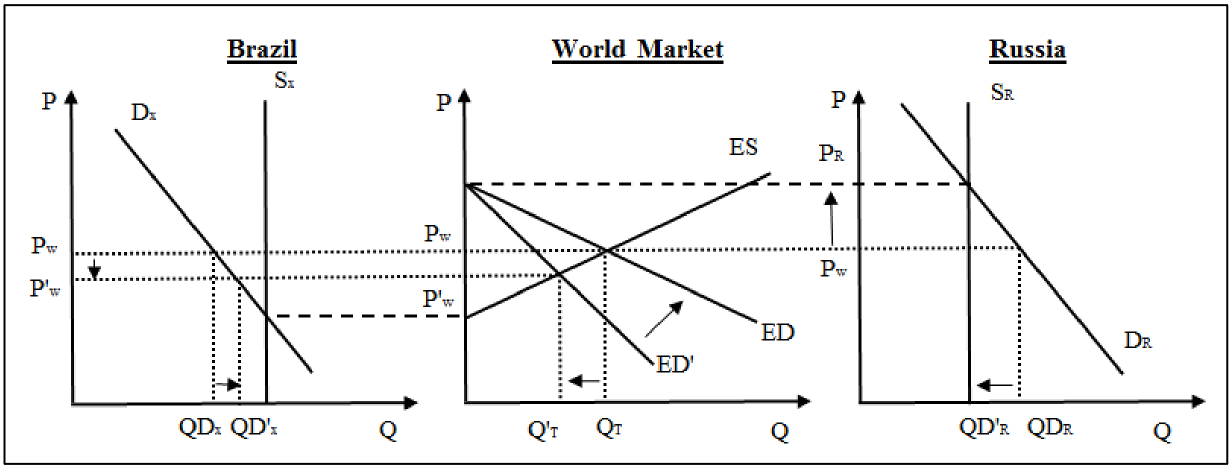

Figure 1. Effects on the Brazilian beef market of an import ban by Russia due to a foot and mouth disease outbreak

Source. Adapted from Peterson et al. (1988).

For simplicity, it is assumed that the only country exporting to Russia is Brazil[2]. Thus, the introduction of an import ban by Russia on the Brazilian beef exports means that all the domestic consumption in Russia would be supplied by the local producers. In this case, Russian imports would fall to zero and the local price would rise from P_W to P_R. In the world market, the excess demand curve would shift from ED to ED' where the excess demand in ED' is driven by other importing countries. This fall in excess demand results in a lowering of the world beef price. This can also be explained by the fact that more beef meat would be available in the Brazilian market. Consumers in Brazil are expected to benefit from the lower prices, while producers would lose. On the other hand, Russian consumers would lose due to higher beef prices while producers would gain.

In summary, the expected effects of FMD outbreaks on the Brazilian meat market coupled with an import ban from its main trade partner, Russia, are a decrease in Brazilian meat prices. These decreases in prices are expected to occur throughout the meat sector in Brazil. In other words, export, wholesale, and farm prices for beef, pork, and chicken are expected to undergo a decrease due to the import ban vis-à-vis the increase in internal meat supply.

Method of Analysis

To quantify and identify the potential impacts of FMD outbreaks followed by an import ban by Russia on the Brazilian meat industry, a time series method is employed. The Vector Error Correction Model (VECM) facilitates the comparison between the actual price that is affected by the FMD outbreak (plus the import ban) and the forecasted price that uses only information before the outbreak occurred. This approach allows the quantification of the impacts on meat prices for price levels for different types of meat and its different levels of the supply chain.

[2] This is a reasonable assumption since historically Brazil exports accounts for 40% of the Russian beef imports.

Vector Error Correction Model

A useful empirical method used to analyze a set of interrelated variables observed over time is a vector autoregression (VAR) model. An unrestricted VAR model with k lags of *M* variables is written:

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

where X is a ($M \times 1$) vector of series at time t, Γ_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 *k* 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 VECM, developed by Johansen (1988), has to be utilized to study both short-run discrepancies and long-run equilibrium. A VECM model is described as follows:

(2) $\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + e_t \ (t = 1, \dots, T)$

where equation (2) is a VAR model in first differences with the addition of a lagged-level vector. The ($M \times M$) coefficient matrix, Π, contains the influence of lagged levels of the analyzed variables on current changes.

When the rank of Π is a positive number, r, and it is less than the number of series in the system, *M*, then $\Pi = \alpha\beta'$, where α and β are (M x r) matrices. The α matrix contains the information on the speed of adjustment and β matrix includes the cointegrating parameters.

There are several approaches to specify the rank of the cointegrating vector (r) and the optimal lag length (k). One can perform the conventional approach which is a two-step procedure involving system-based likelihood ratio (LR) tests to determine r and k sequentially. In other words, optimal lag length is first estimated by the loss metric, (e.g. Schwarz-loss) and then the cointegration rank is determined (usually with a trace test, see below).

The first step is to determine the optimal lag length (k) of the VAR representation via loss metric criteria functions. Here we consider two different loss metrics: (i) the Schwarz-loss criterion (SIC) and (ii) the Hannan and Quinn (HQ). Both methods are asymptotically consistent (meaning as sample size grows to infinity they select the proper lag length with probability one). The second step is to identify the rank of cointegration vectors based on a trace test (Johansen 1988), with the test statistic given by

(3) $Trace = -T \Sigma_{i=r+1}^{k} \ln(1 - \lambda_i)$

where T is the number of observations and λ_i's are ordered Eigenvalues of matrix Π in equation (2).

This two-step approach has its advantages and disadvantages. According to Bruggemann and Lutkepohl (2005), the main advantage of this procedure is computational simplicity. However, unfortunately, one of the main disadvantages of this procedure is that it will likely yield low power and size distortions when the assumption of independent, identically, distributed (i.i.d.) does not hold for the error term (Wang and Bessler 2005). In addition, the two-step procedure requires an arbitrary decision with respect to which should be first determined; the cointegration rank or the optimum lag estimation. The choice of the lag order in the first step has been shown to have a non-trivial impact on the cointegration test performance (Boswijk and Franses 1992).

More recently, model selection methods based on information criteria have been proposed and implemented as an alternative to the two-step procedure (Kapetanios 2004). This method jointly estimates the cointegration rank and the optimal lag length in a VAR. There are two main advantages of the model selection compared with the two-step procedure. First, it eliminates the arbitrary choice associated with identifying the "appropriate" significance level when using the traditional system-based LR tests. Second, the model selection approach allows the researcher to jointly determine the lag order and cointegration rank by minimizing information criteria over a pool of models with various lag orders and cointegration ranks (Wang and Bessler 2005). Furthermore, simulation evidence by Chao and Phillips (1999) and Wang and Bessler (2005) suggests the information criteria approach can complement traditional parametric tests. Here HQ loss metric criterion is used to jointly determine the optimal length of the VAR representation and the cointegration rank. For comparison, both the system-based LR tests (sequential) method and the model selection (joint) procedure are used to determine the optimum lag length (k) and the rank of cointegration (r).

Data

The data used are monthly Brazilian prices of beef, pork, and chicken at the export, wholesale, and farm level from January 1996 to February 2011. All price series at the wholesale and farm levels are provided by the Instituto de Economia Agrícola (IEA 2011) and represent price quotes from farmers located within the state of São Paulo. In the original dataset, the farm level prices for beef and pork were in R$/15 kg[3]. Both beef and pork prices were transformed to Real (R$)/kgs by dividing them by 15 kg. There was no need to transform the farm chicken prices since they were in R$/kg. The wholesale price for chicken is the equivalent to the fresh chicken price and was reported in R$/kg. In Brazil, wholesale pork is commercialized in half carcass units and its price is quoted in R$/kg. The wholesale beef prices were also in R$/kg.

Export price data are from the Secretaria de Comércio Exterior (SECEX/MDIC 2011) and are in U.S. dollars. The nominal exchange rate of the R$ to the U.S. dollar was calculated using data available from ERS/USDA (2011). It is important to mention that the export price was calculated as a proxy for the unit value of the Brazilian exports (total value of exports divided by the quantity). The data were transformed to natural logarithms.

The descriptive statistics for these nine price series are presented in Table 1. The highest meat price is found in the beef market with the export price having the greatest mean (R$5.47/kg). As expected, the mean of export prices for all the analyzed meats was greater than either wholesale or farm price. The largest standard deviation was found in wholesale beef price (R$1.53/kg) and lowest in farm chicken price (R$0.39/kg).

[3] In the Brazilian meat market, there is a common unit called "arroba" to weigh live animals. This unit is equal to 15 kgs.

Table 1. Descriptive statistics on Brazilian meat prices in different levels of the industry, monthly data: January 1996–February 2011.

Variables	Mean	St.Dev.*	Minimum	Maximum
Chicken (R$/kg)				
Farm	1.21	0.39	0.58	2.07
Wholesale	1.74	0.55	0.96	3.09
Export	2.40	0.65	1.27	4.12
Pork (R$/kg)				
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 (R$/kg)				
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

Note. *SD = Standard Deviation.

Empirical Results

In order to determine if the VECM is appropriate for these price data series, nonstationarity of each price series is tested using both Augmented Dickey-Fuller (Dickey and Fuller 1981) and Phillips-Perron (Phillips and Perron 1988) tests. The null hypothesis of both tests is that each evaluated series is nonstationary. The results in Table 2 indicate that both the Phillips–Perron and the Augmented Dickey-Fuller test fail to reject the null hypotheses of nonstationariaty at the 5 percent significance level.

Table 2. Test for nonstationarity of logarithms of Brazilian meat price series, monthly data: January 1996 – February 2011.

Meat Price Series	Augmented Dickey-Fuller	Phillips-Perron
	t-test (k)	z-test
Chicken		
Farm	-1.87 (1)	-1.62
Wholesale	-1.71 (1)	-1.41
Export	-1.98 (1)	-1.87
Pork		
Farm	-1.69 (1)	-1.70
Wholesale	-1.83 (1)	-1.85
Export	-2.30 (1)	-1.73
Beef		
Farm	-0.95 (1)	-0.90
Wholesale	-0.78 (1)	-0.23
Export	-1.77 (2)	-2.05

Note. The 5% critical value for the Augmented Dickey-Fuller and Phillips-Perron tests is -2.89 for both.

Table 3 below 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 summarize fit on 12 different models. Half the models incorporate 11 seasonal variables, with the remaining half having no seasonal variables. Both groups of models use a constant with one through 12 lags (up to 12 lags were analyzed but results are reported for 6 lags in Table 3 to save space). 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 3. 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 1 through 6 (we actually studied lags 1 – 12, but report results on the first six to save space, as all metrics on lags >6 exceed those presented here], 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+11+1)x(logT)/T, Φ =log(|∑|)+(2.00)(9k+11+1)x(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. The model that minimizes the loss metric is selected. The asterisk (''*'') indicates minimum of each column.

The trace tests for both a constant within and outside the cointegrating vector(s) are presented in Table 4. Here one tests sequentially within the table starting at the top going from left to right and from top to bottom (we stop testing with the first "fail to reject" decision, indicated by a double asterisk (**) in the table). The rank of Π is less than or equal to four, with the constant within the cointegration space.

Table 4. Trace statistics on order of cointegration on logarithms of prices for Brazilian meat price series, monthly data: January 1996 –February 2011.

$H_{0:}$ Rank	Trace	C(5%)	Decision	Trace *	C(5%)*	Decision
r = 0	288.21	203.34	Reject	278.79	192.30	Reject
r ≤ 1	225.32	165.73	Reject	216.12	155.75	Reject
r ≤ 2	167.51	132.00	Reject	158.81	123.04	Reject
r ≤ 3	118.63	101.84	Reject	110.09	93.92	Reject
r ≤ 4	74.19	75.74	Fail**	65.81	68.68	Fail
r ≤ 5	48.05	53.42	Fail	40.18	47.21	Fail
r ≤ 6	29.18	34.80	Fail	21.35	29.37	Fail
r ≤ 7	14.93	19.99	Fail	7.74	15.34	Fail
r ≤ 8	4.86	9.13	Fail	0.89	3.84	Fail

Note. Trace and C(5%) refer to the trace statistic and critical values at the 5 percent significance level with a constant in the cointegrating vector, respectively. Trace* and C(5%)* refer to trace statistics and critical values at the 5 percent significance level with a constant outside the cointegrating vector, respectively. The trace test considers the hypothesis that the rank of Π is less than or equal to r. Entries in the column labeled "Decision" refer to the decision to "Reject" or "Fail to Reject" the null hypothesis listed in the far column. The double asterisk (**) indicates the stopping point of testing. Critical values are taken from Hansen and Juselius (1995).

As discussed in the methods section, the model selection method is also applied. This method determines jointly the optimal lag length and cointegration rank. The Hannan and Quinn (1979) Φ statistics (HQ), a widely used information criterion, was selected in this study. Table 5 below presents the HQ value against possible lag order and cointegration rank. HQ loss statistic suggests the model with the minimal information criterion has the lag order of one (k = 1) and four cointegration vectors (r = 4).

Table 5. Hannan and Quinn statistics for different values of cointegration rank (r) and lag length (k)

Cointegration Rank (r)	Number of Lags (k)					
	1	2	3	4	5	6
1	-54.749	-54.405	-53.767	-52.911	-52.080	-51.254
2	-54.810	-54.434	-53.780	-52.906	-52.048	-51.229
3	-54.844	-54.449	-53.799	-52.851	-52.009	-51.214
4	**-54.860**	-54.477	-53.753	-52.811	-51.959	-51.206
5	-54.815	-54.439	-53.700	-52.738	-51.926	-51.183
6	-54.779	-54.397	-53.624	-52.674	-51.859	-51.109
7	-54.749	-54.366	-53.583	-52.631	-51.805	-51.058
8	-54.729	-54.349	-53.562	-52.601	-51.784	-51.022
9	-54.721	-54.339	-53.550	-52.587	-51.772	-51.009

Notes. Hannan and Quinn statistics is calculated according to the following equation: HQ=log(|∑|)+(2.00)(9k+11 +1)x (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. Bold indicates the minimum value of the HQ statistics.

The optimal lag length and the cointegration rank are found to be the same when determined via the two-step procedure (sequentially) or the model selection method (jointly), which is consistent with the results from Wang and Bessler (2005).

The Impacts of the FMD Outbreak on Brazilian Meat Prices[4]

A VECM was estimated using the data from January 1996 to August 2005, 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. Out-of-sample forecasting was done for meat prices for 29 months after the event and six months after the end of the Russian import ban on Brazilian meat (which was December, 2007). The percentage change (ΔP_{ij}) of the actual price relative to the forecasted price of each meat product was calculated for the focus of the study over August 2005 to June 2008.

Figures 2, 3, and 4 illustrate ΔP_{ij} defined over i meat products and j market levels over time for different meats 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. Following is a discussion on the impacts of the FMD outbreak on meat prices for each type of meat.

Beef Prices

In the first four months after the outbreak and three months after the Russian import ban (i.e. by January 2006), export beef prices underwent ambiguous price movements (Figure 2). One month later (February 2006), export beef prices decreased approximately 12 percent. Actual export price recovered three months later (around April 2006) and stayed above its forecast price until December 2006. After December 2006, the actual export price dropped below its forecast price and stayed in that position for 12 months, with the largest decrease in price (nearly 13 percent) in mid-2007, until the lifting 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 approximately 20 percent relative to the forecasted price. By March 2008, perhaps due to potential export market uncertainties, the percentage change in the export price relative to the forecasted export price became negative (a decrease of 5 percent) but recovered one month later.

As for the wholesale beef price, the impact of the FMD outbreak was positive in the short run (up almost 18 percent in the first two months). After dropping below zero in March 2006, the actual wholesale price rebounded five months later and stayed above the forecasted price for most of the study period. Overall, the wholesale beef market appeared to have benefited from the outbreak. Different from the wholesale price, the effects of the FMD outbreak on the farm beef price were negative for most of the period. After two months with almost no variation, the actual farm beef price was below its forecasted value for the next 12 months, decreasing 20 percent by

[4] A reviewer suggested we deflate all data, offering the analysis in real (inflation adjusted) basis. We carried out such using the Índice Nacional de Preços ao Consumidor Amplo (IPCA) adjustment index calculated by the Instituto Brasileiro de Georgrafia e Estatística (IBGE) and retrieved from the Instituto de Pesquisa Econômica Aplicada (IPEA) (IPEA 2015) and found quite similar results. We provide the unadjusted nominal results here, as agents still must react to nominal prices. Readers wishing to see the real-basis results can write the senior author for our real data appendix.

June 2006 and only recovering in October 2006. After a one month recovery, the percentage change in the farm price to the forecasted farm price declined again and remained negative for the next 13 months (until November 2007), one month before the import ban removal by Russia.

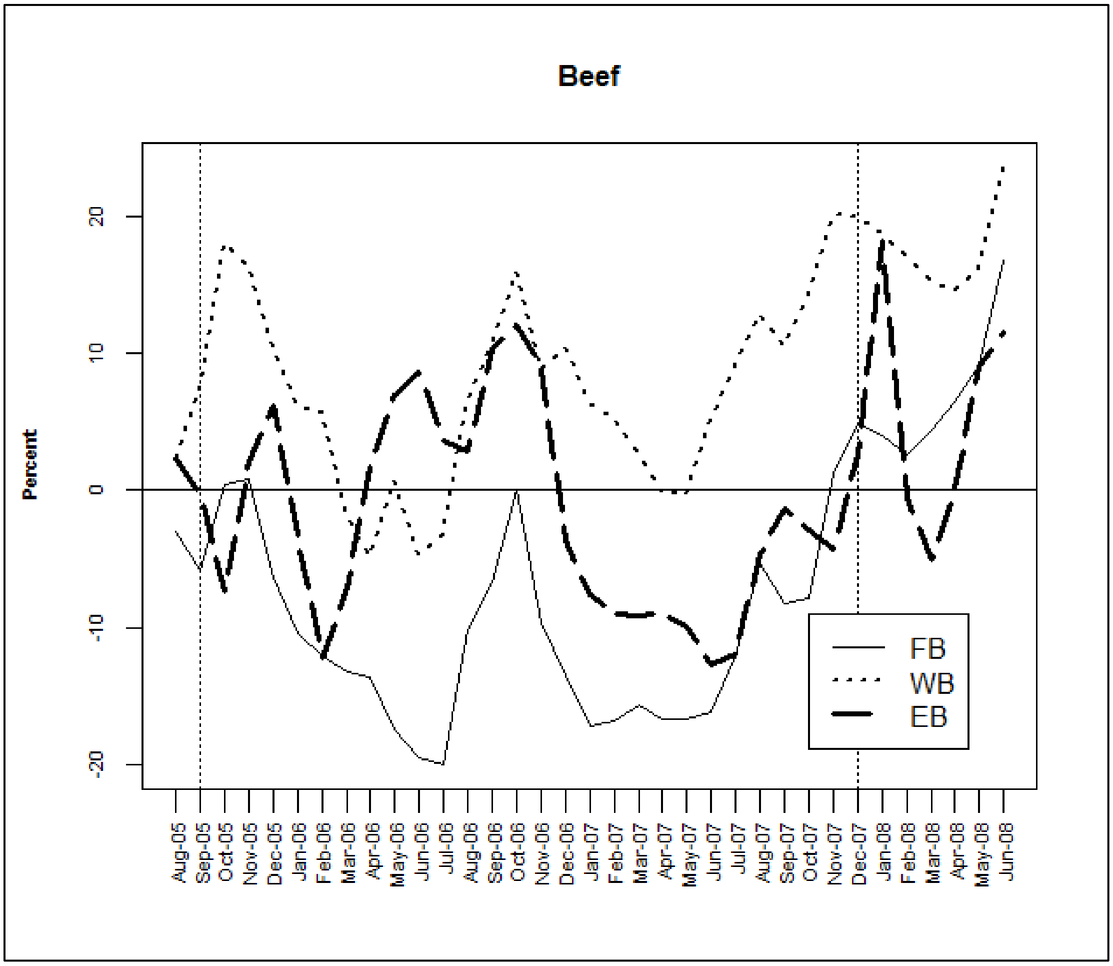

Figure 2. Percentage change in the actual beef prices relative to the forecasted beef price after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007.

Note. Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB). First vertical dotted line is the first FMD outbreak. Second vertical dotted line is the removal of Russian import ban.

Pork Prices

The graph in figure 3 represents the percentage change of the actual price relative to the forecasted price for the pork market. The export pork price reached the lowest percentage decrease six months (March 2006) after the occurrence of the FMD outbreak (down approximately 27 percent), such decrease was the largest in the short run for all the export price series. Three months later, the export pork price recovered, reaching zero percent variation in June 2006. However, one month later, the percentage change of the actual price relative to the forecasted price decreased and remained negative for the rest of the period analyzed. Overall, the percentage change of the actual price relative to the forecast for the export pork price was negative for the entire period, with the exception of one month, and never recovered, even with the lifting of the import ban by Russia in December 2007.

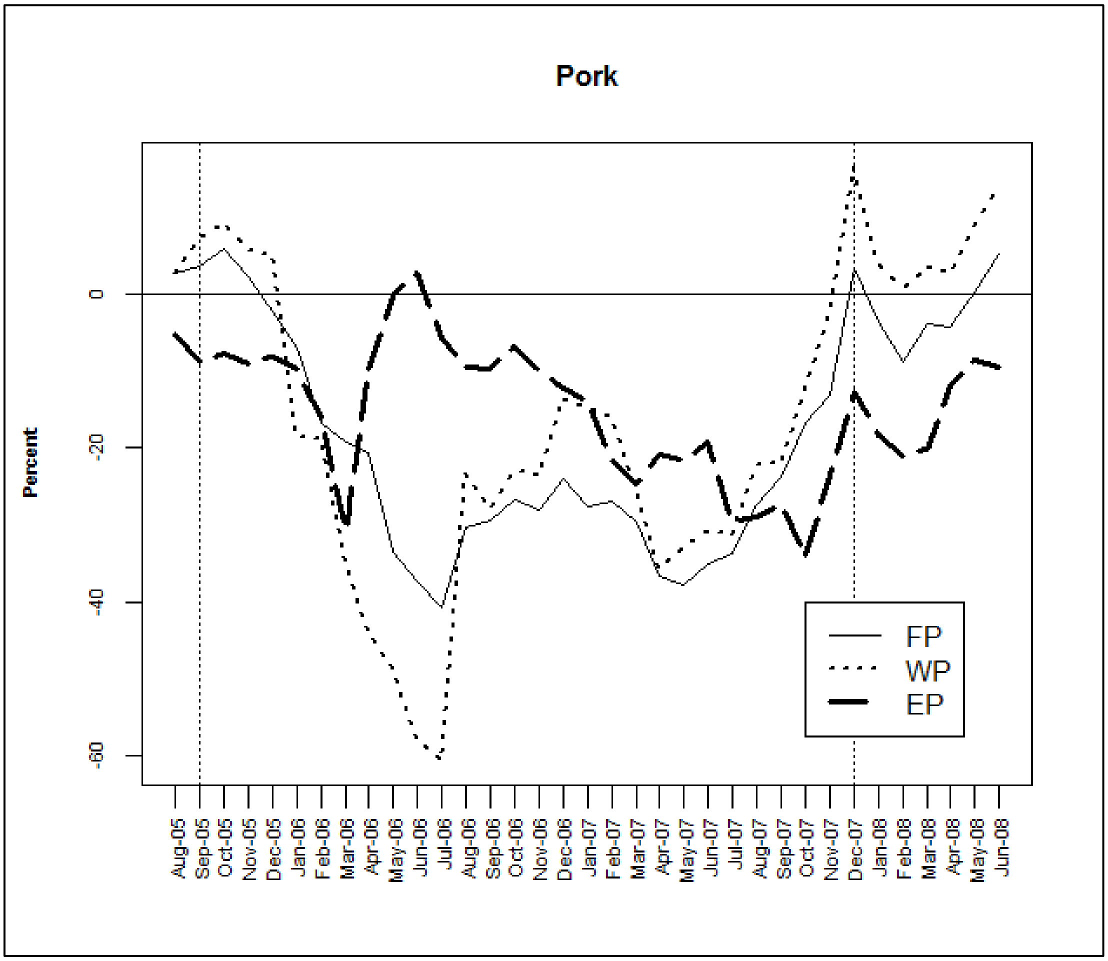

Figure 3. Percentage change in the actual pork prices relative to the forecasted pork prices after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007.

Note. Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP). First vertical dotted line is the first FMD outbreak. Second vertical dotted line is the removal of Russian import ban.

After three months with positive variation, the percentage change of the actual wholesale price relative to its forecasted price underwent a severe decrease following the FMD outbreak. In July 2006, this relationship reached nearly 60 percent, which is the lowest decrease relative to other wholesale prices. The actual price went above the forecasted price only in November 2007, one month before the lift of the import ban by Russia. Regarding the farm pork price, similar to the wholesale price, the lowest percentage change of the actual price relative to its forecasted price occurred in July 2006 (down almost 40 percent). The recovery of the farm pork price only occurred in November 2007. Of all farm price series studied, the price for pork spent the longest period below its forecasted price, totaling 24 months. The only pork prices to recover were the farm and wholesale prices. Export price never recovered during the period of our analysis.

Chicken Prices

Figure 4 presents the percentage change in the actual price to the forecasted price for the chicken market at different market levels. This market is interesting as chicken meat is considered to be a substitute for both beef and pork. In addition, since chicken cannot be infected by FMD, one would expect that the Russian government would not include chicken meat as part of the ban. Still, the Russian government included chicken meat in their import ban of Brazilian meats. As the ban on chicken meat was incorporated, the actual export chicken price declined nearly 35 percent with respect to its forecast (in April 2006). The export chicken price never recovered, not even after the removal of the import ban by the Russian authorities.

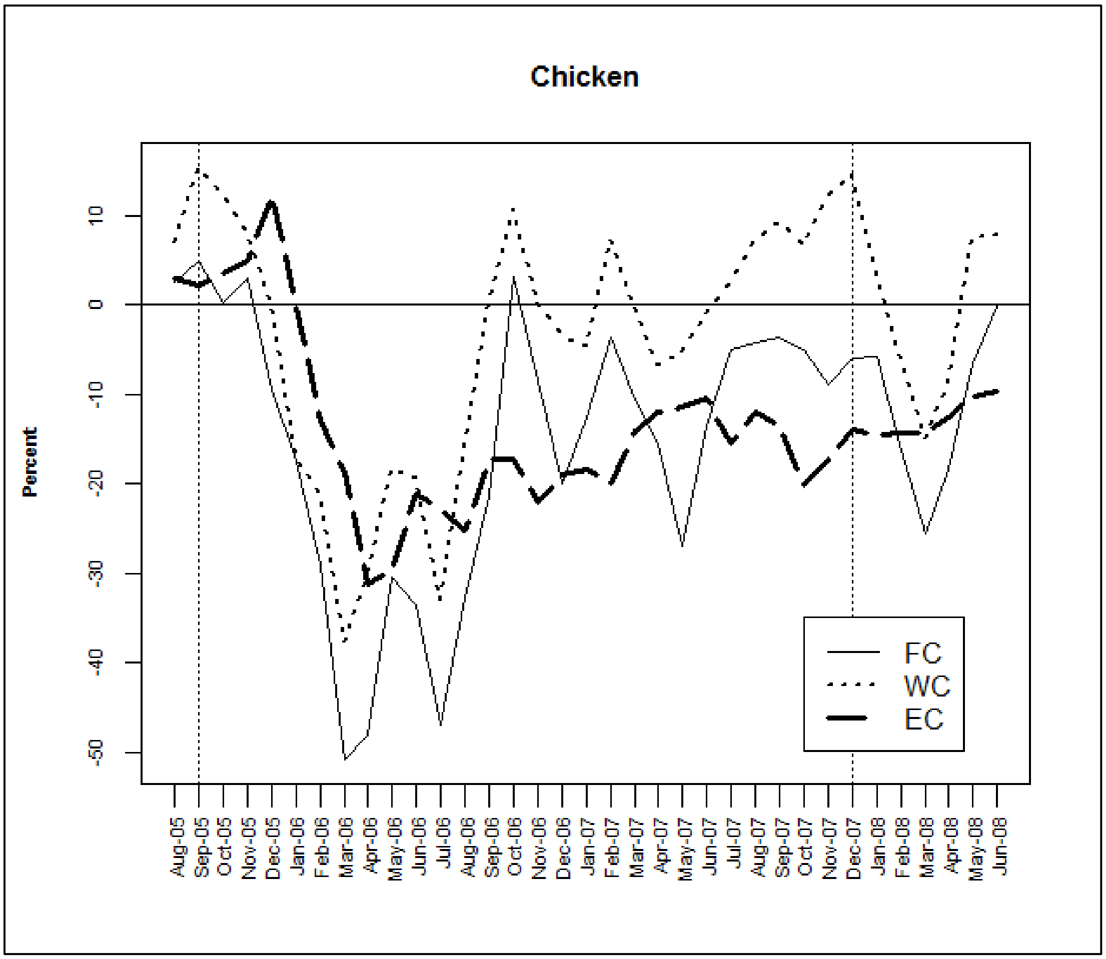

Figure 4. Percentage change in the actual chicken prices relative to the forecasted chicken prices after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007.

Note. Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC). First vertical dotted line is the first FMD outbreak. Second vertical dotted line is the removal of Russian import ban.

From December 2005 to September 2006, the wholesale and farm chicken prices were affected in a similar manner to the export price. The wholesale price increased with respect to its forecast prices in the first three months then it underwent a drastic decline three months later (March

2006). By October 2006, the percentage change of the actual wholesale price relative to its forecasted price rose to nearly 10 percent but one month later this relationship declined and underwent ambiguous price movements for the remainder of the analyzed period. As for the farm chicken price, a decrease in price was observed right after the report of the FMD outbreak. Similarly to the wholesale price, this downward movement in the farm price continued and reached its lowest point in March 2006. The chicken farm price rebounded six months later (in October 2006). For most of the analyzed period, actual farm prices for chicken were below its forecasted prices. This is an interesting finding since the chicken sector was expected to benefit via cross-price effects. Yet, the opposite took place which it can be attributed to the increase in chicken supply due to the Russian import ban.

Conclusions

This study evaluates the market impacts associated with the 2005 FMD outbreak in Brazil. Included in our focus are the consequences of the meat import ban imposed by Russia in response to this FMD outbreak. By using time series methods it was discovered that the 2005 FMD outbreak did cause a price shock to the Brazilian meat market. This discovery is similar to discoveries found in other studies of animal disease outbreaks in Europe and North America (Paarlberg et al. 2008, Teixeira and Maia 2008, Attavanich et al. 2011, Tozer and Marsh 2012).

At the export level, the beef price decreased with respect to its forecasted price in the first two months after the outbreak. After three months of recovery, the beef export price declined and stayed below the forecasted price for four straight months. By April 2006, the beef export price recovered and remained above the forecasted price for seven months. In December 2006, the actual export beef price was below its forecasted price and it only recovered one year later after the removal of the import ban by Russia. On the other hand, the export pork price never fully recovered (with the exception of one month, June 2006) after the import ban was imposed by Russia. The actual export chicken price was above its forecasted price in the first four months that followed the import ban but, similarly to the export pork price, never recovered. These export price declines were expected as it was discussed in the conceptual framework section. An import ban by a large importer would cause an oversupply of the commodity in the domestic market, which would in turn put a downward pressure on the prices. As the import ban was removed by Russia, greater export demand and eventually higher prices in Brazil took place. Comparing our impacts of animal disease outbreaks at export price level results to other studies is not possible. To our knowledge, there are no studies which have investigated the effects of animal disease out breaks coupled with trade bans on export price series.

As for the wholesale prices, the beef series was positive for most of the analyzed period. The actual wholesale beef price was 18 percent greater than the forecasted price in the first month after the outbreak. By March 2006, the actual wholesale beef price declines for a few months and recovers five months later. From August 2006 to the removal of the import ban in December 2007, the wholesale beef price was above its forecasted price for fourteen of the sixteen months. This result does not correspond to our expectations discussed in the conceptual framework section. Although the wholesale beef price underwent price decreases for a few months, the extra supplies dump caused by the import ban was expected to put a downward pressure on prices. Since FMD does not have any impact on human health, the demand for beef at the wholesale level may have put an upward pressure on the prices. As for the wholesale pork price, the results that were expected based on the conceptual framework took place. Similar to the results found in Park et al. (2008), the percentage chance in the actual wholesale pork price to the forecasted price was negative for most the analyzed period. As for the wholesale chicken price, our results were shown to differentiate from Park et al. (2008). Their results showed that the wholesale chicken price benefit from the FMD outbreak in Korea – due to cross-price effects. However, in the Brazilian case, the chicken meat was also part of the import ban by Russia which in turn increased chicken supply thus downward pressure on prices.

As for the farm prices, beef and pork prices experienced negative impacts due to the FMD outbreak and the import ban by Russia. These results correspond to the findings of several studies (Park et al. 2008, Paarlberg et al. 2008, Teixeira and Maia 2008, Tozer and Marsh 2012). As previously discussed, the FMD outbreak coupled with trade bans causes large declines in the prices due to extra supplies being dumped on the domestic market. Similarly to the study by Paarlberg et al. (2008), the recovery of the beef and pork prices begins after the end of the importing restrictions. The farm chicken price surprisingly was below its forecasted price for most of the analyzed period. As occurred in the study done by Paarlberg et al. (2008), a plausible explanation to this occurrence is that the chicken price in an initial instance has a positive correlation with the price of other meats. In other words, in the first few instances after the outbreak, the cross-price effect in the short run does not develop.

Overall, our most important findings can be summarized as follows. First, the negative price shocks caused by the FMD outbreak followed by export restrictions were most prevalent in the pork and chicken meat sectors. This result was found in all levels of the supply chain: export, wholesale, and farm. Second, the farm beef price was shown to have undergone severe negative impacts due to the outbreak. On the other hand, the export beef price underwent ambiguous changes, with prices rising and falling during our study period. An interesting result was found at the wholesale beef level where prices were shown to have benefited from the outbreak and trade restrictions. This last result calls for additional study (perhaps) on market organization and or differences in market power between farm-level suppliers, wholesalers and exporters. Such work is beyond the scope of the current study.

This work contributes to the literature in the following ways: (i) the animal disease outbreaks analyses were performed at the export level for three different types of meat; and (ii) to our knowledge, this study is the first to systematically investigate the impacts of these outbreaks on different levels of the Brazilian meat market. Still, there is additional work to be done. We did not consider the effects of animal disease outbreaks and export restrictions on Brazilian cattle producers' revenues. It is known that animal disease outbreaks cause supply disruptions (i.e. mass slaughter of cattle, hogs, etc.). We do not have precise data of slaughtered animals or data on carcass disposal. With such data an even more complete study could be made. Another interesting future research would be to analyze the impacts of the FMD outbreak on the Brazilian meat supply chain by evaluating the export-wholesale and wholesale-farm price margins.

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