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## **A Foot and Mouth Disease Induced Model of US Excess Supply of Beef**

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## **1. BACKGROUND**

Agriculture is a vulnerable sector of the U.S economy, accounting for 13% of Gross Domestic Product and 15% of employment. It produces quality cheap food for domestic consumption and accounts for more than \$65 billion in export revenues. Contagious animal diseases like Foot and Mouth Disease (FMD) are often referred to as economic diseases because of the magnitude of harm they cause producers, local communities and the consequences in international trade. In recent years, FMD has been at the forefront of public and private sector interest due to its proven crippling effects on agriculture and tourism. Losses from the 2001 FMD outbreak in the United Kingdom are estimated at \$10.7 to \$11.7 billion. The total cost of an FMD outbreak is the sum of eradication cost, production losses, and the loss of exports (Pendell, 2007).

FMD is a highly contagious viral disease affecting primarily cloven-hoofed animals, such as cattle, sheep, swine, and goats have 7 types and over 80 subtypes. Immunity to, or vaccination for, one type of the virus does not protect animals against infection from the other types. FMD-infected animals usually develop blister-like lesions in the mouth, on the tongue and lips, on the teats, or between the hooves, which causes them to salivate excessively or become lame. Other symptoms include fever, reduced feed consumption, and abortions. Cattle and pigs are very sensitive to the virus and show symptoms of the disease after a short incubation period of 3 to 5 days, The incubation period in sheep is considerably longer, about 10 to 14 days, and the clinical signs of the disease are usually mild and may be masked by other conventional conditions, thereby allowing the disease to go unnoticed. FMD is not normally fatal in livestock, though mortality in animals less than one year of age is significantly more probable. It kills approximately five percent of infected animals. Vaccination is being considered as an alternative

preventive and control measure for FMD since it is safe to consume meat from animals that have been vaccinated against the virus without any threat to human. The only recorded human case of FMD in Great Britain occurred in 1966. The infected patient developed a mild temperature, sore throat, blisters on his hands and raised ridges on his tongue, possibly due to drinking FMD-contaminated milk. He suffered no long-term health problems. The mortality rate for non adult animals infected with FMD varies and depends on the species and strain of the virus; in contrast, adult animals usually recover once the disease has run its course. However, because the disease leaves them severely debilitated, meat-producing animals do not normally regain their lost weight for many months, and dairy cows seldom produce milk at their former rate. The disease therefore can cause severe losses in the production of meat and milk.

The FMD virus is easily transmitted and spreads rapidly. Prior to and during the appearance of clinical signs, infected animals release the virus into the environment through respiration, milk, semen, blood, saliva, and feces, The virus may become airborne and spread quickly if pigs become infected because pigs prolifically produce and excrete large amounts of the virus into the air. Animals, people, or materials that are exposed to the virus can also spread FMD by bringing it into contact with susceptible animals.

### **1.1. FMD in the United States**

The first recorded incidence of FMD in the United States was in 1870. The disease was introduced into the country by cattle shipped from England (Meyer, p. 23). Subsequent outbreaks of FMD occurred in 1880, 1884, 1902, 1908, 1914, 1924, (two separate outbreaks) and 1929. The most devastating FMD epidemic ever experienced in this country occurred in 1914. The

epidemic started near Niles, Michigan, and between October 1914 and September 1915, it spread through 22 states and the District of Columbia after it gained entry into the Chicago Stockyards. The epidemic resulted in the subsequent destruction of 77,240 cattle, 85,092 swine, 9,767 sheep and 123 goats.

The 1924 outbreak in California reached epidemic proportions. And, the disease spread to sixteen counties including Los Angeles and San Francisco. More than 109,000 cattle, goats, sheep and swine were depopulated (destroyed) in the course of the eradication program. One added feature of the California epidemic was the involvement of wildlife. During the course of the epidemic, deer in the Stanislaus National Forest became infected after they came in contact with livestock herds driven there for summer pasture. Some 22,000 deer were destroyed before the disease was completely halted.

This paper examines the export effects of a bioterrorist attack such as the introduction of FMD on the US beef industry. The context is to model the US beef market as a price taker on the international beef market, the simplifying “small open economy” assumption of international economics. Although, the beef market is linked to beef prices around the world, we tend to conceive of the US beef market in terms of domestic supply and demand and the resulting domestic equilibrium price. The excess supply of beef is the difference between quantities supplied and demanded that increases with price and responds to other influences on domestic supply and demand.

## 2. MODEL SPECIFICATION AND ESTIMATION PROCEDURES

The model for this study begins with the domestic quantity of beef supplied depending on own price, price of input and input productivity.

$$S_b = S (P_b, P_c, p) \quad - \quad (1)$$

The domestic quantity demanded is a function of own price, the price of substitutes and the effects of demographic variables.

$$D_b = D (P_b, P_s, D_i,) \quad - \quad (2)$$

An outbreak of FMD would lower supply and demand in a closed economy. Thus the quantity decreases while the price effect is ambiguous. If the economy is a price taker in the international beef market, the US beef market is described by the excess supply function. The excess supply model is constructed as the horizontal difference between domestic quantity supplied and quantity demanded.

$$XS = S_b - D_b = XS (P_b, P_c, p, P_s, D_i,) \quad - \quad (3)$$

An increase in  $P_b$  should raise excess supply. Increased productivity  $p$  would also increase  $XS$  while a higher price of substitutes  $P_s$  would lower  $XS$  and demographic variables that reduce domestic demand for beef will increase excess supply. An FMD outbreak in the US beef industry would have tremendous negative effect on exports revenues from beef. Excess demand for beef from the rest of the world may collapse, resulting in the lowering of international price and falling exports.

This paper estimates the excess supply function using time series data gathered from 1977 to 2006. The paper explores various variables that would account for increased supply and

decreased demand. On the supply side, these variables include price of beef, the price of corn, and input productivity. Input productivity will be estimated by the changes in technology over the years. On the demand side, shift variables include own price of beef, prices of pork and chicken and per capita income.

The incidence of FMD is modeled based on historical incidences. The issue in application is the size of the effect of an FMD outbreak on domestic supply and demand, as well as the demand for exports. In 2003, the report of an incidence of Bovine Spongiform Encephalopathy (BSE) in the State of Washington immediately brought the price of cattle down by 16% (Coffey et al., 2005). If the demand of beef falls due to an FMD outbreak, price of substitutes such as pork and poultry will increase. However, since pigs are also susceptible to FMD, consumers will be skeptical about the safety in consuming pork. Thus poultry is likely to get a higher demand than pork.

### 3. ESTIMATION RESULTS

#### 3.1 Estimated Supply Equation

The parameters of the supply model were estimated by ordinary least-squares (OLS). From the regression of natural log (ln) total beef production ( $\ln S_b$ ), log deflated beef price ( $\ln P_b$ ), log deflated of lag total beef production ( $\ln S_{b-1}$ ), log corn price ( $\ln P_c$ ) and technology, the estimated regression equation was obtained as follows:

$$\ln S_b = 5.77 - 0.193 \ln P_b + 0.521 \ln S_{b-1} - 0.009 \ln P_c - 0.023 T \quad (4)$$

Where

- $S_b$  - Total Beef Production (**Million lbs**)
- $P_b$  - Real Price of Beef (**\$/100lbs**)
- $S_{b-1}$  - Lagged Total Beef Production (**Million lbs**)
- $P_c$  - Real Price of Corn (**\$/Bushel**)
- $T$  - Trend (Technological Changes) – (**Years**)

As it can be noticed there is a negative supply response which is an intriguing concept in agricultural markets. The theory states that for animal industries (such as cattle or hogs) where females are valued both as a capital good and a consumption good, an increase in the market price may actually induce producers to reduce the supply of the animal going to market. If the price increase is sufficiently permanent, then producers may optimally retain a larger than average number of females to add to the breeding stock to take advantage of higher prices in the future. The result, at least in the short run, is that we may observe a negative relationship between price and quantity supply (i.e., a downward-sloping supply curve). Many analysts continue to believe that this type of negative supply response continues to exist (e.g., Anderson, Robb, and Mintert (1997)). Trapp (1986) suggests that it is optimal for producers to build up younger, larger breeding herds by culling more old cows and retaining more heifers in response to increasing prices. A negative supply response in U.S female cattle markets is also suggested by Mundlak and Huang (1996) who found a negative relationship between cow slaughter and current and lagged prices in a supply model. Conversely, Mathew's et al. (1999) using data from 1935- 1996, found a negative correlation between changes in cattle inventories and changes in cattle prices. Rucker et al. (1984) in an econometric analysis found that inventories were not



particularly responsive to changes in cattle prices. Thus whether a short-run negative supply response is either theoretically or empirically plausible is still an open question.

### 3.2 Estimated Demand Equation

Following the same steps as in the supply model the exogenous variables are the real price of Beef, the real price of pork, real price of poultry and the real per capita income. The endogenous variable is the beef domestic consumption. Taking the natural log of all the exogenous and endogenous variable and using the ordinary least squares approach (OLS) we obtained estimates of the parameter as follows:

$$\ln D_b = 6.01 - 0.033 \ln P_b + 0.059 \ln P_{pk} + 0.146 \ln P_p + 0.31 \ln PCI \quad (5)$$

Where

$D_b$  - Domestic Consumption of Beef (**Million lbs**)

$P_b$  - Real Price of Beef (**\$/100lbs**)

$P_{pk}$  - Real Price of Pork (**\$/100lbs**)

$P_p$  - Real Price of Poultry (**Cents/lbs**)

$PCI$  - Real Per Capita Income (**\$**)

The signs of the coefficients in the demand equations were all consistent with expectations. Beef demand is inelastic with an own price elasticity of -0.033. This means that, on the average, beef quantity demanded declines by 0.3% given a ten percent increase in beef prices. The elasticities are positive for pork and poultry, indicating they are substitutes.

With the estimated equations, a closed economy market endogenously determines the equilibrium quantity and price. An outbreak of FMD would lower supply and demand and in a closed economy the quantity decreases while the price effect is ambiguous.

### 3.3. Estimated Excess Supply

The estimated excess supply equation ( $X_s$ ) is obtained by taking the horizontal difference between domestic quantity supplied and quantity demanded.

Excess Supply ( $X_s = S_b - D_b$ )

$$X_s = -0.24 - 0.16\ln P_b - 0.059\ln P_{pk} - 0.146\ln P_p - 0.009\ln P_c - 0.31\ln PCI + 0.521\ln S_{b-1} - 0.023T \quad (6)$$

All variables are same as defined above.

The elasticity of excess supply is estimated as -0.16 in the above equation. This is negative and is smaller in magnitude than found in literature. This may be due to the negative elasticity of supply calculated in the supply equation. Theoretically, an increase in  $P_b$  should raise excess supply. Increase productivity would also increase  $X_s$  while a higher price of substitutes would lower  $X_s$ . An FMD outbreak would have ambiguous effects on exports assuming the U.S can export all it wants at the international price. Excess demand for beef from the rest of the world may collapse, however, resulting in a lower international price and falling exports. However, the impact on exports is more likely to be better explained by deriving export elasticities due to the ambiguity in the price elasticity of excess supply.

### 3.4. Estimating Export Elasticity

The export elasticity of beef is derived by the following procedure:

$$X = S - D \quad (7)$$

$$dX/dP = dS/dP - dD/dP \quad (8)$$

$$P/X * dX/dP = dS/dP * P/X - dD/dP * P/X$$

$$\epsilon_X = S/X * \epsilon^S - D/X * \epsilon^D \quad (9)$$

where  $\epsilon_X$  = Export Elasticity

S = Quantity Supply

X = Quantity Exported or Excess Supply

$\epsilon^S$  = Elasticity of Supply

D = Quantity Demanded

$\epsilon^D$  = Elasticity of Demand

plugging in the values of the above parameters and using 2007 supply and demand quantities of beef, the overall export elasticity is estimated as -0.65. This implies that 1% drop in the price of beef due to FMD will result in a 0.65% drop in quantity of beef exported. This value can be used as a basis to see what happens to the export when FMD occurred and prices change by 10%, 15% and 30%.

## 4. SIMULATION RESULTS

Three scenarios regarding decrease in domestic prices developed on the basis of the U.K. Taiwan and Korea experiences when FMD cases occurred in their countries. According to the International Agricultural Trade Report released by the USDA titled Updates Assessment of

European Union Meat Situation. The increase detection of BSE and FMD outbreak have led EU consumer to alter their diets away from beef. Beef consumption for 2001 was estimated to be down 12% from the previous year, while exports were forecast to drop a further 41% in reaction to animal disease outbreak in the EU (Blake, 2001). Beef price across the EU for the first six (6) months of 2001 compared to the previous year have also change dramatically. In Germany beef prices declined about 30%.

In this study the Scenarios include 10%, 15%, and 30% decreases in domestic beef prices. Scenario one is a small single point outbreak, with rapid detection and ability to arrest the disease quickly and restore normal cattle and meat movement in a relatively short time frame. Economic damage would be modest as producers price decline would not be significant and the cost of eradication smaller. The second scenario is a medium sized outbreak which impact on some states and takes a couple of month to contain and eradicate. The third scenario is a large multi-point outbreak which takes up to twelve (12) months to control and eradicate. Under this scenario market become fully closed, price reductions would range from 20% to 30% as a result of expected longer period of trade ban.

#### **4.1. Effects on the Excess supply of Beef**

We assumed that U.S consumers will exercise more caution when purchasing beef at grocery store as a result of the outbreak of FMD. We used the (2007) excess supply quantity and its value in dollars as the base. Ranges of negative shocks to domestic beef prices for U.S were set up based on consumer's responses at the different levels of FMD occurrence. As U.S consumers alter their diet, poultry and pork will become good substitutes with poultry having a higher demand than pork. From literature we assumed that a 10% decrease in the price of beef

due to decrease domestic demand based on the occurrence of FMD will result in a 5% increase in the price of pork and 7.5% increase in poultry. We also assume that the decrease in the price of beef is offset by the increase in the price of pork and poultry. Also we expect that the increase in the price of poultry to be higher than that of pork since pork is also a cloven hoof animal susceptible to the disease.

The results shows that in the occurrence of a small single point Outbreak (see table 1), excess supply of beef will increase by 7% from 6,787millions lbs to 7, 282 millions lbs. This represents a change in value of \$454.83 million. The results show that two factors come into force to determine the change in the excess supply. Table 2 shows the second scenario when beef price decrease by 15% and the price of pork and poultry increases by 5% and 7.5% respectively, the excess supply would change by 21%, 1459 million lbs of beef valued at \$1,339.78 million will be in excess supply. In scenario three, which is the extreme case it is assumed that demand for poultry will continue to increase at a higher rate than demand for pork. The simulation is based on a 30% decrease in the price of beef followed by 10% and 15% increase in pork and poultry prices respectively. The excess supply would change by 43% from 6,787.00 Millions lbs to 9,705 Millions lbs

## **5. CONCLUSION**

Most previous research on FMD has drawn the same general conclusion; a FMD outbreak has severe economic implications. This paper however, focuses on the price impacts resulting from three different disease introduction scenarios. The scenarios included a small single point introduction, a medium-size and a large multipoint outbreak of FMD. The different scenarios were used to demonstrate how the incidence of such a disease would differently affect

beef price and its corresponding impact on exports. The calculated export elasticity shows that export of beef will decrease by 6.5% in a single point occurrence of FMD. This is consistent with the results from the simulation conducted using the estimated excess supply equation. Review of literature shows that if the disease were to occur there will be a rapid decline in beef prices. In contrast to beef prices, chicken and pork as substitutes would benefit from the outbreak and its prices will increase. However, the longer it takes to contain the disease the more the quantity of the excess supply which is a result of both import ban and fall in domestic consumption. Excess supply change by 7% on a small single point outbreak, this percentage reach 21% on the medium outbreak while on the large multipoint outbreak 43% change is observed. This change in the value of excess supply ranges from an amount of \$454.83 million to \$2,679.55 million and represents the loss that could be suffered only in the beef industry in the occurrence of an FMD in the United States. The concern over the safety of beef consumption among consumers might be one of the main factors that caused a substantial decrease in domestic prices. Understanding consumers' reaction to FMD helps the beef industry restore consumer confidence and provides policy makers a basis for countermeasures and compensations.

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**Table1. Effect of a Small Single Point Outbreak of (FMD) on the Excess Supply of Beef**

	Change in Price	X <sub>s</sub> - Base Year (2007)		Simulation Results				
				Change in X <sub>s</sub>			Estimated X <sub>s</sub>	
				(Million Ibs)	(\$' Million)	(%)	(Million Ibs)	(\$' Million)
Beef	- 10%	6,787	6,231.82	7%	7,282	6,686.7	495.4	454.83
Pork	+ 5%							
Poultry	+ 7.5%							

**Table2. Effect of a Medium Sized Outbreak of (FMD) on the Excess Supply of Beef**

	Change in Price	X <sub>s</sub> - Base Year (2007)		Simulation Results				
				Change in X <sub>s</sub>			Estimated X <sub>s</sub>	
				(Million Ibs)	(\$' Million)	(%)	(Million Ibs)	(\$' Million)
Beef	- 15%	6,787	6,231.82	7%	8,246	7,571.6	1,459	1,339.78
Pork	+ 5%							
Poultry	+ 7.5%							

**Table3. Effect of a Large Multi-point Outbreak of (FMD) on the Excess Supply of Beef**

	Change in Price	X <sub>s</sub> - Base Year (2007)		Simulation Results				
				Change in X <sub>s</sub>			Estimated X <sub>s</sub>	
				(Million Ibs)	(\$' Million)	(%)	(Million Ibs)	(\$' Million)
Beef	- 30%	6,787	6,231.82	43%	9,705	8,911.38	2,918.27	2,679.55
Pork	+ 10%							
Poultry	+ 15%							