

A General Equilibrium Analysis of Foreign and Domestic Demand Shocks Arising from Mad Cow Disease in the United States

By Dave Holland and Stephen Devadoss*

Introduction

The U.S. government announced on December 23, 2003 that a Holstein dairy cow on a farm in Mabton, Washington State, was infected with mad cow disease (Bovine Spongiform Encephalopathy or BSE). Humans can contract a fatal form of this disease, known as variant Creutzfeldt-Jakob disease (vCJD), by eating contaminated beef products such as spinal cord and nerve tissues of infected animals.

The discovery of this first case of mad cow disease outbreak in the United States reverberated across the beef and cattle industry, causing serious concerns among ranchers, processors, and consumers. Ranchers were worried about the economic ruin mad cow disease could bring, processors were apprehensive of the falling beef prices, and consumers were concerned about health and safety issues arising from beef consumption. As a food safety precaution, federal authorities recalled about 10,000 pounds of meat from the infected cow and other cows slaughtered on the same day in a Washington State plant (Spokesman-Review, Dec 25, 2003.)

The mad cow disease epidemic in England in the 1980s and 1990s totally crippled the beef industry in that country. When the BSE crisis in England peaked in 1992, more than 7,200 cows were infected in that year alone. From 1995 to 2003, 143 people died from vCJD (NCID). This disease also occurred in other European countries and had adverse effects on cattle and beef industries (Herrmann, Thompson, and Krischik-Bautz). The discovery of a single cow infected with this disease in Alberta, Canada, in May of 2003 caused a heavy loss to the Canadian beef industry as agencies tested and destroyed hundreds of cows. Even though it was an isolated incident, the ensuing public fear resulted in a marked decline in Canadian beef consumption and exports to other countries, which caused beef prices to plummet. Live cattle prices fell from a peak of \$1.10 to \$0.35 per pound.

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The U.S. government took extraordinary measures to protect the health of the public while safeguarding the economic interests of the beef and cattle industry. Because of consumers' concern about the beef safety and the adverse economic impact on the U.S. cattle industry, then Agricultural Secretary Ann Veneman and the National Cattlemen Association repeatedly assured the American public that this case of mad cow disease was a single and isolated incident and not widespread, and it was safe to consume beef. The public was also informed that the infected parts (nerve tissue, spinal cord, and small intestine) of the cow were removed from the food chain (also see Coffey et al.).

This outbreak was expected to drastically affect domestic beef consumption and U.S. beef exports, particularly if the disease were to become widespread. About 26 million cattle are slaughtered annually in the United States, and 90% of the beef is consumed domestically. The United States exports 10% of its beef production. These exports are worth about \$3.0 billion. About 53 countries, including four leading importers (Japan, South Korea, Mexico, and Canada), banned imports of U.S. beef. Other notable countries include Australia, Brazil, China, Colombia, Egypt, Indonesia, Jordan, Lebanon, Malaysia, Russia, Singapore, South Africa, Taiwan, and Thailand (Coffey et al.). U.S. beef exports fell from 2.5 billion lbs in 2003 to 500 million lbs in 2004 (USDA).

Following the discovery of the first case of mad cow disease in the United States, cattle and beef prices declined sharply. The cattle futures price dropped by about 19% and beef cash prices fell by 15 cents a pound in a matter of days (Henderson). Live cattle prices declined sharply from 91 cents per pound on December 22, 2003 to 78 cents on December 26. The beef industry estimated that because of export and domestic demand declines, the ensuing price decline would result in about \$6 billion in losses to the cattle, beef, and allied industries (Spokesman-Review, Jan 2). Henderson projected that the economic cost to the cattle industry would be about \$2 billion and the cost to the beef industry could reach up to \$2 billion.

Since the discovery of the first case, a U.S. born cow with BSE was identified in June 2005, and BSE occurrence remains a serious concern to the cattle and beef industry as a dozen importers, including Japan and Taiwan, have not opened their borders to U.S. beef. Clemens observes that domestic and foreign reactions to BSE cases in North America have permanently changed overseas markets for U.S. beef. In particular, increased surveillance for BSE enhances the discovery of additional indigenous cases. If there is a widespread occurrence, there would be

a large decline in domestic and foreign demand (Coffey et al.).¹ It is worth studying the impacts of such demand declines on the U.S. beef and cattle industry.

The purpose of this study is to analyze, using a general equilibrium model, the economic effects of possible demand declines from mad cow disease outbreaks on the beef and cattle industry under alternative assumptions regarding the severity of outbreaks. In particular, we utilize a computable general equilibrium (CGE) model to conduct scenario analyses of foreign and domestic shocks induced by mad cow disease from an *ex ante* perspective. That is, while the observed magnitude of demand shocks are used as guidelines in developing the exogenous changes, the analyses are not intended to replicate the actual events. The organization of this article is as follows: the next section presents the structure of the general equilibrium model. The third section describes the data used for the analyses. The fourth section discusses the procedures and assumptions employed in the analysis. The fifth section presents the results. The final section provides the summary and conclusions.

The General Equilibrium Model

The mad cow scare not only hurt the beef and cattle industries but also other related industries in the upstream, downstream, and horizontal sectors (McDonald and Roberts). The industries affected on the supply side of the market are ranches, feedlots, slaughter houses, processing plants, feed stores, trucking, and shipping. The industries affected on the demand side are wholesale and retail stores, restaurants, other meat products (poultry, pork, and fish), food items (french fries), trucking, and shipping. Because of these economic interdependences, any shock in the beef and cattle industries will percolate to allied industries. The magnitude of economic loss if households were to lose confidence in the safety of beef would not only have implications for the beef and cattle industries, but would have important implications for other parts of the economy as well. For example, widespread occurrences of BSE can lead to underutilization of slaughtering and processing plants, adverse impact on cattle feed markets

¹ Fox and Blake surveyed consumers to ascertain the potential reduction in beef consumption in response to different intensity of BSE occurrences. They found that in a single case of mad cow disease occurrence, 32% of the consumers indicated that they would consume less beef and 12% would stop beef consumption; if 20 cases of BSE were discovered, 43% of the surveyed said that their beef consumption would decline and 26% would not consume any beef. Additionally, Fox and Blake found that if both questions (one case and 20 cases of BSE discovery) were posed together, 39% would reduce the beef consumption and 46% would not consume any beef. In summary, multiple BSE cases will have significant negative impact on demand (also see Coffey et al.).

(hay and feed grains), job losses, and lower wages to labor and rental rates to capital. A reduction in consumer demand for beef could increase the demand for substitute meats such as pork, chicken, and fish. Similarly, loss of consumer confidence is likely to reduce the demand for beef products marketed in the fast food industry and can lead to significant job and income loss in this industry. Estimates of these impacts will be useful to policy makers in assessing economic damages and implementing policies to prevent future occurrences of BSE. Only a general equilibrium analysis will provide the impacts of the BSE outbreak on all the related industries.

When an unexpected event or catastrophe occurs, there is often a panic among the public, leading to an over reaction. Also, there is a tendency among the public to believe that such an event is going to have widespread consequences across many sectors of the economy. Such was the case in the discovery of mad cow disease in the United States. The initial reaction was that the public lost confidence not only in beef safety but also in other meat and restaurant food safety. Such a loss of confidence can take a toll on the economy. The effects of mad cow disease on other sectors of the economy can be studied only through general equilibrium analysis, which incorporates interlinks among various sectors and captures all direct and indirect effects. Hence, we develop a computable general equilibrium (CGE) model of the U.S. economy to examine the impact of mad cow disease on meat sectors and the rest of the economy. McDonald and Roberts employed a CGE model to study the economy-wide impacts of BSE in the United Kingdom.

The structure of the U.S. CGE model is similar to the standard CGE model built by Lofgren and Gilbert (2002, 2003). An elaborate documentation (of about 60 pages) including the mathematical equations, variable definitions, parameter specifications, and detailed explanations is available from the authors upon request (Authors). The CGE model mathematically represents the inner working of the economy with Walrasian market clearing in all sectors. Representative agents (producers, consumers, institutions, etc.) in the various sectors apply microeconomic behavior, i.e., maximize their objective functions subject to certain constraints. For instance, households maximize utility subject to budget constraints and producers maximize profits given the resource endowments. All markets are interconnected and consistent. For example, commodity demand functions adhere to the first order conditions derived from the utility maximization of the specified utility function, and similarly, factor demand functions come from

the first order conditions of the profit maximization and the specified production function.

Various equations included in the model are discussed next. The model contains four blocks: production and commodity, price, institutional, and system constraints. The production and commodity block specifies Leontief-Constant Elasticity of Substitution (CES) production function, factor demand, intermediate input demand, output conversion, the rest of the world demand for U.S. goods, U.S. import demand, Armington composite supply, import-domestic demand ratio, Armington composite transformation, and export-domestic use ratio.

The Leontief-cum-CES production function employed in the model uses intermediate inputs, capital, and labor. Intermediate inputs enter the production function as Leontief fixed coefficients. Capital and labor comprise the CES part of the production function. The elasticity of substitution between capital and labor is assumed to be 0.99. Thus, the CES part of the production function closely mimics the Cobb Douglas production function. The first order conditions of the Leontief-cum-CES production function yield specifications for factor demand. The intermediate input demand is specified as a fixed proportion of output, a result of the Leontief part of the production function. Capital is sector specific and labor is mobile across the sectors. Total factor supply for the U.S. economy is considered as constant. Rest of the world import demand for U.S. goods is a function of world price.

International trade allows for imperfect substitution between domestic goods and foreign goods, and the general equilibrium models easily incorporate such product differentiation. An Armington/CES function is used to capture the imperfect substitution between domestic goods and imported goods. For example, domestic beef and imported beef generally differ in quality, i.e., they are not necessarily perfect substitutes, but both are combined, albeit with imperfect substitution, to form a final product mixture. Thus, the Armington aggregate comprises the mixture of domestic and imported goods to form the composite commodities. The elasticity of substitution between domestic and imported goods is assumed to be 2.0 for manufacturing sectors, 1.5 for cattle, and 0.5 for wholesale beef.² The first order conditions from the Armington composite generate specifications for domestic demand and import demand functions.

² These elasticity values are selected based on past studies, which are discussed in the sensitivity analysis subsection.

Beef produced for the domestic market can be of different quality than beef produced for the export market. An aggregate composite consisting of domestic use and exports is utilized to differentiate the goods for domestic and foreign markets. A CET (constant elasticity of transformation) function is employed to model this transformation between domestic demand and exports. The elasticity of transformation used in the model is 2.0. The first order conditions from the CET transformation generate the specification for domestic supply and export supply functions.

The price block includes specifications for import price, export price, aggregate or composite demand price, aggregate supply or composite supply price, and activity price. The U.S. prices for import goods are function of world price times exchange rates and any import tariffs. The U.S. prices for export goods are function of world price times exchange rates and tariffs in the foreign countries. The aggregate demand price for the composite beef, generally known as Armington composite demand price or composite household price, is obtained as a weighted average of import price and domestic demand price. The aggregate supply price, known as composite supply price or composite firm price, is obtained as a weighted average of domestic demand price and export price. The activity price is derived from the commodity price using the same weights employed in the activity-commodity conversion equations. Thus, we have import price, export price, domestic demand price, composite supply price, and composite demand price.

The institutional block comprises equations for factor income, gross household income, net household income, household consumption demand, investment demand, government revenue, government expenditure, and indirect taxes. Factor income is given as factor use times factor prices. Gross household income is the sum of factor income, borrowing, and transfers from government, households and the rest of the world. Net household income is gross income minus household transfers, savings, income tax, and transfer to the rest of the world. A Stone Geary utility function, which generates a linear expenditure demand system for households, is employed to model consumer behavior. Unitary income elasticity is assumed in the demand function. Investment demand is equal to investment adjustment factor times the initial level of investment. Government revenue is the sum of income taxes from households, investment income, and indirect tax receipts. Government expenditures include transfer to households,

payments to foreigners, government spending, and subsidies. Indirect tax receipts are collected from production activities.

The system constraint block encompasses the specifications for factor market equilibrium, commodity market equilibrium, balance of payments, savings-investment balance, and price normalization. The factor market equilibrium entails that the sum of factor used in each sector equals the total endowment. In the commodity market equilibrium, the quantity supplied of a commodity equals the quantity demanded for intermediate input use, household consumption, government consumption, savings, and investment. The balance of payment equation states that the sum of export earnings, household transfers from foreigners, government transfers from foreigners, and capital inflow is equal to import spending, factor income transfer to foreigners, and institutional transfer to foreigners. The balance of payments closure keeps foreign savings fixed and allows exchange rates to vary. Savings include household, government, and foreign savings. Investment includes commodity, institutional, and foreign sectors' investments. In the saving-investment closure, marginal propensity to consume is fixed and investment is endogenous, i.e., investment is savings driven. In the price normalization equation, consumer price index is equal to commodity prices weighted by the composition of commodity baskets.

The CGE model ensures that commodity and factor markets balance and that macroeconomic identities hold. Equilibrium prices (commodity prices, factor prices, and the exchange rate) are endogenously determined to clear the product, factor, and foreign exchange markets. Because of the inter-linkages of the sectors, shocks in any sector will seep through the economy and impact the other sectors.

Data

A Social Accounting Matrix (SAM) for the United States was constructed for empirical analysis. The data in the SAM captures a detailed, consistent, and a snapshot representation of various economic activities' interactions. Thus, the SAM includes the complete circular flow of all the transactions in the production, factor, household, government, and ROW sectors. Hence, the SAM is a data counterpart to the CGE model, capturing the numerical form of the budget, resource, physical, and financial constraints of the economy. Each element in the SAM, denoted

as s_{ij} , represents receipts for account i and expenditures for column j . The data in the SAM is used to calibrate the parameters of the behavioral equations in the model. Since the quantity of U.S. beef exports declined by 90% after the discovery of the mad cow disease, we exogenously reduced foreign beef demand by 90%.

The data source of the SAM for our economic model was IMPLAN 2000, which divides the U.S. economy into 528 sectors. Since the model is used for analysis of the impacts of the BSE outbreak, more emphasis was placed on agricultural sectors. Consequently, the data for IMPLAN sectors representing food and agriculture industries and commodities were kept at the most disaggregated level possible, and the data for those industries and commodities in other categories were aggregated. Thus, the 528 sectors of the U.S. economy were aggregated into 231 distinct sectors: 111 commodity sectors, 100 industrial sectors, two primary factors of production (labor and capital), one indirect business tax sector, nine household sectors, six government sectors, one savings and investment sector, and one trading sector (rest of the world). By Walras' law all prices and exchange rates were normalized to one.

The GAMS software with the PATH solver was used to construct and solve the system of simultaneous non-linear equations in the CGE model. The model was initially solved to replicate the base year SAM by appropriately calibrating the parameters of the model.

Analysis

In this section, we describe the procedures and assumptions used for the analysis. The United States exports about 10% of its beef. Published reports indicated that the import ban by more than 50 countries around the world led to about a 90% decline in U.S. beef exports. Consistent with these reports, we assumed that for all scenarios the rest of the world beef and live-cattle demand decreased by 90%.

Since about 90% of U.S. beef is domestically consumed, loss of consumer confidence can result in steep price declines. For example, news media reported that cattle and beef prices fell significantly in the days following the aftermath of the first case of a mad cow disease finding. Since the effect of a single case of mad cow disease on domestic demand is not known, we considered three different cases of domestic demand declines (0%, 10 %, and 25%) to reflect various states of consumer confidence. Each of these cases is analyzed along with a 90% decline

in U.S. beef exports. Thus, the three scenarios are:

Scenario 1: 90% decline in foreign demand and 0 % decline in U.S. domestic demand.

Scenario 2: 90% decline in foreign demand and 10 % decline in U.S. domestic demand.

Scenario 3: 90% decline in foreign demand and 25 % decline in U.S. domestic demand.

Scenario 1 is the most optimistic scenario since the domestic demand does not decline. In contrast, scenario 3 is the most pessimistic scenario because domestic demand declines by 25%. Scenario 2 is the most realistic scenario in that domestic demand declines are modest and generate results that are reasonable and in line with economic changes in the cattle and beef markets. Scenario 3, though pessimistic, produces results consistent with price declines in the first few weeks of the mad cow disease outbreak. Scenario 1 isolates the effect of the import ban by foreign countries on U.S. beef and cattle markets. The last two scenarios examine the total effect of foreign demand and various levels of domestic demand declines on the U.S. beef and cattle markets.

Results

This analysis focused on determining the direct and indirect effects on various sectors resulting from changes in foreign and domestic demand for livestock commodities. Table 1 presents the results of this analysis for the three scenarios. In the interest of brevity, we report the results of quantity and price changes for important variables in cattle and wholesale beef markets. Results of other sectors are available from the authors upon request. Changes in foreign demand directly affect both cattle and wholesale beef sectors, while changes in domestic demand directly affect only the wholesale beef market since U.S. consumers do not directly purchase beef from the cattle market.

While some of the variables in Table 1 are self explanatory, some need additional explanations. Domestic demand is that part of total production kept within the United States. Domestic demand and exports are combined to form the composite of total U.S. production. Imports and domestic demand are combined to form the Armington composite, which are utilized by various institutions (firms, households, government) within the U.S. economy. For prices, we have reported domestic export price, demand price, import price, aggregate supply price, and a composite price of domestic demand and import prices.

First, we describe how the effects of mad cow disease percolate through the economy.

The catalysts for the analysis the reductions in foreign demand and domestic demand resulting from the consumer fear of the mad cow disease. As a result of the demand declines, domestic demand price and export price fall. Also, in response to a leftward shift in domestic and foreign demand, domestic supply price declines and imports fall. Because more than 50 countries banned imports of U.S. cattle and beef, the world demand for non-U.S. cattle and beef rose, which caused the world cattle and beef prices, and thus, import price to the United States, to rise. Since the domestic demand price decrease is larger than the import price increase, the composite demand price also falls. The analysis employed in this CGE model is a short-run investigation.

Several important observations can be made from the results in Table 1. First, since we exogenously reduced the foreign demand by 90%, the equilibrium quantity of cattle and meat exports falls by nearly 90% in all three scenarios. Second, as we would expect, quantity and price impacts are larger for the scenario with 25% reduction in domestic demand. Third, because of the drop in foreign and domestic demand, all equilibrium quantities and prices decline in all three scenarios, except for wholesale beef consumption in the 0% domestic demand shift scenario. In this scenario, reduction in foreign demand is not large enough to offset the lower price effect.

Consider scenario 1 (90% reduction in foreign demand and 0% reduction in domestic demand). As the U.S. exports fall, export prices decline by about 40%, but domestic demand and domestic supply prices drop only by 7% - 9% for live cattle, and the price decrease is even smaller in the beef market.³ Domestic demand and supply prices decrease only by about 4% and 6%, respectively, in the beef market. This is because the United States exports only 10% of its beef, and consequently a large decline in foreign demand does not lead to a steep decline in domestic prices. As beef exports fall, more beef products are available for the domestic market, causing a decline in domestic prices, which results in a small increase in domestic consumption of beef as this scenario assumes domestic consumers do not change their consumption behavior in response to a BSE outbreak. This result corroborates the rise in U.S. beef consumption by 1.8% from 2003 to 2004 as reported in Coffey et al. As the foreign demand for U.S. beef declines, the domestic demand for cattle and slaughtering drops. In response to a fall in domestic prices, cattle and meat supply decreases by about 7.0%. Because of the mad cow disease

³ Coffey et al. found, using a partial equilibrium analysis, that equilibrium beef price declined by about 8.0%-10.0% due to an import ban by the foreign countries.

setback, cattlemen are reluctant to import cattle and slaughter houses also reduce cattle imports. Because of the domestic beef demand increase in this scenario, beef imports also increase. Since the composite demand is a mixture of domestic and imported goods, the composite demand for live cattle also decreases, but the composite beef demand increases.

Scenario 2 examines the effects of a modest reduction in domestic demand (10%) along with a 90% decline in foreign demand. This scenario generates results that are slightly larger than those of scenario 1. However, unlike in scenario 1, the equilibrium quantity of domestic demand for beef declines because of the downward demand shift in this scenario. Domestic demand for cattle falls by about 11% and beef demand by only about 1%. In response to foreign and domestic demand reductions, supply price also declines, which ranges from 11% to 13% in cattle markets and 9% in the beef market. This causes cattle and beef supply to fall. Because of the large shift in domestic demand, imports also fall. The composite cattle and beef demand decreases by about 12% and 1.3%, respectively. Composite demand prices fall in the cattle markets (7%-8%) and in the beef market (4%). The results of this scenario are probably a more realistic depiction of the mad cow disease outbreak in that the price and quantity changes are consistent with economic reasoning.

Scenario 3 is the worst case or the most pessimistic scenario with a 25% domestic demand reduction in addition to a 90% foreign demand decline. In this scenario, domestic demand and supply prices of cattle decline by 17% - 19% and beef prices go down by 12% - 14%. These price drops are in line with the temporary price fall (as noted in the introduction) observed in the days following the aftermath of the mad cow disease discovery and also corroborate the findings of Henderson. However, this price fall was not sustained as the beef and cattle industry recovered after a few weeks. In this scenario, domestic demand for cattle falls by about 19%. In response to the downward shift in domestic demand, cattle and beef imports also decrease. Composite demand declines in cattle and beef markets are considerably higher than those in scenario 2. Our results support the findings of Verbeke and Ward; Herrmann, Thompson, and Krischik-Bautz; and Latouche, Rainelli, and Vermersch that health safety scares due to BSE and other beef related crises do reduce the demand for meat. Burton and Young and Verbeke and Ward also find that negative publicity from TV and press coverage of a BSE crisis reduces the beef demand significantly.

Table 2 presents the effects of a BSE outbreak on revenues, labor income, capital income,

feed prices, substitute meat products, and gross domestic product. As expected, revenues and returns to labor and capital are significantly reduced in all scenarios, but more so in the last two scenarios. The results show that the losses in the cattle industry are significantly larger than in the beef industry, i.e., cattle producers bear the brunt of the adverse impacts. The revenue loss to the cattle producers ranges from 14% to 34% from scenario 1 to scenario 3. The results reveal that the cattle and beef industries will be adversely impacted if the BSE outbreak is extensive.

The effects of price, quantity, and revenue declines are reflected in the labor and capital income losses. Since labor is a derived demand, decline in cattle and beef productions lead to lower labor demand, which results in labor income loss. Because capital is sector specific, i.e., fixed, its use does not decline, but rental rate falls (due to output price and quantity declines) and capital income also falls. The declines in labor and capital incomes in the cattle industry range 24% - 71% from scenario 1 to scenario 3. These declines are smaller in the beef industry. Since feed demand is also a derived demand, feed prices decrease by 4% - 10% from scenario 1 to scenario 3.

The impacts on other meat demands show an increase in scenarios 2 and 3, but practically no change in scenario 1. The negligible change in the consumption of pork, poultry, and fish in scenario 1 is due to the assumption that domestic demand does not shift leftward. However in the other two scenarios, domestic demand does shift leftward, which results in consumers reallocating their budget in favor of substitute meats. Increase in demand is larger for pork, followed by poultry and fish. Substitute meat demand in scenario 3 increases by more than double the increase in scenario 2.

The impacts of the BSE scare in other sectors of the economy, even in our worst case scenario, are negligible because cattle and beef industries are a small part of the overall U.S. economy. Consequently, changes in gross domestic product are very small. McDonald and Roberts found that the BSE crisis in England had larger impacts in the related meat sectors because of the extensive occurrence of the disease and 143 cases of human death. Even with these catastrophes in the beef and cattle industries, McDonald and Roberts found that the macroeconomic effects are minor because the beef and cattle industries are small relative to the overall U.K. economy.

Sensitivity Analysis

Many of the parameters in the model are calibrated from the social accounting matrix of

the U.S. economy, but some of the parameters (e.g., Armington elasticity of substitution and export demand elasticities) are free and assigned values consistent with the equilibrium. We reviewed the literature extensively to select the values for these free parameters. Reinert and Ronald-Host estimated the Armington elasticity of substitution, ranging from a low of 0.14 to a high of 3.49, for 163 U.S. manufacturing sectors. In general, their results indicate that the substitutions between U.S. domestic and imported goods are relatively limited. Shiells and Reinert selected 22 manufacturing sectors from the earlier study of Reinert and Ronald-Host and estimated the elasticity of substitution for U.S. goods and imports from Canada, Mexico, and the rest of the world, which ranged from 0.04 to 2.97. Feenstra incorporated new product varieties into the CES function and obtained the elasticity of substitution ranging from 1.3 to 3.0 for six manufactured goods. Kapuscinski and Warr estimated the elasticity of substitution for the Philippines and the results varied from 0.2 to 4.0, with most of the estimates being greater than one. Bilgic et al. considered U.S. regional economies and obtained the elasticity estimates of 1.5 for farm products, 1.8 for nonmetallic minerals, and 1.1 for all commodities. Purcell estimated Japanese demand elasticity for U.S. beef at -1.8, and Coffey et al. in their analysis of mad cow disease assumed export demand elasticity for U.S. beef at -1.0 and -2.0.

Based on these literature reviews, we considered benchmark Armington elasticities of substitution of 2.0 for manufacturing, 1.5 for cattle sectors, and 0.5 for wholesale beef, and export demand elasticity of -3 for beef and cattle sectors and -5 for all other commodities. Then we conducted sensitivity analyses for more inelastic and elastic values to provide information on the reliability of the results generated from the model. For inelastic values, we chose the Armington elasticity of substitution at 0.99 for manufacturing and cattle sectors, and 0.3 for wholesale beef. For elastic values, the corresponding elasticities of substitution are 3 and 2. For sensitivity analysis of export demand elasticities, we considered -1 and -5 for cattle and beef sectors.

The changes in the key endogenous variables in response to different elasticity parameters are only modest, ranging from about 1% to 3%. The only exception is that the changes in imports and domestic demand are larger, as one would expect, as elasticity of substitution become larger. These sensitivity results highlight the stability of the model and the reliability of our findings.

Summary

This study analyzes the impacts of mad cow disease occurrences in the United States on the cattle and beef industry using a large scale general equilibrium model. Three scenarios, ranging from most favorable to most pessimistic, were considered for the analysis. The most realistic scenario is probably scenario 2 with a 90% decline in foreign demand and 10% reduction in U.S. domestic demand. This scenario generates results consistent with the outcomes after the mad cow disease outbreak in 2003, though scenario 3 produces price results that closely parallel the cattle futures and beef cash price declines (19%) in the days following the discovery of the mad cow disease. However, such a large fall in prices was attributed to the psychological and emotional reactions of traders and consumers to the first case of mad cow disease in the United States and probably did not indicate an equilibrium outcome. The cattle and beef markets were able to recover from this initial price decline within two months.

The impact of mad cow disease even in our worst case scenario is not as damaging as the mad cow disease outbreak in Canada because Canada depends on the foreign market, particularly the United States, for selling about 60% of its cattle and beef. When the United States closed its border, the Canadian cattle and beef industry was economically decimated.⁴ Since the United States exports only 10% of its beef, reduction in foreign imports of U.S. beef did not have large effects. Only if the domestic demand declines significantly, will the economic hardship in the U.S. beef and cattle industry be very large. However, the U.S. government and the cattle industry took several important measures to prevent a precipitous fall in domestic demand. These measures included establishing a coordinated campaign to assure the public that the U.S. beef is safe to consume, instituting proactive steps to ban potentially infected meat entering the food chain, developing a national tracking system of cattle, expanding the number of downer cattle tested for mad cow disease, strengthening the existing ruminant feed ban, enforcing tighter restrictions on slaughterhouse techniques, and implementing a faster testing procedure for mad cow disease. The economic damage was also lessened by the finding that the infected Holstein cow was born in Canada before 1997, the year the United States and Canada banned the practice of feeding the cattle with feed made from animal brain and spinal cord tissue. This finding

⁴ The U.S. import restrictions prohibited more than one million Canadian cattle from entering the United States. These import restrictions created an enormous excess supply and hurt the Canadian cattle industry. Cattle prices in Canada declined by about \$20/cwt (Clemens). The U.S. policy and the ensuing cattle oversupply led Canadian producers to invest in building additional slaughter and processing plants. The U.S. policy also caused U.S. beef packers to lose about \$1.8 billion in beef and byproduct sales revenues (Schroeder and Leatherman).

implied that U.S. cattle, particularly those born after 1997, are likely to be free from mad cow disease.

The economic loss could have been much worse if the mad cow disease outbreak was more extensive, rather than limited to a single case. Our findings suggest that a large scale outbreak could have devastating consequences on the cattle and beef industry. In light of such findings, our results could be used by policy makers to take necessary measures to prevent a future outbreak of mad cow disease.

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**Table 1. Impacts of Mad Cow Disease on Cattle and Beef Industry in Percent Change
(Foreign Demand Declines by 90%)**

	Quantity Impacts(%)			Price Impacts(%)		
	Domestic Demand Shifts by			Domestic Demand Shifts by		
	0%	10%	25%	0%	10%	25%
Exports						
Ranch & Range Cattle	-89.65	-88.94	-87.77	-40.20	-41.49	-43.42
Feeder Cattle	-89.37	-88.57	-87.40	-40.72	-42.13	-43.97
Wholesale Beef	-89.91	-89.39	-88.59	-39.68	-40.68	-42.09
Domestic Demand						
Ranch & Range Cattle	-6.69	-11.17	-18.71	-7.17	-11.24	-17.37
Feeder Cattle	-6.62	-11.09	-18.67	-8.44	-12.78	-18.65
Wholesale Beef	3.17	-0.99	-8.03	-3.96	-7.27	-12.10
Domestic Production						
Ranch & Range Cattle	-7.16	-11.61	-19.11	-7.27	-11.33	-17.45
Feeder Cattle	-7.10	-11.54	-19.07	-8.54	-12.86	-18.73
Wholesale Beef	-6.41	-10.10	-16.38	-5.81	-9.05	-13.76
Imports						
Ranch & Range Cattle	-16.81	-25.96	-39.16	0.21	0.22	0.23
Feeder Cattle	-18.46	-27.81	-40.53	0.21	0.22	0.23
Wholesale Beef	1.00	-4.76	-13.87	0.21	0.22	0.23
Composite Demand						
Ranch & Range Cattle	-7.01	-11.63	-19.38	-6.97	-10.93	-16.92
Feeder Cattle	-6.99	-11.63	-19.40	-8.20	-12.42	-18.16
Wholesale Beef	2.99	-1.30	-8.52	-3.63	-6.69	-11.15

Table 2. Effects of Mad Cow Disease on Key Aggregate Variables (%)

	Domestic Demand Shifts by		
	0%	10%	25%
Revenues			
Ranch & Range Cattle	-13.87	-21.57	-33.15
Feeder Cattle	-14.97	-22.84	-34.13
Wholesale Beef	-12.18	-19.56	-30.68
Returns to Labor			
Ranch & Range Cattle	-24.35	-37.06	-54.82
Feeder Cattle	-34.63	-50.70	-70.41
Wholesale Beef	-8.37	-14.14	-23.61
Returns to Capital			
Ranch & Range Cattle	-24.56	-37.35	-55.18
Feeder Cattle	-34.91	-51.05	-70.77
Wholesale Beef	-8.45	-14.27	-23.81
Feed Price	-3.94	-6.20	-9.73
Substitute Meat Demand			
Pork	0.08	7.12	17.66
Poultry	0.10	5.53	13.13
Fish	0.04	3.44	8.52
Gross Domestic Product	0.07	0.11	0.16