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

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The discovery of the first case of mad cow disease in the United States in 2003 reverberated across the beef and cattle industry. This study employs a general equilibrium model to analyze the potential economic effects of mad cow disease on the beef, cattle, and other meat industries under three scenarios, ranging from most favorable to most pessimistic. The scenario with 90% foreign demand decline and 10% domestic demand reduction generates results consistent with the actual outcomes after the mad cow disease outbreak. Only if domestic demand declines significantly will the economic hardship in the U.S. beef and cattle industry be very large.

Key words: demand decline, economic effects, mad cow disease

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 alarm among ranchers, processors, and consumers. Ranchers were worried about the economic ruin mad cow disease could bring, processors were apprehensive of 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 (Dreyfuss, 2003).

The mad cow disease epidemic in England in the 1980s and 1990s 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 (Sherman, 2004). This disease also occurred in other European countries and had adverse effects on cattle and beef industries (Herrmann, Thompson, and Krischik-Bautz,

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2002). 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.

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' concerns about beef safety and the adverse economic impact on the U.S. cattle industry, then Agriculture Secretary Ann Veneman and the National Cattlemen's Association repeatedly assured the American public that this case of mad cow disease was a single, isolated incident and not widespread, and it was safe to consume beef. The public was also informed that the infected parts of the cow (nerve tissue, spinal cord, and small intestine) had been removed from the food chain (also see Coffey et al., 2005).

This outbreak was expected to drastically affect domestic beef consumption and U.S. beef exports, particularly if the disease were to become widespread. Approximately 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 valued at about $3 billion. Fifty-three countries, including four leading importers (Japan, South Korea, Mexico, and Canada), banned imports of U.S. beef. Other notable countries participating in this ban include Australia, Brazil, China, Colombia, Egypt, Indonesia, Jordan, Lebanon, Malaysia, Russia, Singapore, South Africa, Taiwan, and Thailand (Coffey et al., 2005). Consequently, U.S. beef exports fell from 2.5 billion pounds in 2003, to 500 million pounds in 2004 (USDA/Economic Research Service, 2005).

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¢ a pound in a matter of days (Henderson, 2003). Live cattle prices declined sharply from 91¢ per pound on December 22, 2003, to 78¢ 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 (Gersema, 2003). 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 December 2003 discovery of the first case, a U.S.-born cow with BSE was identified in Texas in June 2005, and another case of mad cow disease was found in Alabama in March 2006. BSE occurrence remains a serious concern to the cattle and beef industry as a dozen importers, including Japan and Taiwan, have not reopened their borders to U.S. beef. Clemens (2005) argues 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. In the event of a widespread occurrence, there would be a large decline in domestic and foreign demand (Coffey et al., 2005).[1] We believe an examination of the

[1] Fox and Blake (2004) surveyed consumers to ascertain the potential reduction in beef consumption in response to different intensities of BSE occurrences. In a single case of mad cow disease occurrence, 32% of the consumers indicated they would consume less beef, and 12% would stop beef consumption; if 20 cases of BSE were discovered, 43% of those surveyed stated their beef consumption would decline, and 26% reported they would not consume any beef. Additionally, Fox and Blake found

impacts of such demand shocks on the U.S. beef and cattle industry is a timely and worthwhile research focus.

Accordingly, 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 magnitudes 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 proceeds as follows. First, the structure of the general equilibrium model is presented. The data used for the analyses are then described, followed by a discussion of the procedures and assumptions employed in the analysis. The next section presents the results of the analysis, and the final section provides a summary and conclusions.

The General Equilibrium Model

The mad cow scare not only hurt the beef and cattle industry, but also other related industries in the upstream, downstream, and horizontal sectors (McDonald and Roberts, 1998). The industries affected on the supply side of the market include ranches, feedlots, slaughter houses, processing plants, feed stores, trucking, and shipping. Those 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 interdependencies, 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 not only would 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 (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 result in significant job and income loss in this industry.

Estimates of these impacts will be useful to policy makers in assessing the magnitude of economic damages and implementing policies to prevent future occurrences of BSE. Only a general equilibrium analysis will provide estimates of 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 overreaction. 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.

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that if both questions (a single case and 20 cases of BSE discovery) were posed together, 39% would reduce their beef consumption, and 46% would no longer consume any beef. In summary, multiple BSE cases will have a significant negative impact on demand (also see Coffey et al., 2005).

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 interlinkages 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 and cattle sectors and the rest of the economy. In an earlier study, McDonald and Roberts (1998) employed a CGE model to investigate 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 constructed by Lofgren (2000) and Gilbert (2002, 2003). For an elaborate documentation including the mathematical equations, variable definitions, and parameter specifications, see Holland, Stodick, and Devadoss (2004). The CGE model mathematically represents the inner workings 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: (*a*) production and commodity, (*b*) price, (*c*) institutional, and (*d*) system constraints. The production and commodity block specifies a Leontief/constant elasticity of substitution (CES) production function, factor demand, intermediate input demand, output conversion, the rest of the world (ROW) 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. Thus, the length of run for the analysis employed in this CGE model is short run. Total factor supply for the U.S. economy is considered fixed. 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.

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 constant elasticity of transformation (CET) 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 model's 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 a function of world price times exchange rates and any import tariffs. The U.S. prices for export goods are a 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 the 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 final block, system constraints, encompasses the specifications for factor market equilibrium, commodity market equilibrium, balance of payments, savings-investment balance, and price normalization. The factor market equilibrium requires that the sum of the factors 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, and investment.

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

The balance-of-payments 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, the consumer price index is equal to commodity prices weighted by the composition of commodity baskets. The price normalization sets the numeraire equal to the CPI.

The CGE model ensures that commodity and factor markets balance, and 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 interlinkages 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 capture a detailed, consistent, snapshot representation of interactions among economic activities. 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 are used to calibrate the parameters of the behavioral equations in the model.

The data source of the SAM for our economic model was IMPLAN 2000 (Minnesota IMPLAN Group, Inc., 2002), 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). All prices and exchange rates were normalized to one.

The GAMS software with PATH Solver was used to construct and solve the system of simultaneous nonlinear equations in the CGE model. The parameters of the model were calibrated from the base year SAM and the model was solved to replicate the base year data.

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 suggest that the import ban by more than 50 countries around the world led to a decline of approximately 90% in U.S. beef exports. Consistent with these reports, we assumed that for all scenarios, the ROW 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. Because 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 in combination with a 90% decline in U.S. beef exports. Thus, the three scenarios are as follows:

- 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—i.e., 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 the cattle and wholesale beef markets. 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, others need additional explanation. 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, which are utilized by various institutions (firms, households, government) within the U.S. economy, are combined to form the Armington composite. 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 are the reductions in foreign demand and domestic demand

Table 1. Impacts of Mad Cow Disease on Cattle and Beef Industry, in Percentage Change (foreign demand declines by 90%)

	Quantity Impacts (%)			Price Impacts (%)		
	Domestic Demand Shifts by:			Domestic Demand Shifts by:		
Variables	0%	10%	25%	0%	10%	25%
Exports:						
Ranch and 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 and 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 and 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 and 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 and 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

resulting from the consumer fear of 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. Since the domestic demand price decreases and import price is constant (except for the exchange rate changes), the composite demand price also falls.

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 would be expected, 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% to 9% for live cattle, and the price decrease is even smaller in the beef market.[3] Domestic demand and supply prices

[3] Using a partial equilibrium analysis, Coffey et al. (2005) found equilibrium beef price declined by about 8%-10% due to an import ban by foreign countries.

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. This 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 finding corroborates the rise in U.S. beef consumption by 1.8% from 2003 to 2004, as reported by Coffey et al. (2005). 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%. As a consequence of the mad cow disease 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. Finally, 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 under 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 approximately 11% and beef demand by only about 1%. In response to foreign and domestic demand reductions, supply price also declines, ranging 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 (11%–12%) and in the beef market (7%). 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. Under this scenario, domestic demand and supply prices of cattle decline by 17% to 19%, and beef prices go down by 12% to 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 (2003). 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 under scenario 2. Verbeke and Ward (2001); Herrmann, Thompson, and Krischik-Bautz (2002); and Latouche, Rainelli, and Vermersch (1998) have found that health safety scares due to BSE and other beef-related crises do reduce the demand for meat. Burton and Young (1996) and Verbeke and Ward (2001) also concluded that negative publicity from TV and press coverage of a BSE crisis reduces demand for beef significantly.

Table 2 reports the effects of a BSE outbreak on revenues, labor income, capital income, feed prices, and substitute meat products. As expected, returns to labor and capital are significantly reduced in all scenarios, but more so in the last two scenarios. Findings reveal that the losses in the cattle industry are significantly larger than in the

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

	Domestic Demand Shifts by:		
Aggregate Variables	0%	10%	25%
Revenues:			
Ranch and 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 and 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 and 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

beef industry, i.e., cattle producers bear the brunt of the adverse impacts. The revenue loss to cattle producers ranges from 14% to 34% from scenario 1 to scenario 3. Based on these results, 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, declines in cattle and beef production 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 from 24% to 71% across the three scenarios. These declines are smaller in the beef industry. Since feed demand is also a derived demand, feed prices decrease by 4% to 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 under 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 under scenario 3 increases by more than double the increase shown for 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 (1998) 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, the authors concluded that the macroeconomic effects were 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 are assigned values consistent with the equilibrium. We reviewed the literature extensively to select the values for these free parameters. Reinert and Ronald-Holst (1992) 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 suggest that the substitutions between U.S. domestic and imported goods are relatively limited. Shiells and Reinert (1993) selected 22 manufacturing sectors from the earlier study of Reinert and Ronald-Holst (1992) 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 (1994) incorporated new product varieties into the CES function and obtained an elasticity of substitution ranging from 1.3 to 3.0 for six manufactured goods. Kapuscinski and Warr (1999) estimated the elasticity of substitution for the Philippines, and their results varied from 0.2 to 4.0, with most of the estimates being greater than one. Bilgic et al. (2002) considered U.S. regional economies and obtained elasticity estimates of 1.5 for farm products, 1.8 for nonmetallic minerals, and 1.1 for all commodities. Purcell (1998) estimated Japanese demand elasticity for U.S. beef at -1.8; and Coffey et al. (2005), 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 an export demand elasticity of -3.0 for beef and cattle sectors and -5.0 for all other commodities. We then 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 3.0 and 2.0. For sensitivity analysis of export demand elasticities, we considered -1.0 and -5.0 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 becomes larger. These sensitivity results highlight the stability of the model and the reliability of our findings.

Summary

This study has analyzed 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 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 experienced 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 implemented several important measures to prevent a precipitous fall in domestic demand. These measures included establishing a coordinated campaign to assure the public that 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 cattle with feed containing animal brain and spinal cord tissue. This finding implies 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. 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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[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, 2005). 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 by-product sales revenues (Schroeder and Leatherman, 2004).

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