The Impact of a BSE Outbreak in a Specific Factors Model

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Abstract This paper gauges the potential impact on the US economy of a large scale BSE outbreak in the context of a specific factors model of production. The collapse in the price of beef and associated price changes lead to general equilibrium adjustments in outputs, wages, and capital returns. Changes in beef output and capital return closely mirror the collapsed price of beef, while pork and poultry industries expand with higher prices. Wages and energy prices fall slightly while capital returns across the rest of the economy rise negligibly.

Keywords: Beef prices, general equilibrium, specific factors, BSE

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1. Introduction

Beef safety incidents such as E coli, foot and mouth, and bovine spongiform encephalopathy or BSE have been highly publicized worldwide. BSE may be linked to human Creutzfeldt-Jakob disease CJD as developed by Holt and Phillips (1988), Dealler (1993), Lacey (1993), and Sawcer et al (1993) making the potential impact of BSE outbreaks on the demand for beef severe. The outbreak in the UK during the mid 1990s led to import bans, increased monitoring, and the virtual collapse of the UK beef industry. The spread of BSE to Japan and Canada during 2003 increased surveillance and research.

When a case of BSE was then reported in Washington during the same year, cattle prices in the US immediately fell 16% and cattle future prices 20%. Both rose back over the coming quarter, however, consistent with a regionally targeted consumer survey reported by Coffey, Mintert, Fox, Schroeder, and Valentin (2005) that finds most consumers did not change habits with the single BSE case but would with an outbreak. Exports had accounted for 10% of US beef revenue but within days of the Washington case US beef was banned in 53 countries and some of the bans lasted for years.

Almost immediately following a subsequent Canadian BSE case the same year, the US and a host of other countries banned Canadian imports. Exports had accounted for almost 40% of Canadian beef production and 30% of fed cattle sales, and the loss of exports led to a 63% decline in Canadian fed cattle prices within three months. In an applied general equilibrium model, Weick and Holland (2006) estimate the import ban increased US fed cattle prices by 2% but also eliminated 11,000 jobs and led to a loss of $1.7 billion lost income.

Jin, Skripnitchenko, and Koo (2004) suggest the Washington case would reduce consumption 10% and exports 75%, and predict additional outbreaks would have larger impacts. They suggest a worse case scenario of a 20% collapse in the price of beef with prices of pork and chicken rising 3%. The present paper examines the economy wide effects of such price changes. Jin and Koo (2003) use the weak form axiom of revealed preferences to test consumer response to food safety information by examining whether Japanese preferences for meat underwent a structural change due to the 2003 BSE outbreak in Japan. They uncover a structural break in consumption per household supporting the assumption of a collapse in the price of beef.

Mattson and Koo (2007) develop an econometric model for beef and cattle prices to estimate the effects removing the trade restrictions imposed following the 2003 cases in Canada and the US. The model is based on issues affecting the US livestock industry in a survey of 30 industry experts. The authors find the price of cattle is affected by trade as well as issues affecting domestic supply and demand.

Marsh, Brester, and Smith (2008) evaluate the economic impact of BSE cases in Canada and the US by estimating market models for fed and feeder cattle with binary BSE event variables. The authors derive comparative statistic changes in cattle prices due to Japan and South Korea keeping their markets closed, estimating price decreases would have lowered revenue by about 5%. They stress that US cattle producers have a strong incentive to maintain access to international beef markets.

Hubbard and Philippidis (2001) employ a modified Global Trade Analysis Project GTAP model to examine the extent to which UK cattle, slaughtering, and meat processing recovered in the wake of the BSE export ban. In the dynamic GTAP model of Ianchovichina and McDougall (2000) they incorporate the impact of the 2001 foot and mouth crisis and allow for investment and variation in the recovery of consumer confidence. The legacy of the export ban appears likely to continue especially for cattle and sheep where exports may be 14% lower in 2020. The impact on the aggregate economy is negligible.

Saghaian (2007) analyzes time series of weekly feedlot, wholesale, and retail beef prices to address the dynamics of price adjustment and finds price transmission is bidirectional but asymmetric in speed and magnitude. The differential impact of exogenous shocks on producers and retailers leads to widening price margins and larger price effects.

The present paper gauges the potential effects of a BSE outbreak in a specific factors model of the US economy. An advantage of the present comparative static model is its straightforward production structure and ease of simulation to various price changes and different degrees of input substitution in production. The focus is on the beef industry as well as pork and poultry in a model with 8 industries and industrial specific capital along with shared labor and energy. The estimated effect on the return to beef industry capital (including land) extends the literature, as does energy input. The model derives comparative static adjustments in the wage, energy price, industrial capital returns, and outputs due to a falling price of beef and rising prices of pork and poultry substitutes.

2. A Specific Factors Model focused on Beef Production

Competitive pricing, full employment, constant returns, and cost minimization are the underlying assumptions of the specific factors model developed by Jones (1971) and Samuelson (1971). Capital is industry specific while labor and energy move freely between industries in the present version of the model that solves for the comparative static adjustments in factor prices and outputs to exogenous price changes due to a BSE outbreak. The model has a rich literature in both theory as in Takayama (1982) and applications as in Thompson (1996).
Substitution elasticities σ summarize how cost minimizing industries alter inputs according to factor prices. Industry shares λ are the portion of inputs in industries and factor shares θ the portion of industry revenues paid factors. The comparative static model in matrix format is

$$\begin{pmatrix} \sigma & \lambda \\ \theta^T & 0 \end{pmatrix} \begin{pmatrix} w' \\ x' \end{pmatrix} = \begin{pmatrix} v' \\ p' \end{pmatrix} \tag{1}$$

where $'$ represents percentage change, w the vector of endogenous factor prices, x endogenous outputs, v exogenous factor endowments, and p exogenous prices. The first equation in (1) is based on full employment and the second on competitive pricing. Price changes due to a BSE outbreak are introduced to gauge adjustments in endogenous factor prices and outputs.

Factor shares θ and industry shares λ are derived from factor payments as in Thompson (1996). Data includes value added and the labor bill in meat and poultry processing, other manufacturing, and services from the 2006 *Economic Census*. Energy spending for manufacturing and services is from the US Department of Energy (2006). Total receipts, labor, and energy data for beef, poultry, pork, and other agriculture are from the 2002 Census of Agriculture *Summary by North American Industry Classification System (NAICS)*. Capital inputs are derived as residuals of value added after the labor and energy bills. The total factor payment matrix is in Table 1.

Table 2 presents the derived factor share matrix θ. Total revenue of the beef industry is \$27.1 billion in Table 1 and the capital share is \$22.3/27.1 = 82%. Capital has the largest factor share in each industry. The service sector has the largest labor factor share at 33.9% followed by other manufacturing and poultry processing with labor shares about half as large. The labor share in beef production is 7.2% and in meat processing 8.8%.

Industry shares λ are portions of factors employed by industry. Summing across rows in Table 1 gives total factor income. Assuming the wage is equalized across industries, total labor income in beef production of \$1.9 billion implies an industry share of \$1.9/\$3,164 = 0.06%. Pork and poultry use half as much labor while meat and poultry processing use 0.2% each. Industry shares of specific capitals are all equal to 1.

2.2 CES Substitution

Substitution elasticities summarize cost minimizing input adjustment to factor price changes as developed by Jones (1965), Jones and Scheinkman (1977), Chang (1979), Takayama (1982), and

Thompson (1995). Following Allen (1938) the cross price elasticity between the input of factor *i* and the payment to factor *k* in sector *j* is

$$E_{ij}^{k} \equiv a_{ij}'/w_k' = \theta_{kj}S_{ij}^{k} \quad (2)$$

where a_{ij} is the cost minimizing input and S_{ij}^{k} is the Allen partial elasticity of substitution. Cobb-Douglas production implies $S_{ij}^{k} = 1$ and constant elasticity of substitution CES implies S_{ij}^{k} is a positive constant. Linear homogeneity implies $\sum_k E_{ij}^{k} = 0$ and each own price elasticity E_{ij}^{i} is the negative of the sum of its cross price elasticities.

Aggregate substitution elasticities are the weighted average of cross price elasticities for each industry,

$$\sigma_{ik} \equiv \sum_j \lambda_{ij} E_{ij}^{k} = \sum_j \lambda_{ij} \theta_{kj} S_{ij}^{k}. \quad (3)$$

Table 4 reports Cobb-Douglas substitution elasticities and CES would scale accordingly. There is no substitution between specific capital inputs across industries.

The largest own substitution occurs for energy and the smallest for poultry capital. Every 1% increase in the price of energy causes a -0.61% decrease in energy input while every 1% increase in the return to poultry capital lowers that capital input by only -0.069%.

The own labor substitution elasticity is larger than the own capital elasticities. Capital is more of a substitute for labor than energy, and energy is more of a substitute for labor than vice versa. Inputs are weak substitutes with any reasonable degree of CES production, consistent with the applied production literature that typically uncovers inelastic substitution.

3. Empirical Results

3.1 Comparative Static Elasticities

The elasticities of factor prices with respect to product prices in Table 5 are derived by inverting the system (1). Every 1% decrease in the price of beef would lower the capital return in the beef industry by -1.22%. The largest other effect would be on the price of energy but it is a decrease of only 0.003%. Returns to all other industry capitals rise slightly as labor and energy are released from beef production. The spillover effects of the price decrease on factor prices are reduced by output adjustments that buffer the impact.

Larger industries would have larger price effects. Every 1% increase in the price of other agricultural products raises that return to capital 1.34% and the price of energy 0.04% with very small losses spread across labor and other capital returns. The wage depends heavily on the price of the large labor intensive service sector.

Thompson and Toledo (2005) show the price elasticities of factor prices are identical for all CES production functions in the specific factors model. It is perhaps surprising that the degree of

CES substitution, from near zero to near perfect, has no effect on the factor price elasticities in Table 5.

Table 6 reports price elasticities of outputs along the production frontier. A higher price draws labor and energy from other industries raising that output. The largest own output effect occurs in other agriculture where a 1% price increase raises output 0.34%. Every 1% decrease in the price of beef lowers output -0.22% with trivial output increases across other industries. The smallest own effect is in the large service sector since there is relatively little labor and energy available in the rest of the economy.

3.2 Simulated Adjustments to Price Changes

If the demand for beef falls, prices of substitute pork and poultry would increase. Prices of meat (beef and pork) processing would seem likely to fall while the price of poultry processing would rise. Other agriculture would enjoy a small increase in demand and there could be small negative spillover effects on prices of manufactures and services.

To gauge adjustments in outputs and factor prices, the effects of two vectors of price changes are examined in Table 7. The first is a stronger effect with a 20% decrease in the price of beef. Pork and poultry prices rise 10% and the rest of agriculture 1%. The price of poultry processing increases 5% while the price of meat processing falls 5%. A 1% fall in the price of manufactures and services is assumed to spill over to those sectors.

Multiply this vector of price changes by the matrix of factor price elasticities in Table 5 to derive predicted factor price adjustments in Table 7. Capital returns in beef production and meat processing fall 12.0% and 5.6%, larger than the underlying price changes due to the magnification effect of Jones (1965). The return to capital in other agriculture increases 1.7% while returns in the pork and poultry industries increase about 11%. Wages and energy prices fall about 1%.

Output effects are derived multiplying output elasticities in Table 6 by the vector of price changes. Beef output falls 4.1% while pork output increases 1.7% and poultry 0.8%. Manufacturing and service outputs fall slightly. Output in other agriculture rises by 1.4%. Output decreases in manufacturing and services are negligible. Beef revenue falls by the sum of the price and output declines, -24.1%. The beef industry, however, makes up only 8.8% of total agriculture and there is a 1.5% increase in net agricultural revenue.

Factor price and output adjustments are proportional to the vector of price changes. The second column in Table 7 supposes a more modest BSE effect with a 10% decrease in the price of beef and other price changes half as large as the first column, and no effect on prices of manufactures or services. Adjustments in the wage and energy price are then negligible. Capital returns are slightly magnified over their price changes, with the return in beef production falling 12.2%. Beef output falls 2.2% and revenue 12.2%. Pork production rises but only 0.77% and poultry production only 0.37%. Total revenue in agriculture rises negligibly by 0.6% under this scenario.

Factor price adjustments are identical for any degree of CES production while outputs effects are scaled. If CES = ½ the output adjustments would be half as large as those in Table 7 and revenue changes diminished accordingly. Estimates of substitution in the applied production literature are typically less than one.

Lower capital returns in beef production and meet processing would diminish investment and eventually the stock of productive capital, leading to larger output adjustments. Suppose capital inputs ultimately change in proportion to their returns with every 1% change in return leading to a 1% adjustment in that capital stock. The subsequent output changes would then closely mirror adjustments in industrial capital stocks given constant returns to scale. The approximate long run output changes would then equal the vector of capital return changes, much larger than the short run changes. Revenue changes would be the sum of these output changes and the underlying price change. Beef revenue would fall 44.1% (32.2%) with the 20% (10%) price decline, while revenue in aggregate agriculture would rise by 2.4% (1.0%) due to the higher prices and increased outputs.

4. Conclusion

The present model provides perspective on the potential impact of a BSE outbreak on the US economy. Beef revenue falls slightly more than the price of beef in the short run but nearly double that amount in the long run due to the associated decreased investment. In aggregate agriculture, the falling beef revenue would be offset by expanding the pork and poultry revenue. There would be negligible decreases in the wage and price of energy, and increases in returns to capital in other agriculture and the rest of the economy.

Endnotes:

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Table 1. Factor Payments $ billion

	Meat Proc	Poultry Proc	Mfg	Services	Beef	Poultry	Pork	Agr
Labor	7.5	5.2	538	2,592	1.9	0.9	0.8	18
Capital	75	31	3,037	4,662	22	20	8.3	120
Energy	3.0	1.3	133	387	2.9	0.5	0.5	24
Total	85	38	3,708	7,641	27	21	9.6	162

Table 2. Factor Shares θ_{ij}

	Meat Proc	Poultry Proc	Mfg	Services	Beef	Poultry	Pork	Agr
Labor	.088	.136	.145	.339	.072	.044	.083	.111
Capital	.876	.828	.819	.610	.821	.931	.867	.740
Energy	.036	.036	.036	.051	.107	.025	.051	.149

Table 3. Industry Shares λ_{ij}

	Meat Proc	Poultry Proc	Mfg	Services	Beef	Poultry	Pork	Agr
Labor	.002	.002	.170	.819	.001	.000	.000	.006
Capital	.009	.004	.381	.585	.003	.003	.001	.015
Energy	.006	.003	.241	.700	.005	.001	.001	.044

Table 4. Substitution Elasticities σ_{ik}

	w_L	w_E	w_K
a_{Labor}	-.401	.049	.000
a_{Energy}	.279	-.609	.001
$a_{Meat\ Proc}$	.088	.036	-.124
$a_{Poultry\ Proc}$	.136	.036	-.172
$a_{Other\ Mfg}$	.145	.036	-.181
$a_{Service}$	.339	.051	-.390
a_{Beef}	.072	.107	-.179
$a_{Poultry}$	.044	.025	-.069
a_{Pork}	.083	.051	-.133
$a_{Other\ Agr}$	.111	.149	-.260

Table 5. Price Elasticities

	$p_{Meat\ Proc}$	$p_{Poultry\ Proc}$	p_{Mfg}	$p_{Service}$	p_{Beef}	$p_{Poultry}$	p_{Pork}	p_{Agr}
w_{Labor}	.001	.001	.064	.933	.0001	.00003	.0001	.002
w_{Energy}	.002	.001	.121	.830	.0032	.0002	.0004	.042
$r_{Meat\ Proc}$	1.14	-.0001	-.011	-.128	-.0001	-.00001	-.00002	-.002
$r_{Poultry\ Proc}$	-.000	1.21	-.016	-.189	-.0002	-.00001	-.00003	-.002
$r_{Other\ Mfg}$	-.0002	-.0002	1.21	-.202	-.0002	-.00001	-.0001	-.002
$r_{Service}$	-.0005	-.0004	-.046	1.05	-.0003	-.00003	-.0001	-.004
r_{Beef}	-.0003	-.0002	-.021	-.190	1.22	-.00003	-.00001	-.006
$r_{Poultry}$	-.0001	-.0001	-.007	-.067	-.0001	1.07	-.00001	-.001
r_{Pork}	-.0002	-.0001	-.013	-.138	-.0002	-.00001	1.15	-.003
$r_{Other\ Agr}$	-.0005	-.0003	-.034	-.308	-.001	-.00004	-.0001	1.34

Table 6. Output Elasticities

	$p_{Meat\ Proc}$	$p_{Poultry\ Proc}$	p_{Mfg}	$p_{Service}$	p_{Beef}	$p_{Poultry}$	p_{Pork}	p_{Agr}
$x_{Meat\ Proc}$	.142	-.0001	-.011	-.128	-.0001	-.00001	-.00002	-.002
$x_{Poultry\ Proc}$	-.002	.208	-.016	-.189	-.0001	-.00001	-.00002	-.002
$x_{Other\ Mfg}$	-.0002	-.0001	.205	-.202	-.0001	-.00001	-.00003	-.002
$x_{Service}$	-.0005	-.0004	-.046	.051	-.0003	-.00003	-.0001	-.004
x_{Beef}	-.0003	-.0002	-.021	-.190	.217	-.00003	-.0001	-.006
$x_{Poultry}$	-.0001	-.0001	-.006	-.067	-.0001	.074	-.00001	-.001
x_{Pork}	-.0002	-.0001	-.013	-.138	-.0002	-.00001	.154	-.003
$x_{Other\ Agr}$	-.0005	-.0003	-.034	-.308	-.001	-.00004	-.0001	.343

Table 7. Factor Price and Output Adjustments

	% Prices		% Factor Prices			% Outputs		
			w_{Labor}	-1.0	0.002			
			w_{Energy}	-0.9	0.01			
Meat Proc	-5	-3	$r_{MeatProc}$	-5.6	-3.4	$x_{MeatProc}$	-0.6	-0.4
Poultry Proc	10	5	$r_{PoulProc}$	12.3	6.0	$x_{PoulProc}$	2.3	1.0
Mfg	-1	0	r_{Mfg}	-1.0	0.0	x_{Mfg}	-.01	0.0
Services	-1	0	r_{Srv}	-1.0	0.0	x_{Srv}	-0.01	0.0
Beef	-20	-10	r_{Beef}	-24.1	-12.2	x_{Beef}	-4.1	-2.2
Poultry	10	5	$r_{Poultry}$	10.8	5.4	$x_{Poultry}$	0.8	0.4
Pork	10	5	r_{Pork}	11.7	5.8	x_{Pork}	1.7	0.8
Agriculture	2	1	r_{Agr}	3.0	1.3	x_{Agr}	1.0	0.4