The Mad Cow Disease Trade Ban and Changes in the U.S. and Canadian Cull Cow Markets: A DAG Analysis

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A directed acyclical graph (DAG) methodology was used to discover changes in price relationships among cull cow markets in the U.S. and Canada resulting from the trade ban initiated by the discovery of bovine spongiform encephalopathy (BSE, also called mad cow disease), in a Canadian cow in 2003. Comparison of the pre- and post-ban DAGs supports the hypothesis that large structural changes in the flow of cull cow market information has occurred with significant changes both within and between countries. The typical flow of information from south to north and east to west was disrupted.

On May 21, 2003 an Angus cow in Alberta, Canada was discovered to have bovine spongiform encephalopathy, or BSE. As a result of the discovery of BSE in Canada, the U.S. imposed an immediate ban on the importation of cattle and meat originating or processed in Canada. Since the U.S. and Canadian markets up to this date were considered to be one market, with the free trade of animals and beef across both borders, the effect of this ban was expected to change the flow of information and products both within and between the two countries. The change in the flow of products was quite abrupt and apparent, with immediate cessation imposed by U.S. federal mandate. The subsequent drop in Canadian prices was also very immediate, as shown in Figure 1. Figure 1 also illustrates the nature and relationship between and within the two national markets; the relatively higher Canadian prices in the first portion of the graph are an artifact of the difference in exchange rates. The Canadian price series were left in Canadian dollars to emphasize the drastic changes that occurred during this period between these markets. What is not evident from this graph is the effect of the ban on the flow of information between regional markets located both in the U.S. and Canada. While the initial ban halted beef from all age classes, the ban was shortly lifted on beef from animals less than thirty months of age. This resulted in an unequal disruption of the market, with the older classes of animals being affected for an extended period.

Cull cows are generally thirty months of age or older and were the class of livestock most affected by this ban. Replacement heifers typically have their first calf around twenty-four months of age. Their first calf is typically weaned six to seven months later, when the heifer is thirty to thirty-one months of age. Weaning time is when most producers make culling decisions. Those heifers that are culled earlier due to the loss of their fetus or calf are generally placed in a feedlot for younger animals and sold as fed heifers, which receive a premium relative to older cull animals. Therefore it is expected that nearly all cull cows are over thirty months of age.

Cull cows are primarily used in the production of “grind” meat made into hamburger as well as other processed beef products. A few are used for primal cuts purveyed as food away from home in discount and volume eateries and low-end steak or buffet chain restaurants. Therefore price series from other value-added products such as lean beef trimmings, cutout beef, and imported beef, all of which are used in much the same way as cull cow beef, were included in the analysis to properly show all prices and beef products affected by cull cows.

Proceeds from cull cows are a significant source of income to cow-calf producers. Feuz has estimated that 15–30 percent of gross annual income from the cow-calf enterprise comes from the sale of cull cows. The percentage for each producer is determined by many factors, including the cow price, production challenges, and management decisions. Flow changes in market information would affect the producer’s view of the market and potentially alter market strategies. It is also of interest to observe what effects the physical separation of two integrated markets has on the flow of information and the implications that might be made by economic theory.

The May 2003 BSE find was the first discovery

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of the disease in North America since the connection between it and human health had been announced by the UK. The U.S. took immediate action and closed the border to all Canadian beef and cattle imports. After a few months, imports of beef from cattle of less than thirty months of age were permitted, excluding live animals. In July 2005 imports of live cattle less than thirty months of age that would be slaughtered in the U.S. before reaching thirty months of age was again permitted. However, as of October 1, 2007 the importation of Canadian cattle over thirty months of age, which includes cull cows, is still prohibited. Prior to the May 2003 border closure, approximately 45 percent of cull cows in Canada were shipped to the U.S. for slaughter; in 2002 it was estimated that of the 990,860 cull cows in Canada, 429,742 were exported to the U.S. Cull cow markets and prices on both sides of the border appear to have been affected as a result of imposed trade restrictions. Due to the close relationship between the cull cow market and the lean beef market, it is expected that the import markets of lean beef and domestic lean beef trimmings were also affected.

Additional cows were discovered with BSE in both the U.S. and Canada, but these discoveries had little effect on the cull cow market. Following the discovery of the cow with BSE in Canada in May 2003 and the border closure by the US, prices for cull cows in Canada begin to decline rather sharply, dropping 50 percent in six weeks and 75 percent in ten weeks. One year after the discovery and the resulting border closure, Canadian cull cows still were at only 50 percent of their pre-border-closure value. By contrast, when the first U.S. BSE-positive cow was identified in December 2003, US cull cow prices declined less than five percent in the first week, and six weeks later prices were actually higher for U.S. cull cows. In June of 2004 another BSE-positive cow was identified in the U.S. and an additional BSE-positive cow was discovered in Canada in December of that same year. The week following each of these two discoveries prices for cull cows in the U.S. and Canada increased following typical seasonal patterns.

The use of a so called complete time-series model (Stockton et al.) introduces the application of a proven methodology which includes the application

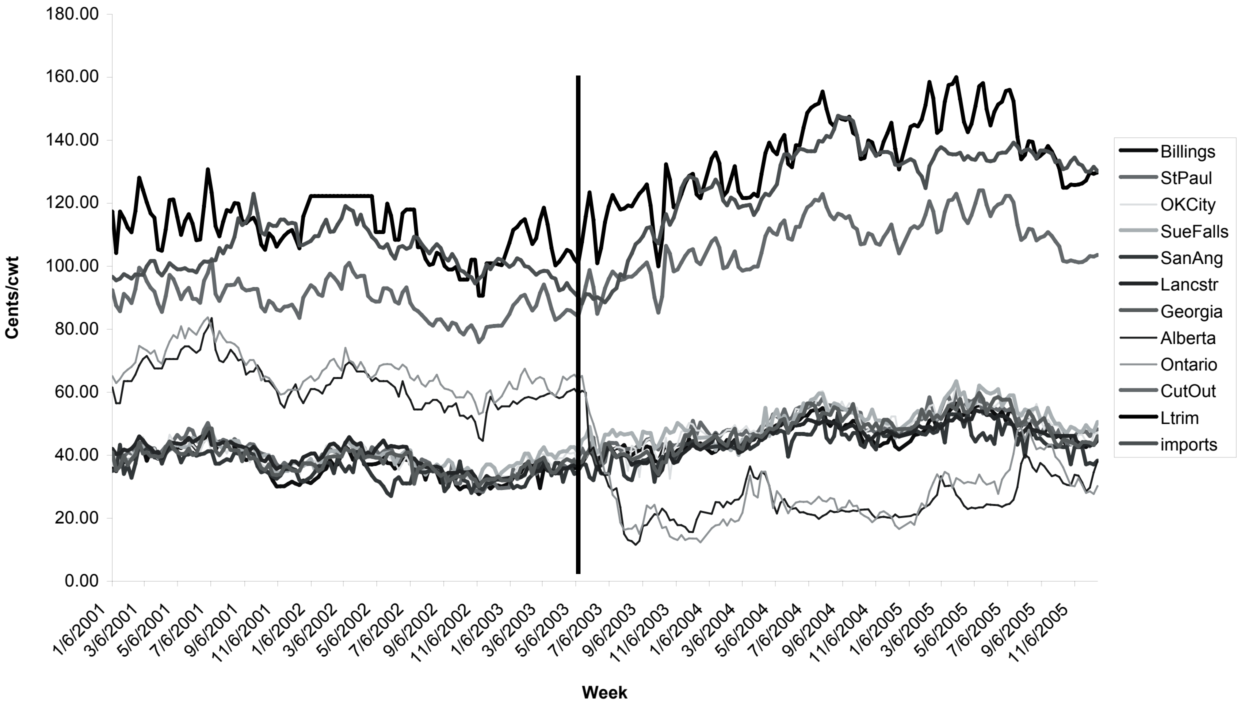

Figure 1. Price Series Used for the DAG Analysis.

of directed acyclical graphs (DAGs) to uncover the relationships of contemporaneous price information in geographically dispersed markets of the U.S. and Canada. Other work, such as that of Bessler and Ankleman, has used the DAG methodology to determine contemporaneous relationships among variables from farm-gate to retail. Here we use the method to identify contemporaneous relationships within a single market level, specifically the change of the flow of information between geographical markets before and after the Canadian–U.S. cattle ban.

This paper directly tracks the changes in information flow in contemporaneous time and the changes that occurred in the U.S.–Canadian cull cow markets as a result of the BSE ban. These changes in information flow provide some explanation of the empirical realities of what occurred as a result of the ban. Additionally, these changes represent changes in the structural nature of information flows, making it possible to identify econometric relationships, which when properly specified indicate the effect dependent on the cause(s). The explanation of how the directed acyclical graph information is used to specify econometric models is beyond the scope of this paper and the authors refer those interested in doing such analysis to the appropriate references (Pearl 2000; Chalak and White).

The application of the DAG methodology here is unique in that it provides more than a simple binary result—the actual differences in the market become transparent, making clear not only that an alteration has occurred but actually mapping that change. This mapping is helpful when used in association with economic principles which at best provide deeper understanding and at worst raise more questions.

Uniquely, this work is one of the first examples where the DAG is used as a tool to identify and confirm a structural change in the market, providing a complement and/or alternative to traditional methods, thus interjecting itself into the discussion within the discipline of this topic. The results portion of the analysis provides a descriptive picture of the changes in information flows as a result of the ban, providing insight to regulators and those concerned with the state of the market. The changes in information flow, when combined with quantitative analysis, although not pursued here, would provide a more complete discussion for those pursing policy impacts of the ban.

Data

Weekly price data from January 2001 through December 2005 collected by the USDA-Agricultural Marketing Service for nine geographically dispersed auction markets were used for this analysis. The auctions markets were the Georgia combined auctions; St. Paul, Minnesota; Billings, Montana; Clovis, New Mexico; Oklahoma City, Oklahoma; Lancaster, Pennsylvania; Sioux Falls, South Dakota; San Angelo, Texas and Torrington, Wyoming. USDA-AMS reports a number of market classes, but this analysis uses the Lean 85–90% market class or, when actual USDA Grades are reported, the Cutter grade. This grade and market class is the most commonly reported across all markets and results in the most consistent time series. Two Canadian markets were reported as well, Alberta and Ontario. Prices from these two markets were obtained from CanFax and are for the D1,2 cow grades and were converted into U.S. dollars. The Canadian cow grades are based on muscling, while the U.S. cow grades are based on marbling and maturity. They are therefore not directly comparable. However, the D1,2 is most commonly reported in Canada and the Cutter is commonly reported the most in the U.S. We assume market participants know the type of cattle represented by each grade and are able to make price decisions accordingly, since prior to the ban about 45 percent of Canadian cull cows, over 400,000 head, were shipped annually to the U. S. for slaughter. The exchange rates used in the conversion were obtained from Wharton Research Data Systems (2006). The exchange rate closest to the Canadians auction market week ending date was applied. Three other beef price series were included in the analysis: the Cutter Cut-out value; the fresh boneless beef 90 percent lean trimmings; and the Australian-New Zealand 90 percent lean market report on the East Coast dock. These prices were all obtained from the Livestock Market Information Center (LMIC 2006).

Means and standard deviations for each of the price series are reported in Table 1. There is frequently no market report for the auctions the week of Christmas or New Years, depending on which day of the week the holiday falls. In the event there were no reports for those two weeks, those dates were omitted from the analysis. The data were also split into pre-BSE and post-BSE periods. The week end-

Table 1. Descriptive Statistics for Weekly Price Data for Nine U.S. Cull Cow Markets, Two Canadian Cull Cow Markets, Cutter Cut-Out Value, Fresh Beef 90% Lean Trimmings Market, and Australian-New Zealand 90% Lean Import Market.[a]

	Continuous (No dropped dates for market adjustment)			Pre BSE (From 01/06/01–05/24/03)			Post BSE (From 09/06/03–12/17/05)		
Market	Mean	Std dev	Weeks[b]	Mean	Std dev	Weeks[c]	Mean	Std dev	Weeks[d]
Georgia	43.13	7.09	253	37.86	3.64	123	49.07	5.42	116
St. Paul	44.4	7.22	253	38.98	4.74	123	50.47	4.49	116
Billings	41.83	6.91	253	36.62	4.56	123	47.47	4.59	116
Clovis	41.52	6.83	253	36.06	2.49	123	47.62	4.38	116
Oklahoma City	44.22	7.33	253	38.55	3.66	123	50.66	4.98	116
Lancaster	42.71	5.52	253	39.34	4.15	123	46.69	4.28	116
Sioux Falls	45.47	7.24	253	39.63	3.39	123	51.65	5.2	116
San Angelo	39.79	6.05	253	35.54	3.84	123	44.82	4.05	116
Torrington	42.07	6.83	253	36.58	3.73	123	47.95	4.5	116
Alberta	30	11.43	253	40.45	4.69	123	20.25	5.17	116
Ontario	32.03	12.64	253	43.25	4.47	123	21.44	4.37	116
Cutter Cut Out	98.84	12.04	253	89.12	5.54	123	109.62	7.96	116
90%L Trim	123.67	16.16	253	111.58	8.38	123	137.3	11.99	116
90%L Imports	115.97	16.19	253	103.97	7.28	123	131.15	8.68	116

[a] All values are in U.S. dollars per hundred pounds (cwt).

[b] January 2001 through December 2005, with the weeks of Christmas and New Years excluded if no data were available.

[c] January 2001 through May 17, 2003, with the weeks of Christmas and New Years excluded if no data were available.

[d] September 6, 2003 through December 2005, with the weeks of Christmas and New Years excluded if no data were available.

ing May 17, 2003 was the last week in the pre-BSE period, as the U.S. closed the border for beef trade with Canada on Tuesday, May 20, 2003. The week of September 6, 2003 was used as the first week in the post-BSE period; this followed the August 27, 2003 reopening of the border to beef from cattle less than thirty months of age. Observations between May 17 and August 31 were not included in either period as the markets, particularly the Canadian markets, were in an adjustment period.

Methods

A directed acyclical graphing (DAG) methodology was used to determine the contemporaneous relationships, or causal flow, among the fourteen weekly time series. The DAG was developed by Pearl (1995) and Spirtes, Glymour and Scheines (1983). The application directly applicable to this work was the price discovery work on the millet market in Bamako, Mali, by Bessler and Kergna (2002). This methodology, however, has been used in many other applications where the discovery of price is a focal point. Bessler and Davis (2004) applied these methods to market classes of livestock in the Texas cattle market and determined that heavy heifer classes (600–700 and 700–800 pound categories) were the causal force in the Texas feeder cattle market. Stockton and Feuz (2006) in a similar way applied this approach to determine the causal relationships between market classes of cull cows in the Sioux Falls, South Dakota market.

Much like the Bessler and Kergna (2002) study, we determined the flow of information or the discovery of prices. In this study however, the flow of information is determined twice, before and after the BSE ban. This pre- and post-ban analysis provides an illustration of the market-information-flow changes and at the same time documents the net effects of those changes on the price-discovery relationships. This documentation is based on the statistical properties of the DAG methodology and establishes an empirical way to pinpoint and reveal the nature of the structural changes that occurred.

Sufficient time has elapsed since the ban to obtain a reasonable amount of information to justify a division of the data and the construction of such models.

Before more is said about the mechanics of the DAG process, it is helpful to understand the premise for using the DAG. Most economic data is secondary or non-experimental in nature and does not provide for the direct identification of cause and effect, so the relationships among variables must be specified by some other means. The most common method of specifying those relationships is the development and use of economic theory. Unfortunately, economic theory does not always provide all of the information needed to adequately model the project in question. This fact is clearly expressed in the literature, which is replete with discussions regarding functional-form and model-specification issues. The DAG methodology is an attempt to replace subjectivity with theoretical empiricism, to go beyond theoretical intuition and provide an empirical method of identifying the causal relationships omitted by current theory.

Typically an econometric model is expressed in terms of the left-hand-side variable being a function of the right-hand-side variable(s). Gujarati (2003) states in his introductory econometrics book,

> “the dependant variable is expressed as a linear function of one or more of the explanatory variables. In such models it is assumed implicitly that causal relationships, if any, between the dependent and explanatory variables flow in one direction only, namely from the explanatory variables to the dependent variable.” (15)

This concept applies not only to linear models but to econometric models in general. It is therefore expedient to carefully distinguish between the causes and effects, thus justifying the use of the DAG to provide the missing information.

While understanding the DAG process is important, detailed explanation will be left to others who have provided ample iterations in the literature, making the explanation here brief and simplistic. A good overview and brief description of the development and characteristics of the DAG process and corresponding assumptions as applied here are found in Casillas-Olvera and Bessler (n.d.).[1]

The DAG method employed here is actually a two-step procedure, which some have identified as either a complete time series (CTS) approach (Stockton et al.) or a dual engine approach (Bessler and Davis 2004). The CTS is complete in the sense that a vector auto-regressive model (VAR) or error-correction model (ECM) is first fit to the data to filter out the dynamic effects, after which the innovations, or errors, are used to draw the actual representation, which can then be decomposed in proper order. A DAG is a drawing of a series of lines with arrows pointing in the direction of cause and effect between vertices, variables where the pattern of flow is non-circular. The relationships represented by lines and arrows are drawn based on statistical pair-wise correlations and the changes in that correlation based on considering the effect of dependency on a third dually correlated variable. This latter concept is called screening-off or, formally, d-separation.

For example, the visual representation, or graphoid, “A→B” indicates that variable A causes variable B. Two other variables represented by “C – D” indicate that C and D are associated but not directed, the cause remaining unknown; we neither know if C causes D or if D causes C. The d-separation concept is used to establish direction or direct arrows, as would be the case where three variables E, F, and G are all correlated or associated with each other; where the variable F is a common cause of E and G and drawn as “E←F→G”. The directional flow is implied by the fact the unconditional association between E and G is non-zero and the conditional association, conditional on F, is zero. The variable F acts as a screen between the variables E and G,

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[1] Please contact David Bessler, Texas A&M University.

and E and G are effectively "screened off" by F. Among these three correlated variables, only three other possible combinations of directional flow or cause would be possible, represented as "E←F←G", "E→F→G", and "E→F←G". In each of these three cases effects are not tied to a common cause. Therefore without further information regarding the three variables, the only instance where direction may be assigned is where d-separation or screening-off occurs. Once the relationships among the three variables are established, determining the causal nature of a fourth correlated variable such as H may provide needed information to direct in the case where causal flow is undetermined. If it is assumed that H is correlated with F, where F is not the common cause of E and G but is the common cause of G and H, d-separation occurs in F for G and H and is represented by the directed graph "G←F→H". The undirected edge between E and F could then be directed by default. Knowing that "E←F→G" is not true leaves only two other possibilities: "E←F←G" or "E→F→G". But, knowing that "G←F→H" is true, we reject that "F←G" leaving only one possible relationship which is directed as, "E→F→G". Combing this knowledge with the "G←F→H" information leads to the completed four variable DAG drawn in Figure 2. This brief explanation is intended to illustrate the logic of creating DAGs, and does not represent the actual application used to create them.

DAG maps are built assuming three basic axioms. These axioms are not dissimilar from the basic axioms used to establish an OLS regression model (Kennedy). However, rather than obtaining parameter estimates, the DAG applies a statistical testing regime used to associate variables by establishing edges and then directs relationships by pointing edges between variables or vectors. The three axioms are: 1) any variables found to have relationships do indeed have those relationships (similar to the commonly made assumption about the unbiased nature of the OLS estimator, that the expected value of the estimate is equal to the actual value of the relationship; 2) any variable associated with another variable has an edge directly to that variable, and associations between variables separated by one or more generations are all passed through the adjacent variables (this could be likened to the functional form which is applied, where, for example, the relationship is assumed to be linear); 3) no significant variable has been left out of the model (this axiom relates to the OLS assumption of no omitted variables, where none are assumed to be left out). Without going into further detail, the point is that the assumptions are no more rigorous than those imposed by the commonly used OLS procedure. Like the OLS procedure, the value and applicability of the DAG results reside in its appropriate application and judicious use.

To create the DAG, it was necessary to identify and account for the dynamic relationships present in the data. This required the building of a dynamic model such as a vector auto-regression model (VAR) or an error-correction model (ECM). The VAR or ECM is used to account for the time order or non-contemporaneous relationships inherent in the data, leaving the resulting innovations containing the contemporaneous relationships and white noise. The first step in building either of these models is to determine the integration level of the data. In a time-series analysis, integration level refers to the data stream's tendency to return to its mean. An integration level of 0, I(0), indicates that the data tends to return to its mean, whereas a data series that returns to its mean after taking the difference between itself and its first lag would have an integration level of 1, or I(1). This required testing each of the fourteen data series with an augmented Dickey-Fuller (ADF) test to determine the integration level of stationarity. We found that the data were generally I(1), which, combined with the visual inspection of the graphed data, where the markets appear to be cointegrated, made the use of the VAR model in the time-series portion of the CTS methodology an appropriate choice. The co-integration assumption was verified using a modified Dickey-Fuller (MDF) test on the fourteen innovation errors, from the vector auto-regression (VAR) (Griffiths, Hill, and Judge 1993). The unrestricted level of the VAR was based on the use of an Akaike loss function. The innovations from the VAR were then used in creating a correlation matrix which served as the input for the DAG analysis. The construction of the DAG was completed using a Bayesian search algorithm, specifically the greedy equivalent search (GES) algorithm found in the TETRAD IV program (see http://www.phil.cmu.edu/projects/tetrad/ and Scheines et al. 1996).

Casillas-Olvera and Bessler (n.d.) describe the GES as a "two phase search algorithm that looks

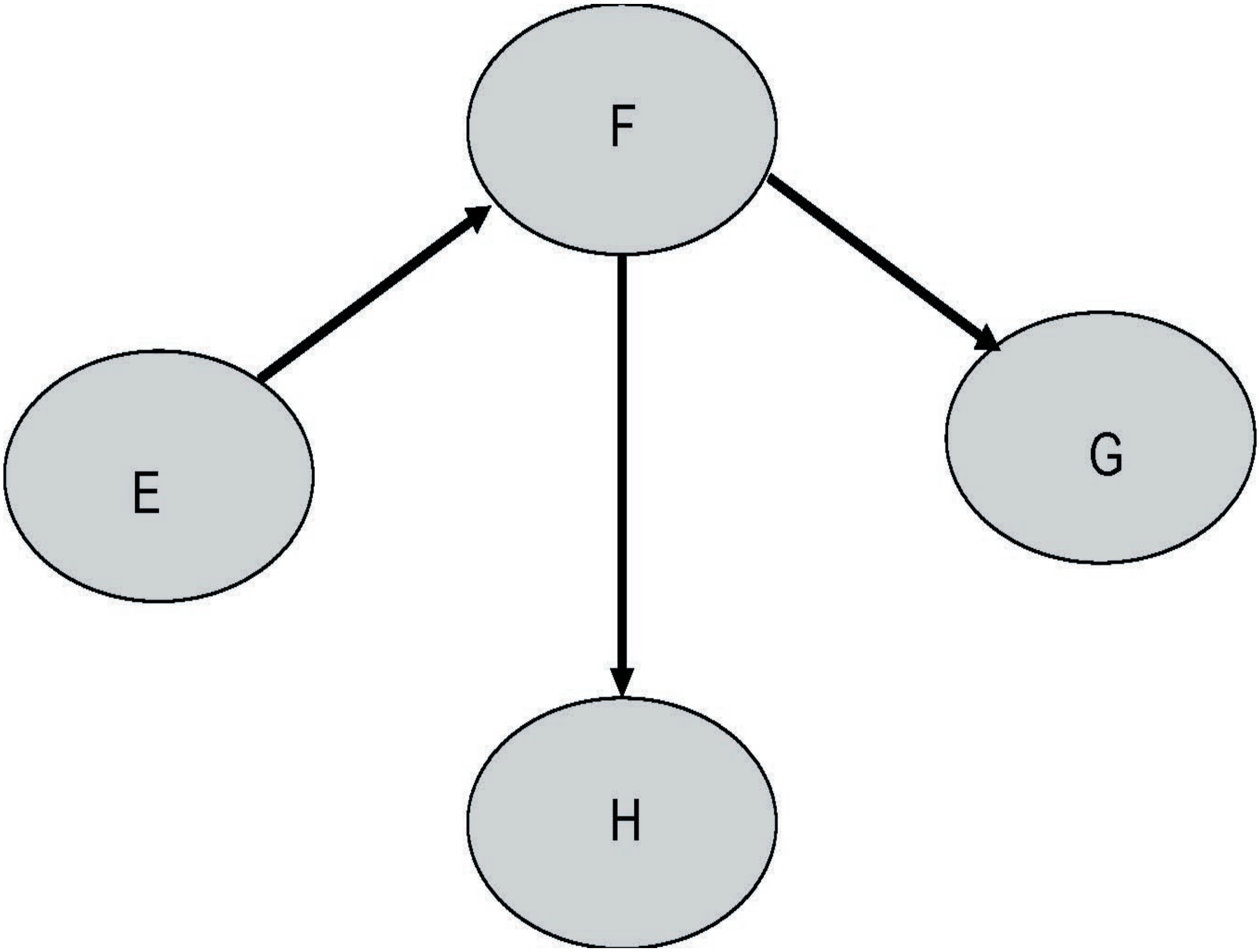

Figure 2. An Example of a Four-Variable DAG.
In a DAG, each of the lines is known as an edge and each edge indicates a relationship between the connected variables. The arrow or lack of an arrow at the end of each line indicates the direction of causality or the causal relationship. In the graph above, information from E flows to F and information from F flows to G and H, where G and H are information sinks, or dead ends, and E is an information source.

over equivalence classes of DAGs starting from a DAG representation with no edges." It is important to note that a DAG without edges implies that all variables are independent of each other. The GES algorithm proceeds in a stepwise fashion, searching over more and more complex DAG representations.

The first phase of the GES adds or reverses arrow direction by using the representation that maximizes the Bayesian loss criterion function for a single iteration. The GES continues to iterate in this first phase until no additional gain can be made in the loss function. Upon completion of the first phase, the second phase commences with the specification of the last iteration of the first phase. It then proceeds through another series of iterations, this time removing edges or reversing arrow directions of existing edges. Again, during this second phase, the GES only selects the DAG specification for that iteration where the Bayesian loss function increases, relative to all other alternative increases in that loss function, selecting the one with the greatest increase; thus the title, greedy search algorithm. Further explanation of this algorithm is described in detail in Chickering (2002), and again briefly in Casillas-Olvera and Bessler (n.d.).

Results

A graph (Figure 1) of all fourteen data series shows that the market classes of cull cows appear to move in a cointegrated fashion. The Canadian cull cow price series for both Ontario and Alberta drop considerably relative to the U.S. cull cow prices near the end of May, coinciding with the BSE-induced trade ban. The build-up of Canadian cull cow supply and the reduction in cull cows available in the U. S., created by the ban, tend to support the hypothesis that during this period causal relationships between the two nations' cull cow markets had changed. The ADF was used for three different periods of the data series. The complete data set as a whole consisted of 253 weeks of observations. The second data set for the weeks proceeding May 24, 2003—referred to here as the pre-BSE-ban period—was made up of 123 weeks of observations. The third data set—the post-BSE-ban period—covers a 116-week period starting in September 6, 2003. The period from May 24, 2003 to September 6, 2003 was omitted to allow the market to settle after the announcement of the BSE ban.

Each of the fourteen variables was tested for stationarity at two levels for each of the three data sets. The complete data set was found to have all fourteen price series stationary at I(1), first difference, at any confidence level (Table 2). The pre-BSE-ban data set was found to have three market series stationary at I(0) with a 95-percent confidence level: Clovis, Georgia, and San Angelo (Table 3). The post-BSE-ban data set has three market series at the same stationarity: Clovis, Oklahoma City and San Angelo (Table 4). While the two shorter

Table 2. Results of the Augmented Dickey-Fuller Test on all Fourteen Price Series for the Complete Period.

	Integration level			
	I(0)		I(1)	
Market	Test statistic	p-value	Test statistic	p-value
Alberta	1.30	0.630	−13.43	0.000
Billings	−1.57	0.497	−14.78	0.000
Clovis	−1.50	0.532	−12.91	0.000
Cut Out	−1.42	0.574	−13.20	0.000
Georgia	−1.41	0.576	−13.93	0.000
Imports (Australia)	−1.52	0.524	−6.47	0.000
Lancaster	−1.61	0.477	−14.38	0.000
Lean Trimmings	−1.88	0.344	−13.74	0.000
Oklahoma City	−1.49	0.538	−13.21	0.000
Ontario	−1.02	0.746	−14.24	0.000
San Angelo	−1.98	0.298	−13.17	0.000
St Paul	−1.35	0.608	−12.98	0.000
Sioux Falls	−2.13	0.232	−14.37	0.000
Torrington	−1.68	0.439	−20.67	0.000

Table 3. Results of the Augmented Dickey-Fuller Test on the Fourteen Pre-BSE-Ban Price Series.

	Integration level			
	I(0)		I(1)	
Market	Test statistic	p-value	Test statistic	p-value
Alberta	−1.27	0.641	−9.11	0.000
Billings	−2.24	0.194	−10.16	0.000
Clovis*	−2.89	0.049	−10.51	0.000
Cut Out	−1.97	0.298	−9.16	0.000
Georgia*	−3.43	0.012	−13.81	0.000
Imports (Australia)	−1.38	0.589	−10.48	0.000
Lancaster	−1.91	0.328	−11.17	0.000
Lean Trimmings	−2.73	0.071	−9.67	0.000
Oklahoma City	−1.91	0.329	−5.83	0.000
Ontario	−1.78	0.388	−9.12	0.000
San Angelo*	−3.85	0.003	−14.81	0.000
St Paul	−1.19	0.678	−9.80	0.000
Sioux Falls	−2.62	0.092	−10.04	0.000
Torrington	−1.78	0.388	−14.50	0.000

*Statistically significant at the 5-percent level.

data sets contain series which vary in integration level, the overall data showed all series to be of the same integration level. Since the complete data series were all I(1), a VAR was used rather than an error-correction model. The pre-BSE-ban models had a Schwarz loss criterion that indicated a VAR(1) system; the Akaike criterion indicated a VAR(2) system. However, since the Akaike loss function is considered to perform more accurately on smaller sample sizes, a VAR(2) was used. The best-fit VAR model reflected by the lowest Akaike and Schwarz loss criterion was a VAR(1) for the post-BSE-ban data set (Table 5). The use of the VAR rather than an ECM was supported by a modified Dickey-Fuller (MDF) on the innovations or error terms, which showed them all to be stationary at the I(0) level for both the pre- and post-BSE models (Tables 6 and 7).

Showing that the innovations are stationary not only confirms that the VAR was the appropriate model of choice but also that the data series are cointegrated and that the estimates resulting from the VAR are superconsistent[2] (Griffiths, Hill, and Judge 1993). The residuals (innovations) from the two VARs were then used to construct the two covariance matrices (Tables 8 and 9). The covariance matrices were the data source for the GES algorithm found in Tetrad IV and were used to create both DAGs (Figures 3–5).

The DAG for the pre-BSE ban period has twenty-three edges, including four undirected edges: those between cutout and Lancaster, cutout and Georgia, cutout and lean trim, and lean trim and San Angelo. The Oklahoma City and Ontario markets and the cutter cut-out value had the most associated edges, six each. Each of these three markets had three out-going edges, with Ontario and Oklahoma City having three in-coming edges and the cutter cut-

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[2] The OLS "estimator works better, in that it converges to the true parameter value faster than usual."

Table 4. Results of the Augmented Dickey-Fuller Test on the Fourteen Post-BSE-Ban Price Series.

	Integration level			
	I(0)		I(1)	
Market	Test statistic	p-value	Test statistic	p-value
Alberta	−2.24	0.194	−7.40	0.000
Billings	−2.35	0.159	−12.32	0.000
Clovis*	−3.19	0.023	−10.96	0.000
Cut Out	−2.08	0.253	−11.16	0.000
Georgia	−2.62	0.092	−9.29	0.000
Imports (Australia)	−2.57	0.103	−8.61	0.000
Lancaster	−2.41	0.141	−10.59	0.000
Lean Trimmings	−2.15	0.227	−11.32	0.000
Oklahoma City*	−3.33	0.016	−14.35	0.000
Ontario	−1.86	0.351	−10.46	0.000
San Angelo*	−3.04	0.034	−9.83	0.000
St Paul	−2.03	0.273	−14.57	0.000
Sioux Falls	−2.07	0.258	−14.49	0.000
Torrington	−1.51	0.523	−13.28	0.000

*Statistically significant at the 5-percent level.

out market having three undirected edges. No individual market was found to be a definitive source of market information. Five markets—Lancaster, Georgia, San Angelo, lean trim, and the cutter cut-out markets—were potentially sources of information, but due to undirected edges remained undetermined. In the case of these five markets, four of them were at least conduits of information, markets that transfer information from at least one market to another market or markets. The exception was San Angelo, which could possibly have been an information sink, a point where information is collected. Three of the auction markets and one product market were sinks of information: Alberta, St. Paul, Billings, and East Cost dock imports (Figure 3). Information flow tends to be east to west, and south to north. The exception to the south-to-north tendency was the flow of information from Ontario to Billings and St. Paul.

The post-BSE-ban DAG (Figures 4 and 5) has twenty edges, three less than the pre-BSE-ban DAG, with changes in all edges but one. Five edges changed direction and fourteen new edges were identified, indicating that seventeen of the pre-BSE edges were dropped. The new flows of information suggest that a huge change had taken place in the way these markets interact. Sioux Falls, Torrington and San Angelo each potentially became information sinks. Ontario became a singularly connected node to Billings and no longer provides information to the Alberta or St. Paul markets, nor does it pass information to Sioux Falls, Lancaster, and Oklahoma City. The south-to-north, east-to-west information flow tendency is no longer observable. Alberta becomes the Canadian market source of information, replacing Ontario. Information flows from Alberta to cutter cut-out, Torrington, and Sioux Falls, with two undirected edges to St. Paul and the lean trimmings market. Oklahoma City, which for the pre-BSE-ban period channeled information

Table 5. Modified Dickey-Fuller* Test for the Pre-BSE-Ban Data Series.

	I(0)	
Market	Test statistic	p-value
Alberta	−15.36	0.000
Billings	−15.65	0.000
Clovis	−15.53	0.000
Cut Out	−12.49	0.000
Georgia	−14.44	0.000
Imports (Australian)	−15.74	0.000
ancaster	−15.28	0.000
Lean Trimmings	−13.01	0.000
Oklahoma City	−15.85	0.000
Ontario	−15.83	0.000
San Angelo	−15.70	0.000
St paul	−15.58	0.000
Sioux Falls	−15.65	0.000
Torrington	−15.72	0.000

*The MDF has a slightly different statistical significance level then the Standard ADF.

from south and east to north and west, now channels information solely to the southeast and the East Coast import market.

Implications

The comparison of the pre- and post-BSE-ban DAGs clearly indicates that causal relationships did change with the initiation of the BSE trade ban. The graph of the raw price data shows that Canadian market prices declined sharply relative to the U.S. prices following the trade ban, supporting the idea that Canada is very dependent upon the U.S. market for its cull cows. The exclusion of the Canadian cull cows from the U.S. changed the relationships and information flow among several U.S. regional markets, both with Canadian regional markets and with other U.S. regional markets. The east Canadian market became almost completely isolated, with the removal of five edges. Eastern and western Canadian markets became completely separated from each other, which is probably an effect of the human population numbers verses the cull cow numbers—eastern Canada has a greater human population, while western Canada has a greater number of beef cattle: 70 percent of all Canadian beef cattle are in Alberta and Saskatchewan. The western Canadian market became more active and became the dominate source of information flow in Canada, adding four new edges of information flows to the U.S.. Interestingly, in the pre-BSE-ban period the east Canadian market passed information to three sinks (a point where information flows in but never out) in the U.S., while post-BSE-ban data show it is the west Canadian market which passes information to U.S. information sinks. Furthermore, the two U.S. post-BSE-ban information sinks were not the same as the pre-BSE-ban sinks. Post-BSE-ban information flows increased between western Canada and non-auction markets, markets where world supplies would have an effect, such as the cut-out and lean trim markets. These results are consistent with the idea that Canada would go elsewhere with its cow beef.

Table 6. Modified Dickey-Fuller* Test for the Post-BSE-Ban Data Series.

	I(0)	
Market	Test statistic	p-value
Alberta	7.17	0.000
Billings	−10.50	0.000
Clovis	−9.90	0.000
Cut Out	−9.86	0.000
Georgia	−8.49	0.000
Imports (Australia)	−8.84	0.000
Lancaster	−10.36	0.000
Lean Trimmings	−10.33	0.000
Oklahoma City	−9.79	0.000
Ontario	−9.71	0.000
San Angelo	−11.13	0.000
St Paul	−11.17	0.000
Sioux Falls	−12.09	0.000
Torrington	−11.87	0.000

* The MDF has a slightly different statistical significance level then the Standard ADF.

Table 7. Lag-Length Choice Criterion: Number of Lags in the Unrestricted Model.

Data series	**VAR (1)**	**VAR (2)**	**VAR (3)**	**Criterion**
Pre-BSE ban	55.52	52.28	52.67	Akaike Loss Criterion
	58.46	61.66	66.65	Schwarz Loss Criterion
Post-BSE ban	53.91	54.04	54.29	Akaike Loss Criterion
	58..92	63.79	68.82	Schwarz Loss Criterion

Table 8. Pre-BSE-Ban Innovation Correlation Matrix.

	Alberta	Billings	Clovis	Cut Out	Georgia	Imports	Lancaster	Lean Trim	Oklahoma City	Ontario	San Angelo	St Paul	Sioux Falls	Torrington
Alberta	1.00													
Billings	0.32	1.00												
Clovis	0.17	0.39	1.00											
Cut Out	0.33	0.43	0.54	1.00										
Georgia	0.32	0.36	0.48	0.59	1.00									
Imports	-0.02	0.14	0.31	0.27	0.12	1.00								
Lancaster	0.25	0.44	0.33	0.52	0.36	0.22	1.00							
Lean Trim	0.30	0.37	0.48	0.72	0.45	0.26	0.43	1.00						
Oklahoma City	0.25	0.45	0.46	0.53	0.53	0.05	0.50	0.51	1.00					
Ontario	0.52	0.45	0.22	0.44	0.41	0.07	0.46	0.43	0.55	1.00				
San Angelo	0.01	0.11	0.12	0.24	0.07	0.21	0.17	0.33	0.19	-0.02	1.00			
St Paul	0.23	0.28	0.31	0.38	0.26	0.09	0.38	0.38	0.30	0.43	0.14	1.00		
Sioux Falls	0.28	0.43	0.41	0.46	0.40	0.13	0.30	0.35	0.35	0.40	0.02	0.25	1.00	
Torrington	0.29	0.50	0.38	0.43	0.33	0.20	0.42	0.36	0.51	0.40	0.21	0.22	0.52	1.00

Table 9. Post-BSE-Ban Innovation Correlation Matrix.

	Alberta	Billings	Clovis	Cut Out	Georgia	Imports	Lancaster	Lean Trim	Oklahoma City	Ontario	San Angelo	St Paul	Sioux Falls	Torrington
Alberta	1.00													
Billings	0.06	1.00												
Clovis	0.32	0.04	1.00											
Cut Out	0.42	-0.02	0.39	1.00										
Georgia	0.25	-0.05	0.27	0.54	1.00									
Imports	0.26	0.20	0.20	0.46	0.31	1.00								
Lancaster	0.36	0.02	0.27	0.57	0.54	0.26	1.00							
Lean Trim	0.50	0.06	0.46	0.38	0.21	0.25	0.33	1.00						
Oklahoma City	0.41	-0.01	0.38	0.99	0.53	0.46	0.55	0.39	1.00					
Ontario	0.13	0.38	-0.02	0.08	0.02	0.20	0.01	0.09	0.10	1.00				
San Angelo	0.26	-0.05	0.26	0.31	0.27	0.32	0.18	0.37	0.31	-0.08	1.00			
St Paul	0.58	-0.02	0.34	0.35	0.25	0.17	0.24	0.45	0.34	0.07	0.23	1.00		
Sioux Falls	0.39	-0.20	0.23	0.43	0.28	0.26	0.20	0.26	0.42	-0.07	0.21	0.34	1.00	
Torrington	0.48	-0.03	0.35	0.33	0.36	0.14	0.29	0.33	0.32	-0.01	0.18	0.34	0.26	1.00

These preliminary findings point to major structural changes in the flow of cull cow market information resulting from the ban and point to a need for further analysis of this market. Has this structural change in information flow continued? What are the implications to long-run trade relations and to the other cattle markets? When or if normal free trade in cattle over thirty months of age is permitted between the U.S. and Canada, will pre-BSE market-information flows return, will the present market-information flows persist, or will there be completely new market-information flows? The BSE-related trade restrictions between the U.S. and Canada altered the North American cull cow markets. While these price fluctuation have certainly altered producers' management and marketing practices, even if only temporarily, what effect will this have on the cyclical nature of the inventory and price cycle in the U.S.?

This paper uncovers and maps the effects of the 2003 BSE ban between the U.S. and Canada. While some value is found in the support of the expectation that the ban created shifts in market flows consistent with Canadian and U.S. dependency, the isolated Canadian market found new connections with the world markets. The challenge now is to continue to interpret those findings and discover further value in their existence. Additional value to the profession is derived from the use of the DAG in a unique way, with the pre-BSE and post-BSE analyses exposing the changes created by the ban. Even more value could be recognized if and when the information from the DAG (the use of the information flows) is incorporated into econometric models. The econometric models once developed could in turn be used to estimate the quantitative effects created by the ban. Secondary effects are also present and, while unintended, are not insignificant; these include the use of the DAG in this unique way, providing for further discussion and investigation into its application as a viable tool to identify and work with structural-change questions. For example if there had been no difference between the pre- and post-BSE DAGs it could be concluded either that the DAG was misapplied or that there is an absence of structural change.

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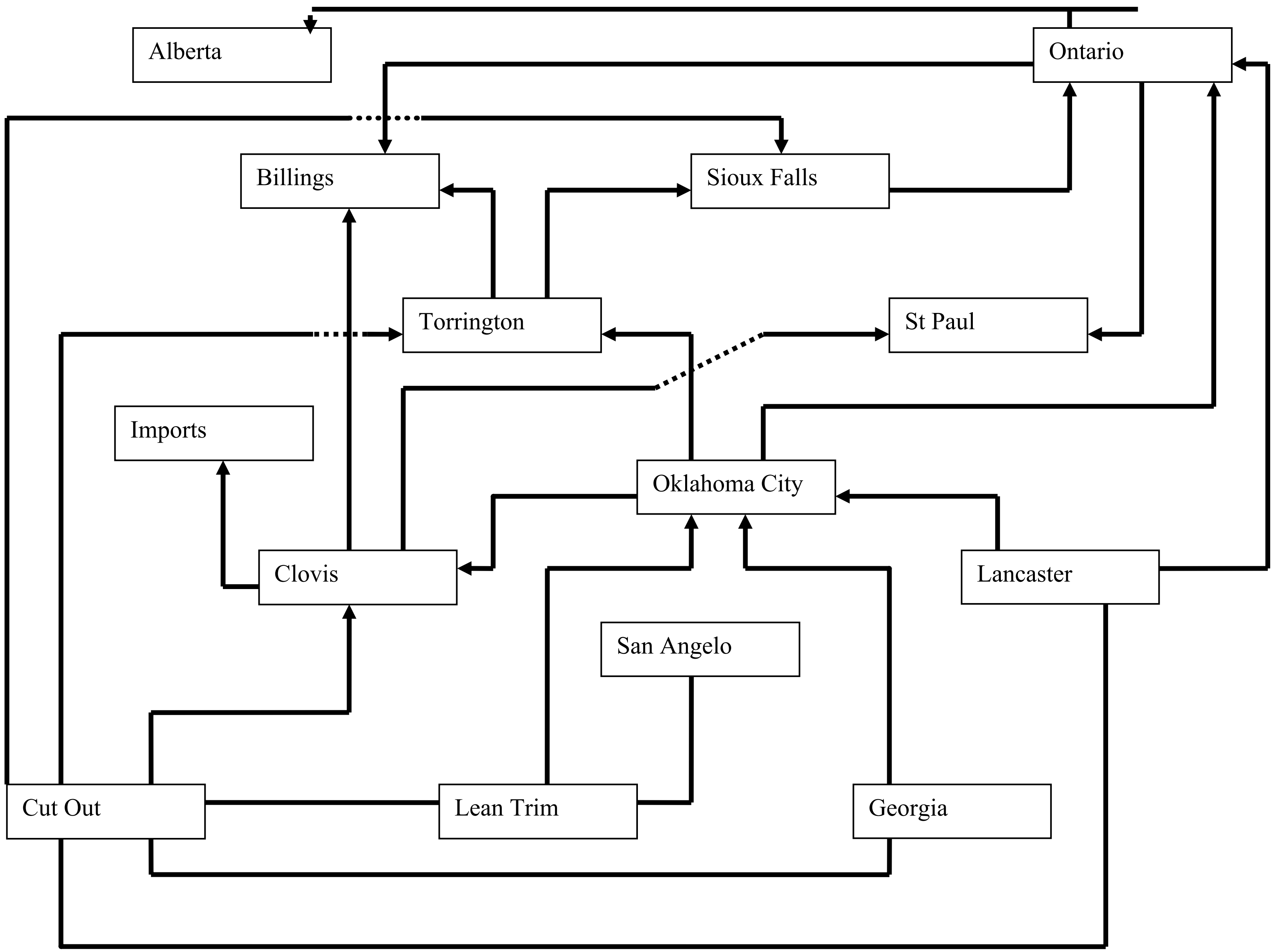

Figure 3. Pre-BSE-Ban Cull Cow Market DAG.

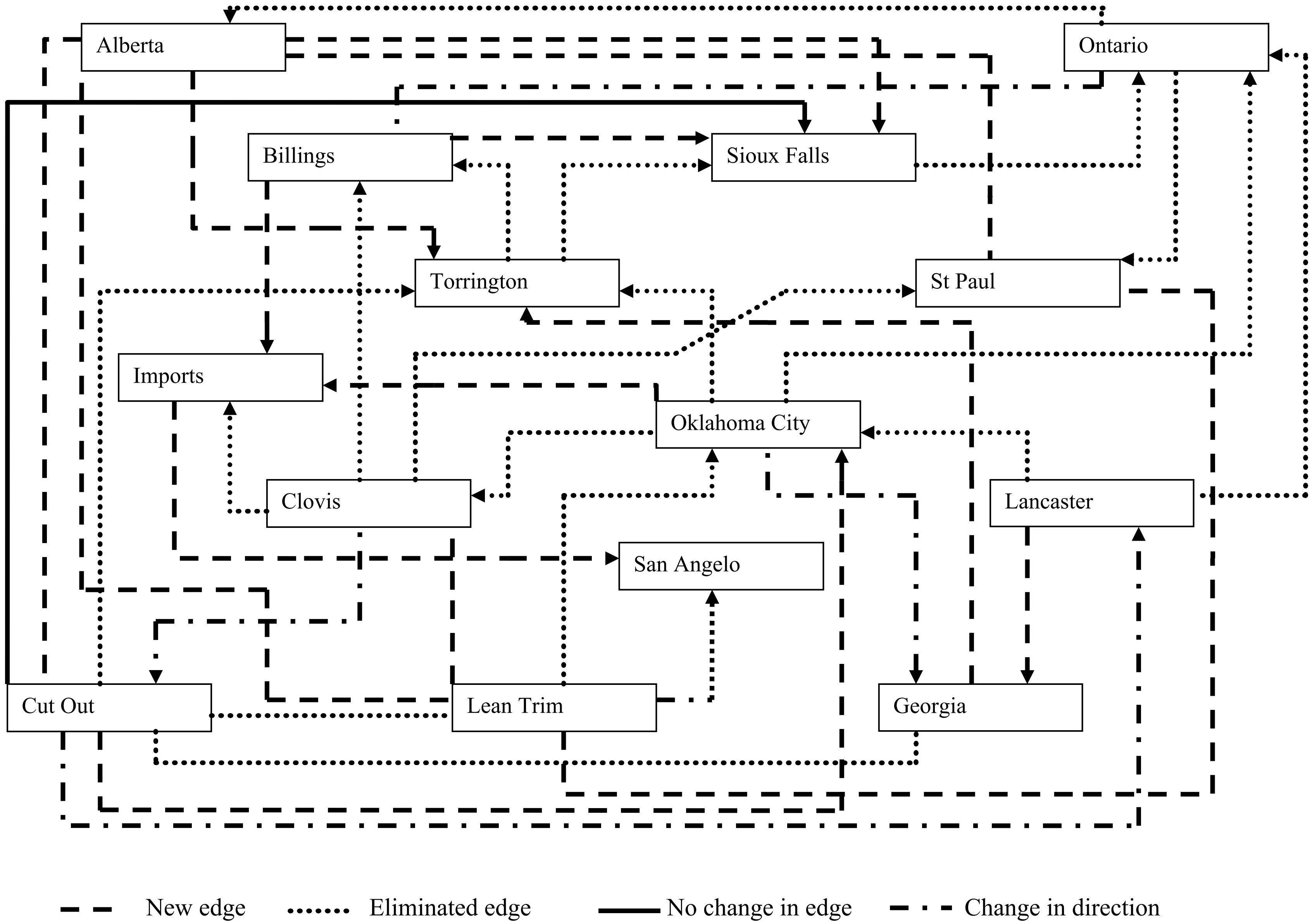

Figure 4. Post-BSE-Ban Cull Cow Market DAG (Removed Edges Included).

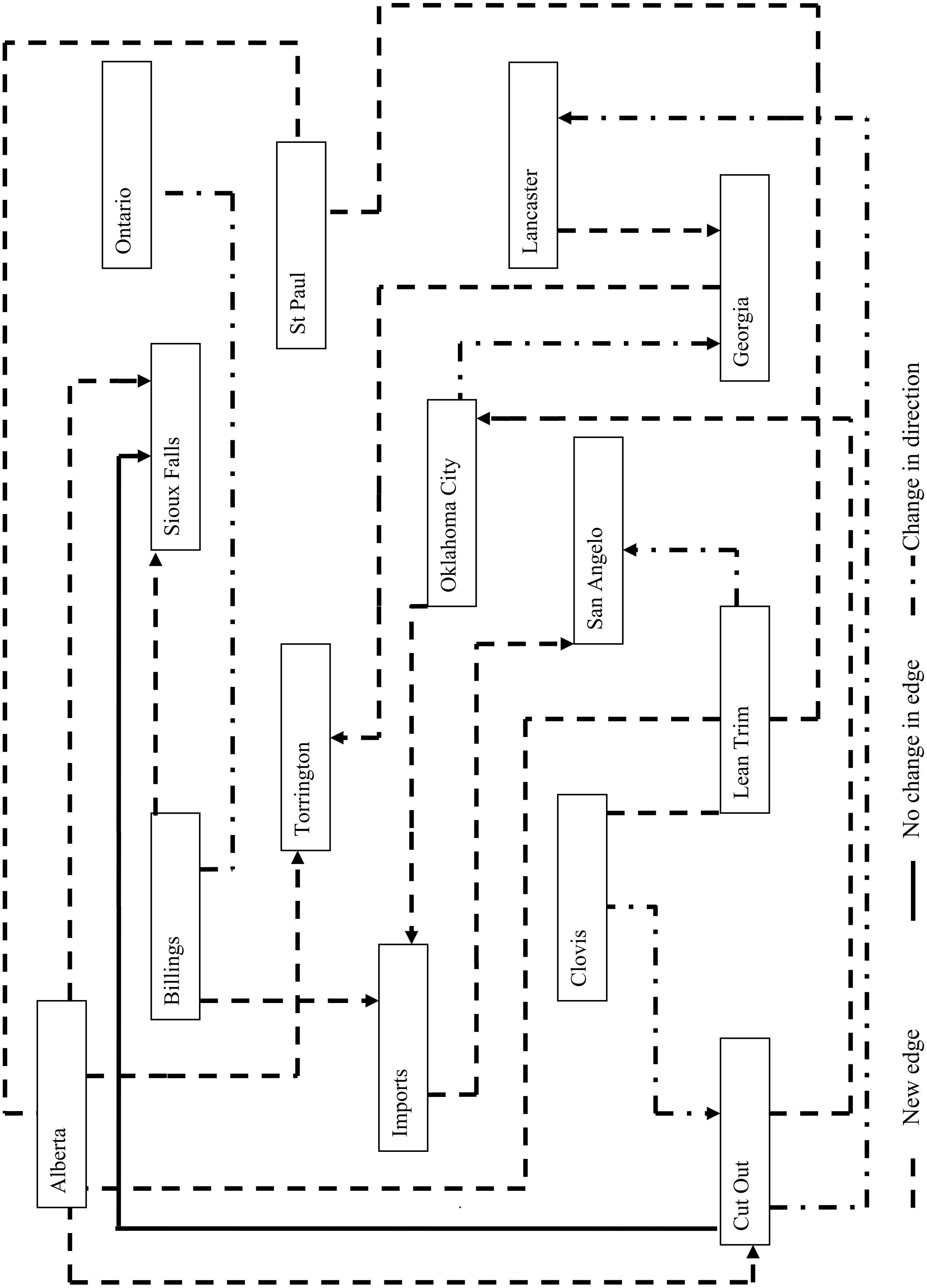

Figure 5. Post-BSE-Ban Cull Cow Market DAG (Removed Edges Not Shown).