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Long-run impacts of trade shocks and export competitiveness: Evidence from the U.S. BSE event

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Abstract

This paper examines how comparative advantages of major beef exporters changed following the 2003 bovine spongiform encephalopathy (BSE) outbreak, which significantly disrupted the U.S. beef trade until approximately 2007. Using longitudinal data on beef export values and constructed revealed comparative advantage measures, we show that while some measures of the long-run impacts of BSE on U.S. beef export competitiveness have returned to pre-2003 levels, the U.S.'s comparative advantage has not. We also examine a hypothetical scenario of no BSE event in 2003 and predict that in the absence of the BSE outbreak, the U.S. beef sector would have been increasingly more competitive by 2017 than it actually was. Long-term trade competitiveness may not simply return to normal even after a short-term disruption.

KEYWORDS

beef exports, BSE, comparative advantage, competition, international trade, trade disruption

JEL CLASSIFICATION

F12, Q17

1 | INTRODUCTION

Shocks from trade disputes, phytosanitary emergencies, and weather impact agricultural export markets. Affected exporters always hope such events are short-lived, yet even when they are, trade interruptions can take time to return to normal. The United States' 2012 drought created opportunities for non-U.S. corn exporters to increase market share in South Korea where the United States is still trying to rebuild its share (USDA-ERS, 2020). A trade dispute beginning in 2018 between the United States and China that led to additional tariffs on U.S. agricultural products including corn, soybeans, cotton, and pork is another example (Marchant & Wang, 2018). Notably, the price spread between United States and Brazilian soybean exports widened to a record-high immediately after tariffs were imposed by China around the middle of 2018, with the U.S. soybean export price remaining low relative to the Brazilian price throughout the rest of the year (Good, 2018). By assuming the tariffs on U.S. agricultural goods remain in effect for the next 10 years, the United States Department of Agriculture (USDA) predicts that U.S.

soybean exports would not return to pre-trade-war levels until 2028 (O'Donoghue, Hansen, & Stallings, 2019).

In late 2019 and early 2020, the United States and China announced a "Phase one" agreement returning some tariffs to pre-2018 levels and freezing others. Nevertheless, the competitive structure of markets may have adjusted in the interim. U.S. farmers are rightly concerned that adverse effects of even short-lived disruptions could permanently alter market relationships as other exporters erode the U.S.'s share in global markets (Balistreri et al., 2018; Elmer & Crampton, 2019; Hirtzer, 2019). In particular, once China finds new trading partners, renegotiation costs can slow any returning market share just as it did for U.S. grain markets following the short-lived 1980 U.S. embargo of the former Soviet Union (Balistreri et al., 2018). Similar evidence can be observed from the recent African Swine Fever outbreaks in China. As the Chinese demand for pork in the global market surged, the United States, in part due to the then ongoing U.S.-China trade disputes, failed to capture as much share of the market compared to major competitors in Europe and Latin America (Xiong & Zhang, 2019).

In this paper, we shed light on how long it takes an export market to recover from a trade disruption. Although at this writing, the current U.S. and China trade disruptions are making headlines, it is difficult to forecast long-run outcomes for something that has limited data. We simply do not know the extent to which the disputes are permanently changing export relationships. The outbreak of bovine spongiform encephalopathy (BSE), also known as mad cow disease, in December 2003 in the United States provides an imperfect yet insightful case study. At the time of the outbreak, it was unclear what the long-run implications to U.S. beef might be. From January 2004 through approximately April 2007, U.S. beef trade with many countries vanished, was restricted, or was intermittent (USDA-FAS, 2019). Using longitudinal data on beef export values, we study the long-run impacts of BSE on U.S. beef export competitiveness, construct the hypothetical scenario of no BSE event in 2003, and then predict what competitiveness might have looked like for the U.S. beef sector.

We create an empirical proxy to measure country-level beef industry comparative advantage over time: the indicator for competitiveness in our study. We show that while the U.S. beef export values have mostly recovered to their pre-BSE levels, the U.S.'s comparative advantage is yet to return to where it was prior to the BSE outbreak. We jointly estimate the effect of the BSE outbreak on the comparative advantages of other major exporters. We find that in the absence of the 2003 U.S. BSE event, the U.S. would have kept its comparative advantage in beef; moreover, its competitiveness would have grown over time. The results indicate significant lingering impacts of BSE on U.S. beef competitiveness that are less obvious when examining export values alone.

This study contributes to the literature in the following ways. First, we construct a modified revealed comparative advantage (RCA) index proposed by Yu, Cai, and Leung (2009) to present the trends of comparative advantage of the U.S. beef industry and other major competitors from year to year. The RCA index was first proposed by Balassa (1977) and reformulated in Balassa (1986), and is used frequently when looking for changes in a country's trade status (Fertö & Hubbard, 2003; Gorton, Davidova, & Ratinger, 2000). However, the original RCA index is neither symmetric nor does it hold either cardinal or ordinal properties (Hoen & Oosterhaven, 2006; Laursen, 2015; Vollrath, 1991; Yu et al., 2009). The asymmetric distribution of the RCA index would violate the normality assumption of error terms in the regression setting. As such, it is not appropriate to be used in our analysis, which aims to estimate and compare comparative advantage among countries and across time. The reformulated RCA index developed and used by Yu et al. (2009) resolves these limitations. To the best of our knowledge, no studies have used an RCA index to study the impact of BSE on beef export competitiveness.

The present research closely relates to the literature examining the trade impacts of BSE events. Morgan (2001) simulates the impacts assuming different scenarios of the effects of earlier BSE outbreaks in Europe on the international beef market showing that beef exports would return to the baseline level by 2006. Mutondo, Brorsen, and Henneberry (2009) and Panagiotou and Azzam (2010) study the welfare loss of U.S. beef producers due to trade bans after the 2003 BSE outbreaks in the United States and estimate a loss ranging from \$500 to more than \$700 million annually. Wigle, Weerahewa, Bredahl, and Samarajeewa (2007) study the effects of trade restrictions due to BSE outbreaks in Canada and find that the general equilibrium effect produces gains for consumers that partially offset producers' losses. However, these studies focus on short-run effects. Using the evidence of the 2003 U.S. BSE outbreaks, the unique contribution of our study is highlighting that trade impacts affect competitiveness long after the disruption ends.

Our study also fits into a broader literature that studies different aspects of the adverse economic impacts of BSE outbreaks in both the United States and other countries. Research finds negative impacts on both demand for beef products (e.g., Burton & Young, 1996; Mangen & Burrell, 2001; Peterson & Chen, 2005; Verbeke & Ward, 2001) as well as producer prices along the beef supply chain (e.g., Hassouneh, Serra, & Gil, 2010; Lloyd, McCorriston, Morgan, & Rayner, 2001; Park, Jin, & Bessler, 2008) in European countries or in major beef-importing countries in the aftermath of either local or global BSE events. Studies of BSE events in the United States have examined the effects of food scares from BSE outbreaks on cattle futures prices and beef sales adjustments, finding evidence of significant structural breaks of futures prices and adverse effects on beef sales following BSE events (Jin, Power, & Elbakidze, 2008; Marsh, Brester, & Smith, 2008; Schlenker & Villas-Boas, 2009; Taha & Hahn, 2014). We extend the literature by providing evidence of the impact of an outbreak of BSE on a country's international competitiveness.

This paper proceeds as follows. In Section 2, we provide background information on the U.S. beef sector's competitiveness in the world market, as well as a brief history of the BSE outbreak in the United States. Section 3 describes the data construction process and presents summary statistics. Section 4 lays out the empirical analyses and discusses results. Finally, Section 5 concludes and discusses future research.

2 | BACKGROUND

2.1 | U.S. beef export competitiveness

The U.S. beef industry operates in a highly competitive global marketplace (Murphy, Pendell, & Smith, 2009; Pendell, Tonsor, Dhuyvetter, Brester, & Schroeder, 2013; Schroeder & Tonsor, 2012). Major competitors include Canada, Australia, New Zealand, Brazil, and Mexico (USDA-FAS, 2019). Historically, the United States has held a comparative advantage in beef production due to a well-developed infrastructure and a reputation for both meat quality and food safety (Adcock, Hudson, Rosson, Harris, & Herndon, 2006; Golan et al., 2004). However, trade relationships, exchange rates, and economic growth rates have all had differing impacts on export competitiveness.

2.2 | 2003 U.S. BSE outbreak

BSE is a neurological disorder of cattle that cannot yet be treated or vaccinated against. Cattle affected by BSE experience degeneration of the nervous system. BSE can be categorized into two types—classical (C-type) and atypical (H-type or L-type). Only the classical BSE is zoonotic, where humans can become infected through consumption of diseased beef products, but symptoms do not appear for some time, making diagnosis, and hence food recalls, more difficult.[1] The disease was officially recognized in the 1980s, and the first diagnosis of classical BSE was reported in the United Kingdom in 1986, with thousands of diagnoses reported over the next decade.

The first case of classical BSE confirmed in North America was in Alberta, Canada in May 2003. In December 2003 a cow in Washington also tested positive for C-type BSE. Immediately, import bans against United States (and Canadian) beef products arose. Most markets, including Japan and South Korea, that were major buyers of U.S. beef at the time, did not reopen their markets until after 2006. Since then, the United States has strengthened regulations on feed imports by following the World Organization for Animal Health (OIE) guidelines, as well as increased traceability of cattle travelling across state borders. There have only been five cases of BSE confirmed in the United States since the 2003 discovery in Washington; all diagnosed as atypical BSE and did not lead to trade issues. In fact, in 2013 the U.S. BSE-status was upgraded to a negligible risk by the OIE. In 2015, the OIE excluded atypical BSE forms from the classical BSE general risk provisions.

3 | DATA

This study examines the 12 largest beef exporters since the 1980s. For each country, we collect annual data on beef (standard international trade classification (SITC): Meat of bovine animals, fresh, chilled or frozen) export value as well as total (SITC: All commodities) export value, which include beef and all other goods from every industry, from the UN Comtrade database from 1980 to 2018.[2] We employ linear interpolation to replace three missing observations by calculating the simple average of previous-year and next-year observations in order to have a balanced dataset.[3] Figure 1 displays beef export values (in USD) of the 12 countries over the sample period. U.S. beef export values experienced a sharp decline immediately after the BSE outbreak in 2003, recovered around 2006, and arguably returned to pre-BSE levels around 2010. Meanwhile, major competitors seem to have absorbed the U.S.'s lost market share to different degrees. Notably, Australia and Brazil surpassed the United States in export value after the BSE outbreak. In fact, the United States did not regain its lead measured by export value until 2017. It is worth noting that while India has also become one of the largest beef exporters, particularly since the late 2000s, its growth was not due to the 2003 U.S. BSE outbreak, as India beef, composed of

[1] See more discussion at https://www.aphis.usda.gov/publications/animal_health/fs-bse.pdf.

[2] "All commodities" refers to all exports, including total merchandise of all goods across industries. This is a term defined in the UN Comtrade reference guide (available at https://unstats.un.org/unsd/tradekb/Knowledgebase/50039/UN-Comtrade-Reference-Tables).

[3] No reasons are mentioned on the Comtrade online database webpage for the three missing observations (out of 444 observations in total). These are Nicaragua in 1987, Panama in 1987, and Paraguay in 1981.

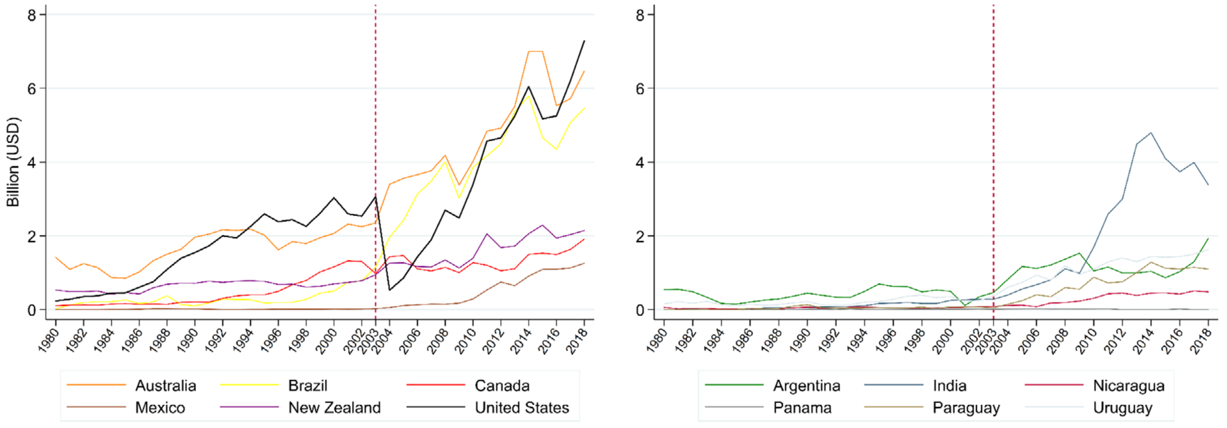

FIGURE 1 Annual beef export values (billion USD) [Color figure can be viewed at wileyonlinelibrary.com]

almost 50% water buffalo, arguably serves a different clientele than that of the major competitors (Aradhey, 2019; Landes, Melton, & Edwards, 2016).

Variable summary statistics and data sources are given in Table 1. The sample period, 1981 to 2017, ends just prior to the U.S. engagement on trade renegotiations with Mexico, Canada, and China.

3.1 | Normalized revealed comparative advantage index

Constructing RCA indices for the United States as well as for 11 other major beef exporting countries, we examine whether the United States has held a comparative advantage in beef exports. The RCA indices of Balassa (1977, 1986) were proposed as empirical proxies for Ricardian comparative advantage. Unfortunately, Balassa's index only indicates whether the country itself has a comparative advantage in a specific product/sector, but it does not hold either cardinal or ordinal properties. Therefore, one cannot compare Balassa's indices across countries. We adopt the normalized RCA index (NRCA) proposed by Yu et al. (2009).[4] The NRCA allows for symmetry and comparability, facilitating its use in an examination of changes to international competitiveness. For a country i exporting good j (beef in our analysis), the NRCA is defined as

$$NRCA_{ij} = \left(\frac{E_j}{E}\right)\left(\frac{E_{ij}}{E_j} - \frac{E_i}{E}\right) \tag{1}$$

where E_{ij} is country i's export of good j, E_i is country i's total export of all commodities, E_j is world's export of good j, and E is world's total export of all commodities. All variables on the right-hand side of the equations are measured in valuation.[5] Under this formulation, a country has a comparative advantage in beef (i.e., $NRCA > 0$) if it enjoys a larger beef export market share than that of total commodities, and does not have a comparative advantage if otherwise (i.e., $NRCA < 0$).[6] Another feature under such formulation is that the NRCA will always range within $[-0.25, 0.25]$.[7]

3.2 | Other data

We collect data on cattle stock and cattle slaughtered, as they contribute to beef production and its export market share. Cattle stock and cattle slaughtered are measured in head. To allow for comparison of cattle production across countries, we further construct a cattle stock-to-slaughter ratio. Exchange rates affect the relative prices of beef exports, and therefore beef export values. Common exchange rate measures are bilateral between two countries, but the exports (both beef and total commodities) are to all trading partners. Therefore, we choose the national currency per SDR (special drawing rights) as the preferred indicator to proxy for the exchange rates, which is comparable across our sample countries.[8] To capture any underlying technological progress that could contribute to the change in a country's comparative advantage in beef, we also include a linear trend variable.

[4] See Sarker and Ratnasena (2014) for in-depth discussion of the development of new RCA indices. The authors also adopt the modified RCA index by Yu, Cai, and Leung (2009) in their analysis on Canadian beef comparative advantage.

[5] Export values are all measured in USD throughout the study.

[6] NRCA indices are relatively small (in absolute value) because of the normalization, which is driven by the term $\frac{E_j}{E}$ (i.e., because beef products only account for a small share of total commodities in the global market).

[7] We refer readers to Yu et al. (2009) for the proof of the property.

[8] The value of SDR is determined by a basket of currencies, including the British pound sterling, the Chinese renminbi, the euro, the Japanese yen, and the U.S. dollar.

TABLE 1 Summary statistics

	N	Mean	Std. Dev.	Min	Max	Unit	Source
Argentina							
Beef export value	37	0.67	0.39	0.11	1.53	Billion USD	UN Comtrade
Cattle stock	37	52.64	2.79	47.97	58.72	Million heads	FAO
Cattle slaughtered	37	12.85	1.20	10.87	16.05	Million heads	FAO
Cattle ratio	37	4.12	0.28	3.39	4.71	Stock per slaughtered	FAO
Consumer price inflation rate	37	224.51	627.01	−1.17	3,079.81	Percentage (%)	World Bank; BIS
Exchange rate	37	4.02	5.41	0.00	22.96	Currency per SDR	IMF-IFS
Australia							
Beef export value	37	2.86	1.71	0.85	7.00	Billion USD	UN Comtrade
Cattle stock	37	25.86	2.25	21.85	29.29	Million heads	FAO
Cattle slaughtered	37	8.46	0.68	7.04	10.10	Million heads	FAO
Cattle ratio	37	3.06	0.25	2.47	3.59	Stock per slaughtered	FAO
Consumer price inflation rate	37	4.01	2.91	0.22	11.35	Percentage (%)	World Bank
Exchange rate	37	1.80	0.33	1.03	2.46	Currency per SDR	IMF-IFS
Brazil							
Beef export value	37	1.71	1.93	0.10	5.79	Billion USD	UN Comtrade
Cattle stock	37	173.27	32.79	121.79	218.20	Million heads	FAO
Cattle slaughtered	37	30.23	8.68	16.50	42.33	Million heads	FAO
Cattle ratio	37	5.92	0.72	4.72	7.38	Stock per slaughtered	FAO
Consumer price inflation rate	37	317.38	681.68	3.20	2,947.73	Percentage (%)	World Bank
Exchange rate	37	1.95	1.69	0.00	4.85	Currency per SDR	IMF-IFS
Canada							
Beef export value	37	0.78	0.53	0.12	1.63	Billion USD	UN Comtrade
Cattle stock	37	12.49	1.15	10.67	14.93	Million heads	FAO
Cattle slaughtered	37	3.79	0.38	3.03	4.47	Million heads	FAO
Cattle ratio	37	3.32	0.38	2.67	4.04	Stock per slaughtered	FAO
Consumer price inflation rate	37	3.01	2.53	0.17	12.47	Percentage (%)	World Bank
Exchange rate	37	1.72	0.22	1.32	2.08	Currency per SDR	IMF-IFS

Continued

TABLE 1 *Continued*

	N	Mean	Std. Dev.	Min	Max	Unit	Source
India							
Beef export value	37	0.96	1.48	0.00	4.80	Billion USD	UN Comtrade
Cattle stock	37	194.81	5.94	185.02	204.58	Million heads	FAO
Cattle slaughtered	37	9.88	0.57	8.63	10.98	Million heads	FAO
Cattle ratio	37	19.75	0.77	18.18	21.46	Stock per slaughtered	FAO
Consumer price inflation rate	37	7.90	3.07	2.49	13.87	Percentage (%)	World Bank
Exchange rate	37	51.48	26.88	10.21	93.40	Currency per SDR	IMF-IFS
Mexico							
Beef export value	37	0.20	0.35	0.00	1.13	Billion USD	UN Comtrade
Cattle stock	37	31.50	1.06	28.88	33.92	Million heads	FAO
Cattle slaughtered	37	6.85	1.33	4.54	8.92	Million heads	FAO
Cattle ratio	37	4.77	0.92	3.58	6.75	Stock per slaughtered	FAO
Consumer price inflation rate	37	25.71	33.92	2.72	131.83	Percentage (%)	World Bank
Exchange rate	37	11.27	8.13	0.03	26.24	Currency per SDR	IMF-IFS
New Zealand							
Beef export value	37	1.02	0.54	0.42	2.29	Billion USD	UN Comtrade
Cattle stock	37	9.05	0.87	7.63	10.37	Million heads	FAO
Cattle slaughtered	37	3.53	0.56	2.60	4.76	Million heads	FAO
Cattle ratio	37	2.59	0.24	2.11	3.04	Stock per slaughtered	FAO
Consumer price inflation rate	37	4.38	4.69	−0.11	16.16	Percentage (%)	World Bank
Exchange rate	37	2.19	0.36	1.36	3.03	Currency per SDR	IMF-IFS
Nicaragua							
Beef export value	37	0.14	0.16	0.00	0.51	Billion USD	UN Comtrade
Cattle stock	37	3.26	0.87	1.89	5.09	Million heads	FAO
Cattle slaughtered	37	0.46	0.20	0.19	0.91	Million heads	FAO
Cattle ratio	37	7.62	1.47	4.53	10.00	Stock per slaughtered	FAO
Consumer price inflation rate	37	745.13	2,188.42	3.52	10,205.03	Percentage (%)	World Bank
Exchange rate	37	17.19	14.42	0.00	41.67	Currency per SDR	IMF-IFS

Continued

TABLE 1 *Continued*

	N	Mean	Std. Dev.	Min	Max	Unit	Source
Panama							
Beef export value	37	0.01	0.01	0.00	0.02	Billion USD	UN Comtrade
Cattle stock	37	1.50	0.10	1.34	1.73	Million heads	FAO
Cattle slaughtered	37	0.31	0.04	0.24	0.42	Million heads	FAO
Cattle ratio	37	4.90	0.47	4.07	6.00	Stock per slaughtered	FAO
Consumer price inflation rate	37	2.07	2.10	−0.07	8.76	Percentage (%)	World Bank
Exchange rate	37	1.37	0.15	1.02	1.58	Currency per SDR	IMF-IFS
Paraguay							
Beef export value	37	0.31	0.41	0.00	1.28	Billion USD	UN Comtrade
Cattle stock	37	9.81	2.35	6.34	14.47	Million heads	FAO
Cattle slaughtered	37	1.14	0.41	0.53	2.07	Million heads	FAO
Cattle ratio	37	9.13	1.90	6.07	12.90	Stock per slaughtered	FAO
Consumer price inflation rate	37	12.47	8.79	2.59	37.26	Percentage (%)	World Bank
Exchange rate	37	4,418.54	3,119.26	134.69	9,126.86	Currency per SDR	IMF-IFS
United States							
Beef export value	37	2.41	1.68	0.28	6.20	Billion USD	UN Comtrade
Cattle stock	37	98.98	7.03	88.53	115.44	Million heads	FAO
Cattle slaughtered	37	36.02	2.77	29.32	41.27	Million heads	FAO
Cattle ratio	37	2.75	0.12	2.57	3.04	Stock per slaughtered	FAO
Consumer price inflation rate	37	3.00	1.80	−0.36	10.33	Percentage (%)	World Bank
Exchange rate	37	1.37	0.15	1.02	1.58	Currency per SDR	IMF-IFS
Meat slaughtering labor cost	37	10.20	2.48	7.09	14.98	USD per hour	BLS
Corn futures	37	3.17	1.26	1.73	6.92	USD per bushel	Macrotrends LLC
Uruguay							
Beef export value	37	0.57	0.50	0.10	1.50	Billion USD	UN Comtrade
Cattle stock	37	10.87	1.11	8.69	12.66	Million heads	FAO
Cattle slaughtered	37	1.89	0.36	1.26	2.62	Million heads	FAO
Cattle ratio	37	5.88	0.84	4.47	7.90	Stock per slaughtered	FAO
Consumer price inflation rate	37	31.13	30.67	4.36	112.53	Percentage (%)	World Bank
Exchange rate	37	18.48	15.81	0.01	42.51	Currency per SDR	IMF-IFS

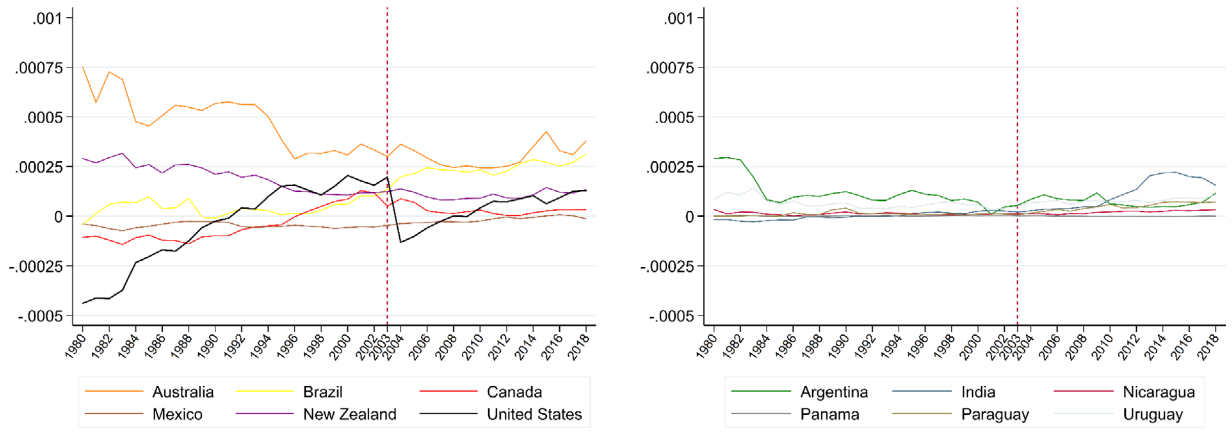

FIGURE 2 Normalized revealed comparative advantage [Color figure can be viewed at wileyonlinelibrary.com]

Ideally, we would also like to control for other sources of cattle production costs. Because not all exporters in our analysis have available producer prices, we instead use the inflation rate of local consumer prices, as the rate of change between consumer and producer prices tend to be similar.[9] Corn futures prices are used as a proxy for feed costs to control for factors that are correlated with a country's comparative advantage in beef. As feed data are not readily available for all countries, we use U.S. corn futures as a covariant proxy for feed costs in other countries as well. We collect the U.S. corn futures prices, calculated as a simple average of daily nearby corn futures prices during a year. For the United States, we also include slaughtering labor cost to better proxy for the cost of beef production.[10]

4 | EMPIRICAL ANALYSES

4.1 | Revealed comparative advantage in the beef sector

Figure 2 shows each country's NRCA in beef exports over the sample period.

Australia has been receiving a lower price in beef finishing, compared to most of its competitors, reflecting a lower production cost (Behrendt & Weeks, 2017).[11] Indeed, Australia has been leading other competitors in comparative advantage. The United States had been enjoying an increasingly strong share in the beef export market relative to its total exports since the 1980s, and started to have a comparative advantage after the 1990s until the discovery of BSE in December 2003. Like the impact on beef export values, trade bans on U.S. beef resulted in an adverse shock to its competitiveness, with the U.S. NRCA falling to levels last seen in the late 1980s. What Figure 2 also shows is that no single country completely snatched the lost U.S. market advantages. Instead, U.S. competitiveness appears to have been redistributed to a handful of other exporters. This graphical evidence suggests that the market moved toward a higher level of competitiveness all-around.[12]

4.2 | Seemingly unrelated regressions (SURs) estimation

Next we estimate the impacts of the BSE outbreak on comparative advantages in beef. We correlate the NRCA with variables we consider would contribute to its variation. Because the NRCA is constructed using exports to all importing countries instead of bilateral exports, we can view these exporters as serving the world market together. As a result, we estimate the 12 equations simultaneously as a seemingly unrelated regression system, with potentially correlated, cross-equation errors.

[9] Consumer prices for all 12 countries are collected from the World Bank. Data for Argentina are missing after 2013. We fill its missing values from the Bank for International Settlements (BIS).

[10] A note on using corn and labor costs. The United States is the world's largest producer and exporter of corn. As such, U.S. corn futures have a major impact on the world corn price as well as the corn trade. Using corn futures in country-specific regressions may not make the best proxy for country-specific feed costs, but leaving it out is likely a worse decision because of its correlation with those costs. As to using U.S. labor costs, while such data are not available for the other countries, unlike using U.S. corn futures to proxy for country-specific feed costs, slaughtering labor costs depend on many factors that are country specific and are not likely tied to what is happening in U.S. labor markets.

[11] Recent drought events in Australia have increased prices, but Australia remains an efficient producer with high returns (Behrendt & Weeks, 2017).

[12] We note that our observation of relatively stable comparative advantage in beef for Australia and New Zealand, especially in the late 2010s, is consistent with Sanderson and Ahmadi-Esfahani (2011), who model the long-run impacts of climate change on countries' comparative advantage in the livestock industry.

Estimating the long-run effect of the BSE outbreak on comparative advantage is our main interest. We first discuss the construction of the variables that we use in the regression model to capture the long-run effect of the BSE event. Rather than simply estimating the average difference of comparative advantage in beef before and after the 2003 BSE outbreak with a BSE dummy variable, our goal is to examine any possible nonlinear response over time. To do so, we first generate nonlinear trend variables using the restricted cubic spline function. The intuition behind constructing the spline function is to first split the sample period with knots, where each knot defines the end of one segment and the start of another; each segment between knots is then fitted with a curve, whereas periods outside this range (i.e., segments before the first knot and after the last knot) are fitted linearly.[13] In our main specification, the restricted cubic spline function generated five knots at years 1983, 1991, 2000, 2009, and 2016, respectively. After constructing the trend variables, we made them interact with the BSE dummy variable (doing so means the trend variables prior to 2003 will have zero values). The purpose of creating the interaction terms is twofold. First, we want to control any nonlinear effect of the 2003 BSE outbreak on comparative advantage in beef in the postevent period. Second, by only fitting these trend variables in the postevent period, we avoid overfitting our model over the full sample period.

We estimate the system of equations specified in Equation (2):

$$\begin{aligned} NRCA_{iy} &= \beta_{i0} + \beta_{i1} cattle\_ratio_{iy} + \beta_{i2} corn_y + \beta_{i3} cpi_{iy} \\ &\quad + \beta_{i4} xrate_{iy} + \beta_5 labor\_cost\_US_{iy} + \beta_{i6} t1_y \\ &\quad + \beta_{i7} BSE_y \times t1_y + \beta_{i8} BSE_y \times t2_y + \beta_{i9} BSE_y \\ &\quad \times t3_y + \beta_{i10} BSE_y \times t4_y + \varepsilon_{iy}. \end{aligned} \tag{2}$$

Consistent with Equation (1), i denotes country, and y denotes year. For each country (ignoring subscripts), $catte\_ratio$ is the cattle stock-to-slaughter ratio,[14] $corn$ is the corn futures price (identical across all equations), cpi is the inflation rate for consumer prices, $xrate$ is the national currency per SDR that we use as the indicator for exchange rate, and $labor\_cost\_US$ is the meat slaughtering labor cost that only appears in the U.S. equation. $t1$ is a linear trend variable. $t2$, $t3$, and $t4$ are nonlinear trend variables generated using the restricted cubic spline function, which along with the linear trend variable, are interacted with the BSE dummy variable that equals zero prior to 2003, and one afterwards.

One concern with Equation (2) is that while $cattle\_ratio$ contributes to the variation of NRCA, it is likely a channel through which the BSE outbreak impacts a country's NRCA in beef (i.e., an outcome variable of BSE outbreak). For instance, the United States may decrease its cattle slaughter rate in response to import bans from other countries after the BSE outbreak. This suggests that the effect of the BSE outbreak on NRCA can be biased toward statistical insignificance once $cattle\_ratio$ is held constant in the regression. In the extreme case, if one believes that $cattle\_ratio$ is the only channel through which the BSE outbreak impacts NRCA, then one would erroneously conclude that there is no correlation between the BSE outbreak and beef export competitiveness from the regression result after controlling for $cattle\_ratio$. In such case, the variable $cattle\_ratio$ is often referred to as "bad controls" in the econometrics literature (Angrist & Pischke, 2009).

One way to avoid the "bad controls" problem is to exclude that variable from the regression. However, this comes with a cost that the regression may instead suffer from omitted variable bias. We use a method in the spirit of the hedonic demand theory formulated by Rosen (1974), which is commonly used in the literature studying demand for differentiated products or for nonmarket goods. The hedonic approach features a pricing equation that regresses, for instance, the price of a differentiated good on a vector of characteristic variables. One can then obtain the residual term from the regression, which is interpreted as the implicit price of the product not explained by the characteristic variables.[15] Our application implements a first-stage regression of $cattle\_ratio$ on the post-BSE trend variables to obtain the predicted error for each country:

$$\begin{aligned} cattle\_ratio_{iy} &= \gamma_{i0} + \gamma_{i1} BSE_y \times t1_y + \gamma_{i2} BSE_y \times t2_y \\ &\quad + \gamma_{i3} BSE_y \times t3_y + \gamma_{i4} BSE_y \times t4_y + \epsilon_{iy}. \end{aligned} \tag{3}$$

Our goal here is to recover the portion of the variation in $cattle\_ratio$ that is not an outcome of the BSE event. By construction, the predicted error term $\widehat{\epsilon_{iy}}$, the residual variation of $cattle\_ratio$, is not correlated with the post-BSE trend variables. We then replace $cattle\_ratio$ with $\widehat{\epsilon_{iy}}$ in Equation (2) to estimate the following system of equations:[16]

[13] These nonlinear trend variables, and the locations and number of knots are generated using STATA's mkspline command. See https://www.stata.com/manuals13/rmkspline.pdf.

[14] We prefer the cattle stock-to-slaughter ratio to two separate variables of cattle stock and cattle slaughter in the equation to avoid potential high collinearity between the two variables. The correlation coefficients between cattle stock and cattle slaughtered for most countries are above 0.7.

[15] See Trajtenberg (1989) and Crespi et al. (2016) for examples using predicted error terms in regressions containing variables with hedonic features.

TABLE 2 Seemingly unrelated regressions

	(1)NRCA1	(2)NRCA2	(3)NRCA3	(4)NRCA4	(5)NRCA5	(6)NRCA6
cattle_ratio1	−0.0773 (0.0477)					
cpi1	-0.0001^{**} (2.19×10^{-5})					
x_sdr1	0.0169 (0.0134)					
cattle_ratio2		-0.3304^{***} (0.0702)				
cpi2		0.0010 (0.0080)				
x_sdr2		0.2959^{**} (0.1268)				
cattle_ratio3			-0.3653^{***} (0.0998)			
cpi3			-2.13×10^{-5} (4.36×10^{-5})			
x_sdr3			0.2810^{***} (0.0493)			
cattle_ratio4				-0.5381^{***} (0.1332)		
cpi4				0.0773^{***} (0.0183)		
x_sdr4				0.4420 (0.3463)		
cattle_ratio5					-0.1614^{*} (0.0949)	
cpi5					−0.0040 (0.0151)	
x_sdr5					0.0364^{***} (0.0092)	
cattle_ratio6						0.1529^{**} (0.0716)
cpi6						0.0015^{*} (0.0009)

Continued

TABLE 2 *Continued*

	(1)NRCA1	(2)NRCA2	(3)NRCA3	(4)NRCA4	(5)NRCA5	(6)NRCA6
x_sdr6						−0.0153
						(0.0140)
trend1	−0.0187***	−0.0522***	−0.0698***	0.1462***	−0.0554*	0.0296*
	(0.0037)	(0.0089)	(0.0139)	(0.0130)	(0.0290)	(0.0159)
Corn	0.0270	0.0027	−0.0621	−0.0134	−0.0198	0.0040
	(0.0287)	(0.0432)	(0.0588)	(0.0719)	(0.0634)	(0.0494)
$t1 \times$ BSE	−0.0017	0.0053	−0.0083	0.0102	0.0144	0.0007
	(0.0041)	(0.0053)	(0.0081)	(0.0098)	(0.0089)	(0.0068)
$t2 \times$ BSE	1.2751	−3.6448	5.8674	−6.9654	−10.5867*	−0.5024
	(2.9662)	(3.8034)	(5.7471)	(6.9556)	(6.3580)	(4.8168)
$t3 \times$ BSE	−3.4774	9.8682	−15.1470	18.2501	29.2754*	1.3630
	(8.1096)	(10.3801)	(15.6740)	(18.9730)	(17.3459)	(13.1453)
$t4 \times$ BSE	3.3552	−9.2449	12.9688	−16.5608	−28.9122*	−1.1827
	(8.0319)	(10.2030)	(15.3836)	(18.6279)	(17.0380)	(12.9199)
Intercept	36.6713***	103.1570***	138.3584***	−291.9763***	108.8143*	−59.6726*
	(7.545)	(17.4950)	(27.7071)	(25.6645)	(57.5342)	(31.7246)
N	37	37	37	37	37	37
R^2	0.5538	0.8759	0.9578	0.9107	0.9691	0.7726
Adjusted R^2	0.4050	0.8345	0.9438	0.8809	0.9588	0.6968
ADF test	0.0075	0.0043	6.83×10^{-7}	0.0021	0.0037	0.0452
	(7)NRCA7	**(8)NRCA8**	**(9)NRCA9**	**(10)NRCA10**	**(11)NRCA11**	**(12)NRCA12**
re_cattle_ratio7	−0.1125(0.0738)					
cpi7	−0.0002(0.0051)					
x_sdr7	0.1130(0.0816)					
re_cattle_ratio8		−0.0597**(0.0248)				
cpi8		$8.79 \times 10^{-6}(1.16 \times 10^{-5})$				
x_sdr8		−0.0035(0.0152)				
re_cattle_ratio9			−0.1780(0.3039)			
cpi9			0.1891**(0.0934)			
x_sdr9			0.1438(1.3690)			
re_cattle_ratio10				−0.0803**(0.0272)		
cpi10				0.0333***(0.0060)		
x_sdr10				−0.0001(0.0001)		
re_cattle_ratio11					−0.0669(0.1220)	
cpi11					0.0119(0.0090)	

Continued

TABLE 2 *Continued*

	(1)NRCA1	(2)NRCA2	(3)NRCA3	(4)NRCA4	(5)NRCA5	(6)NRCA6
*x_sdr*11					0.4163***	
					(0.1513)	
*labor_cost_meat*11					−0.2789***	
					(0.0418)	
*re_cattle_ratio*12						−0.3385***
						(0.0517)
*cpi*12						−0.0058***
						(0.0020)
*x_sdr*12						0.0263***
						(0.0099)
*trend*1	−0.0628***	−0.0001	0.0136	0.0248	0.1217***	−0.1094***
	(0.0064)	(0.0162)	(0.0366)	(0.0196)	(0.0106)	(0.0148)
Corn	−0.0184	−0.0018	−0.1808	−0.2502***	0.0168	0.0571
	(0.0386)	(0.0451)	(0.2901)	(0.0737)	(0.0220)	(0.0705)
$t1 \times$ BSE	0.0072	0.0090	0.0085	0.0118	−0.0003	−0.0072
	(0.0049)	(0.0058)	(0.0369)	(0.0100)	(0.0029)	(0.0097)
$t2 \times$ BSE	−5.0136	−6.5236	−4.8527	−8.8871	−0.1673	5.0976
	(3.5168)	(4.1213)	(26.2866)	(7.1499)	(2.0944)	(6.8850)
$t3 \times$ BSE	13.6239	17.9222	11.3291	25.3047	0.4469	−13.5795
	(9.5976)	(11.2484)	(71.6974)	(19.5087)	(5.7199)	(18.7867)
$t4 \times$ BSE	−12.9545	−17.6694	−6.4751	−26.8731	−0.4067	13.0194
	(9.4355)	(11.0589)	(70.3412)	(19.1666)	(5.6319)	(18.4599)
Intercept	124.5505***	−0.2519	−26.4547	−49.6609	−240.0150***	218.1345***
	(12.7307)	(32.2769)	(72.0833)	(39.0024)	(20.6672)	(29.5301)
N	37	37	37	37	37	37
R^2	0.9304	0.7606	0.5684	0.9528	0.9788	0.8771
Adjusted R^2	0.9073	0.6808	0.4244	0.9371	0.9707	0.8362
ADF test	0.0001	0.0028	0.0002	3.21×10^{-5}	0.0006	1.11×10^{-10}

Notes: Argentina (1), Australia (2), Brazil (3), Canada (4), India (5), and Mexico (6). For all equations, NRCA indices are standardized, and *re_cattle_ratio* denotes the residual variation of the original *cattle_ratio* variable, obtained from the first-stage equation. *trend*1 is the linear trend variable. $t1 \times$ BSE denotes the post-BSE linear trend variable, and $t2 \times$ BSE, $t3 \times$ BSE, and $t4 \times$ BSE denote the post-BSE nonlinear trend variables, generated by the restricted cubic spline function. ADF test presents the MacKinnon approximate *p*-value from the augmented Dickey–Fuller test of a unit root process on the predicted error in each equation.

New Zealand (7), Nicaragua (8), Panama (9), Paraguay (10), United States (11), and Uruguay (12). For all equations, NRCA indices are standardized, and *re_cattle_ratio* denotes the residual variation of the original *cattle_ratio* variable, obtained from the first-stage equation. *trend*1 is the linear trend variable. $t1 \times$ BSE denotes the post-BSE linear trend variable, and $t2 \times$ BSE, $t3 \times$ BSE, and $t4 \times$ BSE denote the post-BSE nonlinear trend variables, generated by the restricted cubic spline function. ADF test presents the MacKinnon approximate *p*-value from the augmented Dickey–Fuller test of a unit root process on the predicted error in each equation.

***$p< .01$,
**$p< .05$,
*$p< .1$.

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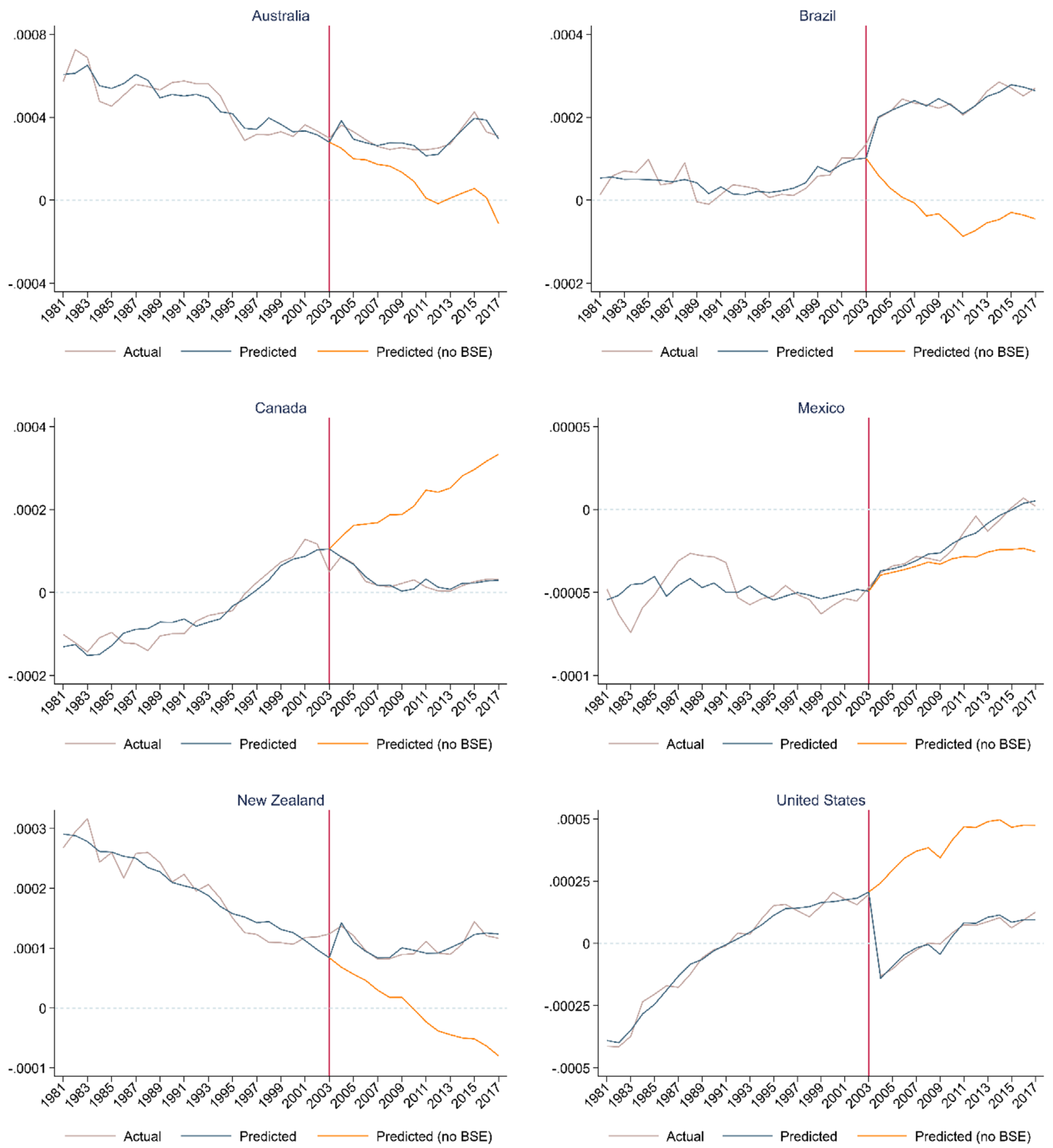

FIGURE 3 Predicted NRC —BSE versus no-BSE [Color figure can be viewed at wileyonlinelibrary.com]

$$NRCA_{iy} = \alpha_{i0} + \alpha_{i1}\hat{\epsilon}_{iy} + \alpha_{i2}corn_y + \alpha_{i3}\text{cpi}_{\text{iy}} + \alpha_{i4}xrate_{iy} + \alpha_5 labor\_cost_{iy} + \alpha_{i6}t1_y + \alpha_{i7}BSE_y \times t1_y + \alpha_{i8}BSE_y \times t2_y + \alpha_{i9}BSE_y \times t3_y + \alpha_{i10}BSE_y \times t4_y + \xi_{iy} \quad (4)$$

where all variables are the same as in Equation (2), except for $\widehat{\epsilon_{iy}}$, the residual variation of *cattle_ratio*.

We standardize the NRCA in Equation (4) so that the interpretation of the estimated coefficients will be how many standard deviations of change in NRCA given a unit change in a right-hand-side variable. The results of interest, however, are the predicted values of NRCA from the regression model. Once Equation (4) is estimated, we obtain the predicted NRCA for all countries. We also predict the NRCA under the counterfactual scenario of no BSE outbreak in 2003 by replacing the BSE dummy variable with zero values in the post-BSE periods to study the impacts of the BSE outbreak.

[16] We present and discuss the result using the unaltered cattle stock-to-slaughter ratio in the Online Appendix.

4.3 | Estimation results

For brevity, although the system of equations is for the top 12 beef exporting nations, the discussion of findings will focus on the United States as well as the most recent top five exporters: Australia, Brazil, Canada, Mexico, and New Zealand. Table 2 presents the estimation of the SUR models from Equation (4) for all 12 countries.

Given that there are 37 observations in each equation, we adopt the small sample adjustment when performing the estimation.[17] In most cases, the coefficients of variables related to cost of production are not statistically significant, except for the meat packer labor cost in the United States equation. Still, the regression models fit the variation of NRCA well based on the *R*-square values for the top five exporting countries, suggesting the variation is mostly explained by the trend variables that capture other unobserved underlying changes in factors contributing to comparative advantage.[18] We also perform the augmented Dickey–Fuller test on the predicted residual for each equation, rejecting the null hypothesis of a unit root.

Next we turn to the presentation of the predicted NRCA over time from the SUR estimations as shown in Figure 3.[19] Our model predicts that not only would the United States have continued having comparative advantage (i.e., NRCA > 0) in beef after 2003, but it would have steadily increased in the absence of the BSE event. In actuality, the United States today is only as competitive as it was 20 years ago. A simple test of the model is that a similar story is observed for Canada, which was also impacted by a BSE outbreak in 2002.[20]

On the other hand, we observe that Australia, Brazil, and New Zealand would have shown decreased comparative advantages in beef without the 2003 BSE outbreak and these three countries were all on track to lose their comparative advantages (i.e., NRCA < 0) in beef over time, *ceteris paribus*. Mexico's NRCA would have displayed little change had there been no BSE outbreak. This is likely because Mexico, similar to India, has not been directly competing with Australia, New Zealand, and the United States in the large markets of Japan, South Korea, and Taiwan.

We check the robustness of the results by exploring alternative specifications of our SUR model. The estimation results from using the cattle stock-to-slaughter ratio in Equation (2) are qualitatively like those using the residual variation of the ratio that is free of the 2003 BSE effect. This suggests that the impact of the outbreak on a country's comparative advantage was not through the channel of the cattle stock-to-slaughter ratio. One concern with including multiple nonlinear trend variables would result in overfitting of our model. We also estimate Equation (4), but replace the post-BSE nonlinear trend variables generated by the restricted cubic spline function with only the second order of the linear trend variable. These results are consistent with the previous SUR model.[21]

5 | CONCLUSIONS

As trade disruptions made headlines in 2018–2019, one concern was the long-run impacts to export competitiveness. Such impacts are difficult to ascertain until more data become available. Phytosanitary emergencies can provide insight into these potential impacts because they cause disruptions that are often expected to be short-lived, similar to trade disputes. What we see however is that even a short-term market closure can lead to long-term consequences to market structure that linger beyond the event's conclusion. Trade negotiators who drag their feet can hurt the long-run competitiveness of their own country. In this study, we provide evidence of the effect of the 2003 BSE outbreak in the United States on global beef export competitiveness. We first show that the comparative advantage of the U.S. beef sector in the world market was significantly impacted by the BSE outbreak of 2003, but while export *values* eventually returned to preoutbreak levels, comparative advantage has not. The international beef market has become more competitive since the outbreak. We also predict comparative advantages under the counterfactual scenario of no-BSE event. Our results show that in the absence of the BSE outbreak, the U.S. beef sector would have been increasingly more competitive by 2017 than it actually was.

A criticism of our approach might be in the use of the SUR model instead of relying on a natural experiment. After all, only the United States and Canada were impacted directly with BSE in 2002 and 2003, which might lend itself to a comparison of impacted versus nonimpacted exporters. Recent developments in the causal inference literature, for example, might provide alternative methods

[17] Instead of the number of sample observations n, the alternate divisor used to compute the covariance matrix takes the form $\sqrt{(n-k_i)(n-k_j)}$, where k_i and k_j are the numbers of parameters in equation i and j (Kauermann & Carroll, 2001).

[18] R^2 values for the top five exporters are around 90%, and lower for Mexico at around 60%.

[19] To save space, figures of the prediction results for the six other countries are presented in the Online Appendix.

[20] Canada, while also hit by BSE and whose NRCA has been trending downward since, did not experience the sharp decline that United States did. This is likely due to the availability of a traceability program in Canada that was not available in the United States.

[21] We thank an anonymous referee for raising this check. Tables and figures for the additional results are presented in the Online Appendix.

that seem to fit this setting. Abadie, Diamond, and Hainmueller (2010) propose a synthetic control method that is commonly used to estimate treatment effects where the treatment is at the aggregate level, and there is only a single treated unit (e.g., a country). The advantage of this method is, instead of extrapolating the data to predict the no-BSE scenario (i.e., replacing the BSE dummy variable with zero values after 2003), we might directly estimate the counterfactual scenario using other countries that we argue were not impacted by the BSE outbreak as the control units. However, such methods are problematic given that competing countries will pick up the lost U.S. market share. In other words, natural experiments are biased because—in this case—spillover effects of the BSE event invalidate the experiment: there is no control group. SUR controls for correlated error terms, on the other hand.

Another criticism of our method might be in misinterpreting why the United States (and Canada) suffered for such a long time from the BSE outbreak. It could be that consumers changed their preferences for U.S. beef, something for which our model does not account. However, research that studies the BSE outbreak and consumer response in the United States find somewhat mixed results, and it appears that BSE had only a temporary effect on consumer demand (Pritchett, Johnson, Thilmany, & Hahn, 2007). Marsh et al. (2008) study the effects of the U.S. BSE outbreak on domestic fed cattle prices finding that the impacts of BSE on demand come from the trade bans, not from changes in domestic consumer preferences.

Research studying the potential impacts of the 2018–2019 China-U.S. trade disputes is important but is limited to descriptive analyses or simulation studies for which changes to market structure (e.g. equilibrium displacement) can only be guessed in the short run (Balistreri et al., 2018; Marchant & Wang, 2018). As more data become available, these studies take on greater information. Even with its “comparing apples to oranges” limitations, the lesson from our BSE case study has an important implication. Using longitudinal data on beef exports before and after the 2003 BSE event, we directly observe longer impacts of a significant, albeit arguably short-lived, trade interruption and show that a country’s export competitiveness can take a long time to recover, if at all. Relatedly, Furceri, Hannan, Ostry, and Rose (2018) estimate the medium-term impact of countries that impose trade barriers and find that countries raising tariffs actually experience decreased productivity, but not improved trade balance, suggesting markets disrupted do not easily bounce back after the disruption, regardless of being on one side or the other of the trade barrier. Our findings also shed light on the implication of the african swine fever (ASF) outbreaks in China since late 2018. China increased its pork imports due to domestic supply shortages, yet U.S. pork producers were limited in gaining as much market share in part due to the ongoing trade disputes (Xiong & Zhang, 2019). Future research should study whether U.S. comparative advantage was helped by ASF but harmed by the dispute.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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