Long-Run Impacts of Trade Shocks and Export Competitiveness: Evidence from the U.S. BSE Event

Chen-Ti Chen  
_Iowa State University_, ctc@iastate.edu

John M. Crespi  
_Iowa State University_, jcrespi@iastate.edu

William Hahn  
_U.S. Department of Agriculture_

Lee L. Schulz  
_Iowa State University_, lschulz@iastate.edu

Fawzi Taha  
_U.S. Department of Agriculture_

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

Disciplines
Agricultural and Resource Economics | Behavioral Economics | Economic Theory | International Economics | Longitudinal Data Analysis and Time Series

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Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Chen-Ti Chen is Graduate Student, Department of Economics, Iowa State University, Ames, IA 50011. E-mail: ctc@iastate.edu.

John M. Crespi is Professor, Department of Economics, Iowa State University, Ames, IA 50011. E-mail: jcrespi@iastate.edu.

William Hahn is Agricultural Economist, US Department of Agriculture Economic Research Service, Washington, DC 20036. E-mail: William.hahn@usda.gov.

Lee L. Schulz is Associate Professor, Department of Economics, Iowa State University, Ames, IA 50011. E-mail: lschulz@iastate.edu.

Fawzi Taha is Agricultural Economist, US Department of Agriculture Economic Research Service, Washington, DC 20036. E-mail: fawzi.taha@usda.gov.

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For questions or comments about the contents of this paper, please contact John Crespi, jcrespi@iastate.edu

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Long-Run Impacts of Trade Shocks and Export Competitiveness: Evidence from the U.S. BSE Event

Chen-Ti Chen. Dept. of Economics. Iowa State University.

John M. Crespi. Center for Agricultural & Rural Development and Dept. of Economics. Iowa State University.

William Hahn. Economic Research Service. USDA.

Lee L. Schulz. Center for Agricultural & Rural Development and Dept. of Economics. Iowa State University.

Fawzi Taha, Economic Research Service. USDA.

Abstract. This paper examines how comparative advantages of major beef exporters changed following the 2003 bovine spongiform encephalopathy outbreak (BSE), which significantly disrupted the U.S. beef trade until approximately April 2007. Using longitudinal data on beef export values and constructed revealed comparative advantage measures, we show that while some measure 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 what exporters’ competitiveness would have looked like. The authors discuss the implications for recent trade disruptions.

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JEL codes: F12, Q17

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1. Introduction

Shocks from trade disputes and phytosanitary emergencies occasionally impact agricultural export markets. Affected exporters always hope that such events are short-lived. A trade dispute beginning in 2018 between the United States and China is a pertinent example that has led to additional tariffs on U.S. agricultural products including corn, soybeans, cotton, and pork (Marchant and Wang 2018). Notably, the price spread between U.S. 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 2019) predicts that U.S. soybean exports would not return to pre-trade-war levels until 2028. However, even if the U.S. and China ended their disputes in 2019 or 2020 and the tariffs returned to pre-2018 levels, 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 2019; Hirtzer 2019). In particular, once China finds new trading partners, renegotiation costs can slow the U.S. in regaining 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).

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 has mostly recovered back to their pre-BSE levels, the U.S.’s comparative advantage has 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 et al. (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 (Gortan et al. 2000; Ferto and Hunnard 2003). However, the original RCA index features unsatisfactory
characteristics that are not appropriate to be used in statistical analyses (Vollrath 1991; Hoen and Oosterhaven 2006; Yu et al. 2009; Laursen 2015). The reformulated RCA index developed and used by Yu et al. (2009) resolves these limitations. To the best of our knowledge, we are not aware of any studies that have used an RCA index to study the impact of BSE on the U.S.’s beef sector competitiveness.

Different aspects of the adverse economic impacts of BSE outbreaks have been studied both in the U.S. and other countries. Research finds negative impacts on consumer demand for beef products in the aftermath of local BSE events (e.g., Burton and Young 1996; Mangen and Burrell 2001; Verbeke and Ward 2001; Peterson and Chen 2005). Other studies 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 et al. 2008; Marsh et al. 2008; Schlenker and Villas-Boas 2009; Taha and Hahn 2014). We add to this literature by providing evidence of the impact of an outbreak of BSE on a country’s international competitiveness. The aforementioned studies tend to focus on the short-run impacts of BSE, our results highlight the significance of long-run impacts on a country’s trade performance.

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**
United States Beef Export Competitiveness

The U.S. beef industry operates in a highly competitive global marketplace. 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. However, the United States can be at a disadvantage relative to cost of production. For example, a pound of grass-fed beef can typically be produced at lower cost, where the majority of U.S. beef is grain-fed.

Competitive advantages can also be built around the sophisticated use of information. Globally, animal identification and traceability are important components of managing animal and human health and food safety (Schroeder and Tonsor 2012). Traceability systems also enhance communication and coordination by delivering information up and down the supply chain to benefit producers, processors, and consumers. Smith et al. (2005) reported that the United States is “lagging behind many countries in developing traceability systems for food in general and especially for livestock, and their products” (p. 174). Of the world’s eight largest exporters, six have in place mandatory cattle animal identification and traceability systems. Only the United States and India have not adopted mandatory national identification and traceability systems (Schroeder and Tonsor 2012). In short, the United States’ beef industry today faces a highly competitive and developing global market place (Murphy et al. 2009; Schroeder and Tonsor 2012; Pendell et al. 2013). Trade relationships, exchange rates, and economic growth rates in other countries all affect the export demand profile.

2003 U.S. BSE Outbreak

Bovine spongiform encephalopathy (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 became officially recognized in the 1980s, and the first diagnosis of classical BSE was reported in the United Kingdom in 1986, spreading throughout the country and lasting for almost a decade. Thousands of classical BSE cases were reported during this period, raising public health concerns across the world.

The first case of classical BSE confirmed in North America was in Alberta, Canada in May 2003. In December 2003 a cow in Washington State also tested positive for C-type BSE. Immediately, import bans against U.S. (and Canadian) beef products arose. Most markets, including Japan and South Korea, who were major buyers of U.S. beef at the time, did not re-open their markets until after 2006. Since then, the United States has strengthened regulations on imports of feeds 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 U.S. since the 2003 discovery in Washington State; all diagnosed as atypical BSE and did not lead to trade issues.\(^2\) In fact, in 2013 the U.S. BSE-status was upgraded to negligible risk by the OIE. In 2015, the OIE excluded atypical BSE forms from the classical BSE general risk provisions.

3. Data

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

\(^2\) The five cases reported were in the following states: Texas, Alabama, California, and Florida.
This study examines the 12 largest beef exporters since the 1980s. For each country, we collect annual data on beef (SITC: Meat of bovine animals, fresh, chilled or frozen) export value as well as total (SITC: All commodities) export value (both in USD) from the UN Comtrade database from 1980 to 2018. 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 of the 12 countries over the sample period. As shown, U.S. beef export value experienced a sharp decline immediately after the BSE outbreak in 2003, followed by a quick recover since around 2006, and restored its pre-BSE level around 2010. Meanwhile, major competitors all seem to have absorbed the lost market share from the U.S. to different degrees. Notably, Australia and Brazil surpassed the U.S. in export value after the BSE outbreak. In fact, the U.S. 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 almost 50 percent water buffalo, arguably serves a different from clientele than that of the major competitors (Landes et al. 2016; Aradhey 2019).

³ No reasons are mentioned in the data source for the three missing observations. These are Nicaragua in 1987, Panama in 1987, and Paraguay in 1981. We choose to do simple linear interpolation because only three observations out of 444 are missing. An alternative is to predict the missing values by regressing each country’s trade value on variables that can explain variation in trade values.

Basic summary statistics and the sources of all the data used in the analysis are placed in the appendix. 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 heads. 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. Given that the
exports are not bilateral, we choose the national currency per SDR (special drawing rights) as the
preferred indicator.4

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.5 Corn futures prices are used as a proxy for feed costs. For the United
States, we also include meat slaughtering labor cost to better proxy for the cost of beef
production. Such data are not available for the other countries. To capture any underlying
 technological progress that could also contribute to the change in a country’s comparative
advantage in beef, we include a linear trend variable. We control for nonlinearities in the
following manner. The main interest of the study is to estimate the long-run effect of the BSE
outbreak on comparative advantage. Hence, to examine any possible nonlinear impact over time,
we generate nonlinear trend variables using the restricted cubic spline function, instead of
generating a simple dummy variable indicating the BSE event.6 We do so by interacting
nonlinear trend variables, generated using STATA’s mkspline command, with the BSE dummy
variable. The five knots are generated at years 1983, 1991, 2000, 2009, and 2016. Given only
post-BSE periods are fitted with nonlinear trend variables, only two knots (2009 and 2016) are
used.

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4 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.
5 Consumer prices for all 12 countries are collected from the World Bank. Data for Argentina is missing after 2013.
We fill its missing values from the Bank for International Settlements (BIS).
6 See https://www.stata.com/manuals13/rmkspline.pdf for the discussion of the underlying generating process.
4. Empirical Analyses

Revealed Comparative Advantage in the Beef Sector

To examine whether the U.S. has held a comparative advantage in beef exports, we construct revealed comparative advantage (RCA) indices for the U.S. as well as for eleven other major beef exporting countries. The RCA index was first proposed by Balassa (1977) and reformulated in Balassa (1986) as an empirical proxy for Ricardian comparative advantage. While useful, Balassa’s original RCA index features some unsatisfactory characteristics. In particular, the 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 or over time. Following recent literature, we adopt the normalized revealed comparative advantage (NRCA) index proposed by Yu et al. (2009). The NRCA index 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 index is defined as

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

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. 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

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7 See Sarker and Ratnasena (2014) for in depth discussion of the development of new RCA indices. Sarker and Ratnasena (2014) also adopt the modified RCA index by Yu et al. (2009) in their analysis on Canadian beef comparative advantage.
advantage if otherwise (i.e., $NRCA < 0$). Figure 2 shows each country’s NRCA in beef exports over the sample period.

[Insert Figure 2: Normalized Revealed Comparative Advantage]

Australia has a lower beef production cost and indeed, we see that Australia has been leading other competitors in comparative advantage. The U.S. 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, where the U.S. NRCA in beef fell 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 re-distributed to a handful of other exporters. This graphical evidence suggests that the market moved toward higher competitiveness all-around.9

**Seemingly Unrelated Regressions (SURs) Estimation**

We next move to estimating the impacts of the BSE outbreak on the U.S. and other countries’ comparative advantage in beef. We limit the sample period to cover 1981 to 2017, ending just prior to the U.S. engagement on trade renegotiations. We correlate the NRCA index with variables we consider would contribute to its variation. Because the NRCA index is constructed using exports to all importing countries instead of bilateral exports, we can view these exporters

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8 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).

9 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.
as serving the world market together. As a result, we estimate the twelve equations simultaneously as a seemingly unrelated regression system, with potentially correlated, cross-equations errors. The system of equations is specified in equation (2):

\[
NRCA_{iy} = \beta_{i0} + \beta_{i1}cattle\_ratio_{iy} + \beta_{i2}corn_{y} + \beta_{i3}cpi_{iy} + \beta_{i4}xrate_{iy} + \\
\beta_{i5}labor\_cost\_US_{iy} + \beta_{i6}t1_{y} + \beta_{i7}BSE_{y} \times t1_{y} + \beta_{i8}BSE_{y} \times t2_{y} + \\
\beta_{i9}BSE_{y} \times t3_{y} + \beta_{i10}BSE_{y} \times t4_{y} + \epsilon_{iy}.
\]

Consistent with equation (1), \( i \) denotes country, and \( y \) denotes year. For each country (ignoring subscripts), \( \text{cattle\_ratio} \) is the cattle stock-to-slaughter ratio\(^{10} \), \( \text{corn} \) is the corn futures price, \( \text{cpi} \) is the inflation rate for consumer prices, \( \text{labor\_cost\_US} \) 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 \( \text{cattle\_ratio} \) contributes to the variation of NRCA, it is also likely a channel through which the BSE outbreak impacts a country’s NRCA in beef. For instance, the U.S. 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 towards statistical insignificance once \( \text{cattle\_ratio} \) is held constant in the regression. In the extreme case, if one believes that \( \text{cattle\_ratio} \) 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.

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\(^{10}\) 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.
after controlling for \textit{cattle\_ratio}. To address this issue, we implement a first-stage regression of \textit{cattle\_ratio} on the post-BSE trend variables and obtain the predicted error term for each country:

\begin{equation}
\text{cattle}\_\text{ratio}_iy = \gamma_{i0} + \gamma_{i1}BSE_y \times t1_y + \gamma_{i2}BSE_y \times t2_y + \gamma_{i3}BSE_y \times t3_y + \\
\gamma_{i4}BSE_y \times t4_y + \epsilon_{iy}.
\end{equation}

By construction, the predicted error term $\epsilon_{iy}$, which we interpret as the residual variation of \textit{cattle\_ratio}, is not correlated with the post-BSE trend variables. Therefore, we replace \textit{cattle\_ratio} with $\epsilon_{iy}$ in equation (2) to estimate the following system of equations:\textsuperscript{11}

\begin{equation}
\text{NRCA}_iy = \alpha_{i0} + \alpha_{i1}\bar{\epsilon}_iy + \alpha_{i2}\text{corn}_y + \alpha_{i3}\text{cpi}_iy + \alpha_{i4}\text{cpi}_iy + \alpha_{i5}\text{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},
\end{equation}

where all variables are the same as in equation (2), except for $\epsilon_{iy}$, the residual variation of \textit{cattle\_ratio}.

To aid in discussion, we standardize the NRCA indices in equation (4), thus the interpretation of the estimated coefficients will be how many standard deviations of change in NRCA given a unit change in a given right-hand-side variable. The results of interest are the predicted values of NRCA from the regression model. Once equation (4) is estimated, we obtain the predicted NRCA indices for all countries. We also predict the NRCA indices 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.

\textit{Estimation Results}

\textsuperscript{11} We also present the result of using the unaltered cattle stock-to-slaughter ratio in the appendix.
For the sake of brevity, although the system of equations is for the top 12 beef exporting nations, the discussion of findings will focus on the U.S. as well as the top five exporters: Australia, Brazil, Canada, Mexico, and New Zealand. Table 1 present the estimation of the SUR models for all 12 countries.12

[Insert Table 1: Seemingly Unrelated Regressions]

Given that there are 37 observations in each equation, we adopt the small sample adjustment when performing the estimation.13 In most cases, the coefficients of variables related to cost of production are not statistically significant, except for the meat slaughtering house labor cost in the U.S. equation. Still, the regression model fits the variation of our NRCA indices 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 advantage14.

Next we turn to the presentation of the predicted NRCA indices over time from the SUR estimations as shown in Figure 315. Our model predicts that not only would the U.S. would 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 U.S. today is only as competitive as it was twenty years ago. A simple test of the model is that a similar story is observed for Canada, who was also impacted by a BSE outbreak in 2002.16

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12 The estimated results of equation (3) are presented in the appendix.
13 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.
14 R^2 values for the top five exporters are around 90%, and lower for Mexico at around 60%.
15 Figures of the prediction results for the six other countries are presented in the appendix.
16 Canada, while also hit by BSE and whose NRCA has been trending downward since, did not experience a sharp decline as the United States did. This is likely due to the availability of a traceability program in Canada that was not available in the United States.
On the other hand, we observe that Australia, Brazil, and New Zealand would have shown a decreasing trend in their comparative advantage in beef without the 2003 BSE outbreak and these three countries were all on track to lose their comparative advantage (i.e., NRCA < 0) in beef over time. 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 U.S. in the large import markets of Japan, South Korea, and Taiwan.

[Insert Figure 3: Predicted NRCA — BSE vs. no-BSE]

5. Conclusions

As trade disruptions made headlines in 2018 and 2019, one concern has been 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 lingers beyond the phytosanitary 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 U.S. 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 pre-outbreak 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 U.S. and Canada were impacted directly with BSE in 2002 and 2003, which might lend itself to a comparison of impacted versus non-impacted exporters. Recent developments in the causal inference literature, for example, might provide alternative methods that seem to fit this settings. Abadie et al. (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 U.S. (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. This is possible, however, Marsh et al. (2008) studied this issue precisely and conclude that the impacts of BSE on demand come from the trade bans, not from changes in consumer preferences.

Research studying the potential impacts of the China-U.S. trade disputes (2018-19) is important but are 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 (Marchant and Wang 2018; Balistreri et al. 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. Markets disrupted do not easily bounce back after the disruption. Using longitudinal data on beef exports that spans 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.
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Figures and Tables

Figure 1: Annual Beef Export Values (Billion USD)
Figure 2: Normalized Revealed Comparative Advantage

[Graph showing normalized revealed comparative advantage for various countries over time.]

- Australia
- Brazil
- Mexico
- New Zealand
- Canada
- United States
- Argentina
- Panama
- India
- Paraguay
- Nicaragua
- Uruguay
Table 1: Seemingly Unrelated Regressions

1-1: Argentina, Australia, Brazil, Canada, India, and Mexico

|                | (1) NRCA1 | (2) NRCA2 | (3) NRCA3 | (4) NRCA4 | (5) NRCA5 | (6) NRCA6 |
|----------------|----------|----------|----------|----------|----------|----------|
| re.cattle.ratio1 | -0.077   | (0.048)  |          |          |          |          |
| cpi1           | -5.63e-5 |          |          |          |          |          |
|                | (2e-2)   |          |          |          |          |          |
| x.sdr1         | 0.017    | (0.013)  |          |          |          |          |
| re.cattle.ratio2 | -0.330***| (0.070)  |          |          |          |          |
| cpi2           | 0.001    |          |          |          |          |          |
| x.sdr2         | 0.28e**  |          |          |          |          |          |
|                | (0.127)  |          |          |          |          |          |
| re.cattle.ratio3 |          |          | -0.365***| (0.100)  |          |          |
| cpi3           | -2.13e-5 |          |          |          |          |          |
| x.sdr3         | 0.281*** |          |          |          |          |          |
|                | (0.049)  |          |          |          |          |          |
| re.cattle.ratio4 |          |          |          | -0.538***| (0.133)  |          |
| cpi4           |          | (0.077***|          |          |          |          |
|                |          | (0.018)  |          |          |          |          |
| x.sdr4         |          |          | 0.442    |          |          |          |
|                |          |          | (0.346)  |          |          |          |
| re.cattle.ratio5 |          |          |          |          | -0.161* | (0.095)  |
| cpi5           |          |          |          |          |          | 0.004    |
| x.sdr5         |          |          |          |          | 0.086***| (0.009)  |
|                |          |          |          |          |          |          |
| re.cattle.ratio6 |          |          |          |          |          | 0.153**  |
| cpi6           |          |          |          |          |          | (0.072)  |
| x.sdr6         |          |          | -0.015   |          |          | (0.001)  |
| trend1         |          |          |          |          |          | (0.014)  |
| corn           |          |          |          |          |          |          |
| t1×BSE         |          |          |          |          |          |          |
| t2×BSE         |          |          |          |          |          |          |
| t3×BSE         |          |          |          |          |          |          |
| t4×BSE         |          |          |          |          |          |          |
| cons           |          |          |          |          |          |          |

Columns (1) to (6) refer to the list of 6 countries in alphabetical order: Argentina, Australia, Brazil, Canada, India, and Mexico. For all equations, NRCA indices are standardized, and re.cattle.ratio denotes the residual variation of the original cattle.ratio variables, obtained from the first-stage equations. trend1 is the linear trend variable. t1×BSE denotes the post-BSE linear trend variable, and t2×BSE, t3×BSE, t4×BSE denote the post-BSE non-linear trend variables, generated by the restricted cubic spline function. *, **, and *** denote significance at the 10%, 5%, and 1% level.
Table 1: Seemingly Unrelated Regressions. (Continued.)

1-2: New Zealand, Nicaragua, Panama, Paraguay, United States, and Uruguay

|                | (7)       | (8)       | (9)       | (10)      | (11)      | (12)      |
|----------------|-----------|-----------|-----------|-----------|-----------|-----------|
| re_cattle_ratio7| -0.113    |           |           |           |           |           |
|                | (0.074)   |           |           |           |           |           |
| cpi7           | -2.06e-4  |           |           |           |           |           |
|                | (0.005)   |           |           |           |           |           |
| x_sdr7         | 0.113     |           |           |           |           |           |
|                | (0.082)   |           |           |           |           |           |
| re_cattle_ratio8| -0.060*** |           |           |           |           |           |
|                | (0.025)   |           |           |           |           |           |
| cpi8           | 8.79e-6   |           |           |           |           |           |
|                | (1.16e-5) |           |           |           |           |           |
| x_sdr8         | -0.004    |           |           |           |           |           |
|                | (0.015)   |           |           |           |           |           |
| re_cattle_ratio9| -0.178    |           |           |           |           |           |
|                | (0.304)   |           |           |           |           |           |
| cpi9           | 0.180**   |           |           |           |           |           |
|                | (0.003)   |           |           |           |           |           |
| x_sdr9         | 0.144     |           |           |           |           |           |
|                | (1.569)   |           |           |           |           |           |
| re_cattle_ratio10 | -0.080*** |           |           |           |           |           |
|                  | (0.027)   |           |           |           |           |           |
| cpi10          | 0.033***  |           |           |           |           |           |
|                | (0.006)   |           |           |           |           |           |
| x_sdr10        | -6.15e-5  |           |           |           |           |           |
|                | (5.01e-5) |           |           |           |           |           |
| re_cattle_ratio11 | -0.067    |           |           |           |           |           |
|                  | (0.222)   |           |           |           |           |           |
| labor_cost_mest11 | -0.259*** |           |           |           |           |           |
|                  | (0.042)   |           |           |           |           |           |
| cpi11          | 0.012     |           |           |           |           |           |
|                | (0.009)   |           |           |           |           |           |
| x_sdr11        | 0.416***  |           |           |           |           |           |
|                | (0.131)   |           |           |           |           |           |
| re_cattle_ratio12 | -0.330*** |           |           |           |           |           |
|                  | (0.032)   |           |           |           |           |           |
| cpi12          | -0.066*** |           |           |           |           |           |
|                | (0.002)   |           |           |           |           |           |
| x_sdr12        | 0.026***  |           |           |           |           |           |
|                | (0.010)   |           |           |           |           |           |
| trend1         | -0.063*** | -1.12e-4  | 0.014     | 0.025     | 0.122***  | -0.109*** |
|                | (0.006)   | (0.016)   | (0.037)   | (0.020)   | (0.011)   | (0.015)   |
| corn           | -0.002    | -0.002    | -0.181    | -0.259*** | 0.017     | 0.057     |
|                | (0.039)   | (0.045)   | (0.074)   | (0.022)   | (0.071)   |           |
| t1xbse         | 0.007     | 0.009     | 0.008     | 0.012     | -2.55e-4  | -0.007    |
|                | (0.006)   | (0.006)   | (0.057)   | (0.010)   | (0.003)   | (0.010)   |
| t2xbse         | -5.014    | -6.524    | -4.853    | -8.887    | -0.167    | 5.098     |
|                | (3.517)   | (4.121)   | (2.6287)  | (7.150)   | (2.094)   | (6.885)   |
| t3xbse         | 13.624    | 17.922    | 11.329    | 25.305    | 0.447     | -13.579   |
|                | (9.595)   | (11.248)  | (7.1967)  | (19.509)  | (5.729)   | (18.787)  |
| t4xbse         | -12.955   | -17.669   | -6.475    | -26.373   | -0.407    | 13.019    |
|                | (9.435)   | (11.059)  | (7.0341)  | (19.167)  | (5.532)   | (18.460)  |
| cons           | 124.550***| -0.252    | -26.435   | -49.661   | -240.015***| 218.135***|
|                | (12.731)  | (32.277)  | (72.086)  | (39.002)  | (29.067)  | (29.590)  |

|                | N  | 37 | 37 | 37 | 37 | 37 |
|----------------|----|----|----|----|----|----|
| R^2            | 0.9304 | 0.7606 | 0.5683 | 0.6528 | 0.9788 | 0.8771 |
| Adjusted R^2   | 0.9072 | 0.6808 | 0.4244 | 0.8971 | 0.9706 | 0.8361 |

Columns (7) to (12) refer to the list of 6 countries in alphabetical order: New Zealand, Nicaragua, Panama, Paraguay, United States, and Uruguay. 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 equations. trend1 is the linear trend variable. t1xbse denotes the post-BSE linear trend variable, and t2xbse, t3xbse, t4xbse, cons denote the post-BSE non-linear trend variables, generated by the restricted cubic spline function. *, **, and *** denote significance at the 10%, 5%, and 1% level.
Figure 3: Predicted NRCA — BSE v.s. no-BSE
## Appendix

Table A1: Summary Statistics

| Variable            | N  | Mean    | Std. Dev. | Description                        | Source       |
|---------------------|----|---------|-----------|------------------------------------|--------------|
| cattle_stock<sub>1</sub> | 38 | 52.72002| 2.79745   | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>2</sub> | 38 | 25.87205| 2.224555  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>3</sub> | 38 | 171.8402| 33.52359  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>4</sub> | 38 | 12.47874| 1.33065   | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>5</sub> | 38 | 194.5914| 6.01659   | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>6</sub> | 38 | 31.40562| 1.213485  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>7</sub> | 38 | 9.025953| 0.8744042 | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>8</sub> | 38 | 3.236072| 0.871131  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>9</sub> | 38 | 1.493978| 0.103577  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>10</sub> | 38 | 9.701431| 2.407057  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>11</sub> | 38 | 99.29926| 7.210674  | Cattle stock (million heads)       | FAO          |
| cattle_stock<sub>12</sub> | 38 | 10.8747 | 1.099701  | Cattle stock (million heads)       | FAO          |
| cattle_slaughter<sub>1</sub> | 38 | 12.87176| 1.189742  | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>2</sub> | 38 | 8.472082| 0.6735622 | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>3</sub> | 38 | 29.85377| 8.872003  | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>4</sub> | 38 | 3.796979| 0.3782814 | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>5</sub> | 38 | 9.876028| 0.5635206 | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>6</sub> | 38 | 6.773944| 1.39638   | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>7</sub> | 38 | 3.153335| 0.5573023 | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>8</sub> | 38 | 0.478751| 0.203793  | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>9</sub> | 38 | 0.306296| 0.04605   | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>10</sub> | 38 | 1.125664| 0.4172916 | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>11</sub> | 38 | 36.03836| 2.735739  | Cattle slaughtered (million heads) | FAO          |
| cattle_slaughter<sub>12</sub> | 38 | 1.87983 | 0.3564109 | Cattle slaughtered (million heads) | FAO          |
| corn                | 40 | 3.197255| 1.216446  | Corn futures ($/Bu)                | Macrotrends LLC |
| cpi<sub>1</sub>      | 39 | 216.4515| 61.339    | Consumer price inflation rate       | World Bank; BIS |
| cpi<sub>2</sub>      | 39 | 410.9882| 3.017124  | Consumer price inflation rate       | World Bank    |
| cpi<sub>3</sub>      | 39 | 309.1216| 67.43259  | Consumer price inflation rate       | World Bank    |
| cpi<sub>4</sub>      | 39 | 3.171091| 2.717863  | Consumer price inflation rate       | World Bank    |
| cpi<sub>5</sub>      | 39 | 7.908843| 3.083302  | Consumer price inflation rate       | World Bank    |
| cpi<sub>6</sub>      | 39 | 25.19677| 33.18579  | Consumer price inflation rate       | World Bank    |
| cpi<sub>7</sub>      | 39 | 4.834514| 5.023596  | Consumer price inflation rate       | World Bank    |
| cpi<sub>8</sub>      | 39 | 7.07.5122| 21.36207  | Consumer price inflation rate       | World Bank    |
| cpi<sub>9</sub>      | 39 | 2.336301| 2.789264  | Consumer price inflation rate       | World Bank    |
| cpi<sub>10</sub>     | 39 | 12.50468| 8.18081   | Consumer price inflation rate       | World Bank    |
| cpi<sub>11</sub>     | 39 | 3.268079| 2.435917  | Consumer price inflation rate       | World Bank    |
| cpi<sub>12</sub>     | 39 | 31.35265| 30.54628  | Consumer price inflation rate       | World Bank    |
| labor_costmeat<sub>1</sub> | 39 | 10.24368| 2.624154  | Meat slaughtering labor wage ($)    | BLS           |
Table A1: Summary Statistics (Continued)

| Description                  | Source  |
|------------------------------|---------|
| N               | Mean    | Std. Dev. | Description                  | Source  |
| v.beef<sub>1</sub> 39 | .699369 | .4322438  | Beef export value (billion $) | Comtrade |
| v.beef<sub>2</sub> 39 | 2.917069| 1.782814  | Beef export value (billion $) | Comtrade |
| v.beef<sub>3</sub> 39 | 1.76192 | 1.990317  | Beef export value (billion $) | Comtrade |
| v.beef<sub>4</sub> 39 | .7939098| .5563645  | Beef export value (billion $) | Comtrade |
| v.beef<sub>5</sub> 39 | .963747 | 1.499935  | Beef export value (billion $) | Comtrade |
| v.beef<sub>6</sub> 39 | .2231722| .3830925  | Beef export value (billion $) | Comtrade |
| v.beef<sub>7</sub> 39 | 1.033329| .560565   | Beef export value (billion $) | Comtrade |
| v.beef<sub>8</sub> 39 | .149085 | .1656376  | Beef export value (billion $) | Comtrade |
| v.beef<sub>9</sub> 39 | .0075896| .0061413  | Beef export value (billion $) | Comtrade |
| v.beef<sub>10</sub> 39| .3181687| .418687   | Beef export value (billion $) | Comtrade |
| v.beef<sub>11</sub> 39| 2.479568| 1.846289  | Beef export value (billion $) | Comtrade |
| v.beef<sub>12</sub> 39| .5869272| .5177137  | Beef export value (billion $) | Comtrade |
| x.sdr<sub>1</sub> 39 | 4.835561| 7.815817  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>2</sub> 39 | 1.787339| .3406786  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>3</sub> 39 | 1.980901| 1.75723   | Currency per SDR             | IMF-IFS |
| x.sdr<sub>4</sub> 39 | 1.718998| .2143212  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>5</sub> 39 | 51.58142| 27.98552  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>6</sub> 39 | 11.39118| 8.520946  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>7</sub> 39 | 2.163675| .3786204  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>8</sub> 39 | 17.45648| 14.85838  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>9</sub> 39 | 1.370551| .147741   | Currency per SDR             | IMF-IFS |
| x.sdr<sub>10</sub> 39| 4.40425 | 3170.728  | Currency per SDR             | IMF-IFS |
| x.sdr<sub>11</sub> 39| 1.370551| .147741   | Currency per SDR             | IMF-IFS |
| x.sdr<sub>12</sub> 39| 18.64481| 16.19116  | Currency per SDR             | IMF-IFS |
Table A2: First-Stage Regressions

A2-1: Argentina, Australia, Brazil, Canada, India, and Mexico

|           | (1) cattle_ratio1 | (2) cattle_ratio2 | (3) cattle_ratio3 | (4) cattle_ratio4 | (5) cattle_ratio5 | (6) cattle_ratio6 |
|-----------|------------------|------------------|------------------|------------------|------------------|------------------|
| t1×BSE   | 0.001            | 0.002            | 0.018            | -0.016           | -0.015           | -0.006           |
|          | (0.010)          | (0.008)          | (0.019)          | (0.014)          | (0.024)          | (0.024)          |
| t2×BSE   | -0.897           | -1.621           | -12.819          | 11.503           | 10.822           | 4.353            |
|          | (7.168)          | (5.955)          | (13.534)         | (9.976)          | (16.613)         | (16.658)         |
| t3×BSE   | 2.369            | 4.573            | 34.541           | -31.248          | -29.881          | -12.146          |
|          | (19.473)         | (16.176)         | (36.766)         | (27.100)         | (45.130)         | (45.252)         |
| t4×BSE   | -2.001           | -4.919           | -32.641          | 30.204           | 30.583           | 12.621           |
|          | (18.911)         | (15.710)         | (35.706)         | (26.318)         | (43.828)         | (43.946)         |
| .cons    | 4.115***         | 2.979***         | 6.301***         | 3.336***         | 19.443***        | 5.292***         |
|          | (0.058)          | (0.048)          | (0.109)          | (0.081)          | (0.134)          | (0.135)          |

N          | 37               | 37               | 37               | 37               | 37               | 37               |

$F$-prob   | 0.5228           | 0.0604           | 0.0001           | 0.5321           | 0.0039           | 0.0000           |

$R^2$      | 0.9928           | 0.2396           | 0.5219           | 0.0913           | 0.3855           | 0.5592           |

Adjusted $R^2$ | -0.0206           | 0.1446           | 0.4622           | -0.0223          | 0.3087           | 0.5041           |

Columns (1) to (6) refer to the list of 6 countries in alphabetical order: Argentina, Australia, Brazil, Canada, India, and Mexico. cattle_ratio is defined as the ratio of cattle stock over cattle slaughtered. t1×BSE denotes the post-BSE linear trend variable, and t2×BSE, t3×BSE, t4×BSE denote the post-BSE non-linear trend variables, generated by the restricted cubic spline function. *, **, and *** denote significance at the 10%, 5%, and 1% level. $F$-prob refers to the joint significance test result.

A2-2: New Zealand, Nicaragua, Panama, Paraguay, United States, and Uruguay

|           | (7) cattle_ratio7 | (8) cattle_ratio8 | (9) cattle_ratio9 | (10) cattle_ratio10 | (11) cattle_ratio11 | (12) cattle_ratio12 |
|-----------|------------------|------------------|------------------|---------------------|---------------------|--------------------|
| t1×BSE   | -0.005           | -0.019           | -0.021           | 0.046               | -0.002              | 0.017              |
|          | (0.007)          | (0.027)          | (0.015)          | (0.066)             | (0.004)             | (0.029)            |
| t2×BSE   | 3.443            | 14.343           | 15.183           | -34.367             | 1.492               | -12.305            |
|          | (5.107)          | (19.385)         | (10.399)         | (46.583)            | (2.706)             | (20.260)           |
| t3×BSE   | -9.071           | -40.796          | -41.902          | 95.166              | -4.227              | 33.740             |
|          | (13.875)         | (52.660)         | (28.251)         | (126.545)           | (7.351)             | (55.038)           |
| t4×BSE   | 7.982            | 44.417           | 42.134           | -97.564             | 4.602               | -33.484            |
|          | (13.474)         | (51.141)         | (27.436)         | (122.895)           | (7.139)             | (53.450)           |
| .cons    | 2.677***         | 8.551***         | 5.023***         | 9.592***            | 2.728***            | 6.170***           |
|          | (0.041)          | (0.157)          | (0.084)          | (0.377)             | (0.022)             | (0.164)            |

N          | 37               | 37               | 37               | 37               | 37               | 37               |

$F$-prob   | 0.0041           | 0.0000           | 0.0055           | 0.1265             | 0.0291             | 0.0879             |

$R^2$      | 0.3718           | 0.7670           | 0.3588           | 0.1958             | 0.2791             | 0.2179             |

Adjusted $R^2$ | 0.2933           | 0.7379           | 0.2787           | 0.0953             | 0.1890             | 0.1202             |

Columns (7) to (12) refer to the list of 6 countries in alphabetical order: New Zealand, Nicaragua, Panama, Paraguay, United States, and Uruguay. cattle_ratio is defined as the ratio of cattle stock over cattle slaughtered. t1×BSE denotes the post-BSE linear trend variable, and t2×BSE, t3×BSE, t4×BSE denote the post-BSE non-linear trend variables, generated by the restricted cubic spline function. *, **, and *** denote significance at the 10%, 5%, and 1% level. $F$-prob refers to the joint significance test result.
Figure A1: Predicted NRCA — BSE v.s. no-BSE (Six Other Countries)
Table A3: Seemingly Unrelated Regressions (Unaltered Cattle Ratio)

A3-1: Argentina, Australia, Brazil, Canada, India, and Mexico

|                      | (1)          | (2)          | (3)          | (4)          | (5)          | (6)          |
|----------------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                      | NRCA1        | NRCA2        | NRCA3        | NRCA4        | NRCA5        | NRCA6        |
| cattle_ratio1        | -0.077       |              |              |              |              |              |
|                      | (0.048)      |              |              |              |              |              |
| cpi1                 | -5.65e-5***  |              |              |              |              |              |
|                      | (2.19e-5)    |              |              |              |              |              |
| x.sdr1               | 0.017        |              |              |              |              |              |
|                      | (0.013)      |              |              |              |              |              |
| cattle_ratio2        | -0.330***    |              |              |              |              |              |
|                      | (0.070)      |              |              |              |              |              |
| cpi2                 | 0.001        |              |              |              |              |              |
|                      | (0.008)      |              |              |              |              |              |
| x.sdr2               | 0.286**      |              |              |              |              |              |
|                      | (0.127)      |              |              |              |              |              |
| cattle_ratio3        |              |              |              | -0.965***    |              |              |
|                      |              |              |              | (0.100)      |              |              |
| cpi3                 |              |              | -2.31e-5     |              |              |              |
|                      |              |              | (4.36e-5)    |              |              |              |
| x.sdr3               |              |              | 0.281***     |              |              |              |
|                      |              |              | (0.049)      |              |              |              |
| cattle_ratio4        |              |              |              |              | -0.538***    |              |
|                      |              |              |              |              | (0.133)      |              |
| cpi4                 |              |              |              | 0.077***     |              |              |
|                      |              |              |              | (0.018)      |              |              |
| x.sdr4               |              |              |              | 0.442        |              |              |
|                      |              |              |              | (0.346)      |              |              |
| cattle_ratio5        |              |              |              |              |              | -0.161*      |
|                      |              |              |              |              |              | (0.065)      |
| cpi5                 |              |              |              |              | -0.004       |              |
|                      |              |              |              |              | (0.015)      |              |
| x.sdr5               |              |              |              | 0.086***     |              |              |
|                      |              |              |              | (0.009)      |              |              |
| cattle_ratio6        |              |              |              |              |              | 0.153**      |
|                      |              |              |              |              |              | (0.072)      |
| cpi6                 |              |              |              |              | 0.002*       |              |
|                      |              |              |              |              | (0.001)      |              |
| x.sdr6               |              |              |              |              | -0.015       |              |
|                      |              |              |              |              | (0.014)      |              |
| trend1               | -0.019***    | -0.032***    | -0.070***    | 0.146***     | -0.055*      | 0.030*       |
|                      | (0.004)      | (0.004)      | (0.014)      | (0.013)      | (0.029)      | (0.016)      |
| t1xbse               | 0.002        | 0.002        | 0.002        | 0.001        | 0.012        | 0.002        |
|                      | (0.004)      | (0.005)      | (0.008)      | (0.010)      | (0.009)      | (0.007)      |
| t2xbse               | 1.206        | -4.181       | 1.185        | -0.776       | -8.840       | -1.168       |
|                      | (2.964)      | (3.794)      | (5.821)      | (7.225)      | (6.566)      | (4.824)      |
| t3xbse               | -3.294       | 11.379       | -2.530       | 1.435        | 24.452       | 3.221        |
|                      | (8.103)      | (10.354)     | (15.872)     | (19.700)     | (17.933)     | (13.164)     |
| t4xbse               | 3.200        | -10.870      | 1.046        | -0.307       | -23.975      | -3.113       |
|                      | (8.026)      | (10.173)     | (15.559)     | (19.317)     | (17.689)     | (12.938)     |
| corn                 | 0.027        | 0.003        | -0.002       | -0.013       | -0.020       | 0.004        |
|                      | (0.029)      | (0.043)      | (0.059)      | (0.072)      | (0.063)      | (0.049)      |
| cons                 | 36.990***    | 104.142***   | 140.060***   | -290.181***  | 111.963***   | -80.482*     |
|                      | (7.437)      | (17.459)     | (29.122)     | (25.016)     | (57.220)     | (31.966)     |

Columns (1) to (6) refer to the list of 6 countries in alphabetical order: Argentina, Australia, Brazil, Canada, India, Mexico. For all equations, NRCA indices are standardized, and cattle.ratio is defined as the ratio of cattle stock over cattle slaughtered. trend1 is the linear trend variable. t1xbse denotes the post-BSE linear trend variable, and t2xbse, t3xbse, t4xbse denote the post-BSE non-linear trend variables, generated by the restricted cubic spline function. *, **, and *** denote significance at the 10%, 5%, and 1% level.

N     37
R²    0.5538
Adjusted R² 0.4968
### A3-2: New Zealand, Nicaragua, Panama, Paraguay, United States, and Uruguay

|                  | (7) NRCA7 | (8) NRCA8 | (9) NRCA9 | (10) NRCA10 | (11) NRCA11 | (12) NRCA12 |
|------------------|-----------|-----------|-----------|-------------|-------------|-------------|
| cattle_ratio7    | -0.113    |           |           |             |             |             |
|                  | (0.074)   |           |           |             |             |             |
| cpi7             | -2.06e-4  |           |           |             |             |             |
|                  | (0.005)   |           |           |             |             |             |
| x.sdr7           | 0.113     |           |           |             |             |             |
|                  | (0.082)   |           |           |             |             |             |
| cattle_ratio8    |           | -0.060**  |           |             |             |             |
|                  |           | (0.025)   |           |             |             |             |
| cpi8             | 8.73e-6   |           |           |             |             |             |
|                  | (1.16e-5) |           |           |             |             |             |
| x.sdr8           | -0.004    |           |           |             |             |             |
|                  | (0.015)   |           |           |             |             |             |
| cattle_ratio9    |           | -0.178    |           |             |             |             |
|                  |           | (0.304)   |           |             |             |             |
| cpi9             |           | 0.180**   |           |             |             |             |
|                  |           | (0.003)   |           |             |             |             |
| x.sdr9           |           | 0.144     |           |             |             |             |
|                  |           | (1.269)   |           |             |             |             |
| cattle_ratio10   |           |           | -0.080*** |             |             |             |
|                  |           |           | (0.027)   |             |             |             |
| cpi10            |           |           | 0.036***  |             |             |             |
|                  |           |           | (0.006)   |             |             |             |
| x.sdr10          |           |           | -0.15e-5  |             |             |             |
|                  |           |           | (5.01e-5) |             |             |             |
| cattle_ratio11   |           |           |           | -0.067      |             |             |
|                  |           |           |           | (0.122)     |             |             |
| labor_cost_meat11|           |           |           |            -0.275*** |             |             |
|                  |           |           |           | (0.042)     |             |             |
| cpi11            |           |           |           | 0.012       |             |             |
|                  |           |           |           | (0.009)     |             |             |
| x.sdr11          |           |           |           | 0.410***    |             |             |
|                  |           |           |           | (0.151)     |             |             |
| cattle_ratio12   |           |           |           | -0.339***   |             |             |
|                  |           |           |           | (0.092)     |             |             |
| cpi12            |           |           |           | -0.068***   |             |             |
|                  |           |           |           | (0.062)     |             |             |
| x.sdr12          |           |           |           | 0.028**     |             |             |
|                  |           |           |           | (0.010)     |             |             |
| trend1           | -0.063*** | -1.12e-4  | 0.014     | 0.025       | 0.122***    | -0.109***   |
|                  | (0.006)   | (0.016)   | (0.037)   | (0.020)     | (0.011)     | (0.015)     |
| t1xbse           | 0.007     | 0.008     | 0.005     | 0.016       | -3.80e-4    | -0.002      |
|                  | (0.005)   | (0.006)   | (0.037)   | (0.010)     |             |             |
| t2xbse           | -4.026    | -5.068    | -2.154    | -11.647     | -0.068      | 0.032       |
|                  | (5.530)   | (4.097)   | (26.01)   | (7.160)     |             |             |
| t3xbse           | 12.603    | 15.488    | 3.881     | 32.945*     | 0.164       | -2.150      |
|                  | (9.649)   | (11.719)  | (72.588)  | (19.542)    |             |             |
| t4xbse           | -12.056   | -15.019   | 1.015     | -34.709*    | -0.099      | 1.683       |
|                  | (9.481)   | (10.981)  | (71.303)  | (19.209)    |             |             |
| corn             | -0.018    | -0.002    | -0.181    | -0.230***   | 0.017       | 0.057       |
|                  | (0.030)   | (0.045)   | (0.290)   | (0.074)     |             |             |
| .cons            | 124.882***| 0.258     | -25.502   | -48.891     | -239.833*** | 220.223***  |
|                  | (12.786)  | (32.306)  | (72.513)  | (39.115)    | (20.792)    | (29.475)    |

**Columns (7) to (12) refer to the list of 6 countries in alphabetical order: New Zealand, Nicaragua, Panama, Paraguay, United States, and Uruguay. For all equations, NRCA indices are standardized, and cattle ratio is defined as the ratio of cattle stock over cattle slaughtered. trend1 is the linear trend variable. t1×BSE denotes the post-BSE linear trend variable, and t2×BSE, t3×BSE, t4×BSE denote the post-BSE non-linear trend variables, generated by the restricted cubic spline function. ***, ***, and *** denote significance at the 10%, 5%, and 1% level.**
Figure A2: Predicted NRCA with unaltered cattle ratio — BSE v.s. no-BSE
Figure A2: Predicted NRCA with unaltered cattle ratio — BSE v.s. no-BSE (Continued)