Economic Implications of a Foot and Mouth Disease Free Latin American Beef Sector

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Abstract

Foot and mouth disease (FMD) has caused significant damage to Latin America's beef sector through both production losses and limits to international market access. Using a base year of 2001, we utilize historical outbreak data and estimated production losses in select Latin American countries in tandem with a global economic modeling framework to understand what the domestic and international price effects as well as trade effects could have been, had FMD outbreaks in 2001 been prevented. Results show that Uruguay would have benefited most if production losses resulting from FMD would have been mitigated. This study is a first step in understanding the economic implications of an FMD-free Latin America on the world meat and livestock markets.

Introduction

Transboundary animal diseases (TADs) cause significant economic losses throughout the world, but producers in less developed countries (LDCs) are at particular risk because livestock provide not only income and an asset base, but also food, draught power and various social functions (Rich and Perry 2011). In evaluating TAD impacts, it is now recognized that poverty implications, technical feasibility and political desirability play a role in disease response program selection in LDCs (Perry and Rich 2007; Perry and Grace 2009). Furthermore, the cost benefit offset of eradication versus management programs will vary by disease, where high impact diseases do not necessarily carry high benefits from eradication (Perry and Grace 2009).

Foot-and-mouth disease (FMD) is considered one the most dangerous livestock diseases in the world based on its highly infectious nature; moreover, it is also considered one of the most dangerous *economic* diseases for its implications on long term animal productivity and on international market access. The motivations behind FMD control and the pathway of control/eradication programs for LDCs versus developed countries are marked. Some see the eradication of FMD as a major development milestone in the globalized environment (Perry and Rich 2007), especially given the fact that FMD is ranked within the top 10 diseases constraining poverty alleviation (Perry et al. 2002). The danger presented by FMD for both developed and less developed countries has resulted in a world eradication goal under the joint FAO-OIE Global Framework for the Control of Transboundary Animal Diseases (GF-TADs) and the subsequent Progressive Control Pathway for Foot-and-Mouth Disease (PCP-FMD). The FMD profile of Latin America is characterized by a few endemic[1] areas and intermittent outbreaks in FMD-free areas, most likely resulting from disease spread from endemic areas. Combined with the proximity to major livestock producing and consuming countries along the Pacific Rim that are currently FMD-free, Latin America is likely to benefit greatly from FMD eradication. In 2007, Argentina, Brazil and Paraguay agreed to the formation of intensive surveillance areas in zones along shared borders in an effort to mitigate the spread of transboundary diseases such as FMD (OIE, 2012).

[1] A country is considered FMD endemic when FMD is maintained in the population resulting in regular cases.

This study assesses the economic implications of FMD in a global modeling framework that estimates the changes in domestic and international prices and quantities that would have arisen, had there been no production losses from FMD outbreaks in the region in 2001. Specifically, we shock total factor productivity of the cattle meat sector in each Latin American region by historical observations of meat production losses resulting from FMD in Latin America. Relatively little research exists to fully examine the economic effects of FMD on the beef sector in a general equilibrium framework and this works aims to fill this gap.

Background

The beef sector in Latin America, excluding Mexico, comprised eleven percent of the value of world beef exports in 2001(GTAP Database Version 6) as illustrated by Figure 1. Within Latin America, Brazil is the largest single country exporter of beef, followed by Argentina and Uruguay as shown in Figure 2 (GTAP Database Version 6). It is without question that the region has been limited in its ability to compete in the global beef market as a result of the presence of FMD and the various trade restrictions that have been put in place to protect against the spread of the disease.

Figure 1. Value of Beef Exports in 2001 by Region
(GTAP Database Version 6)

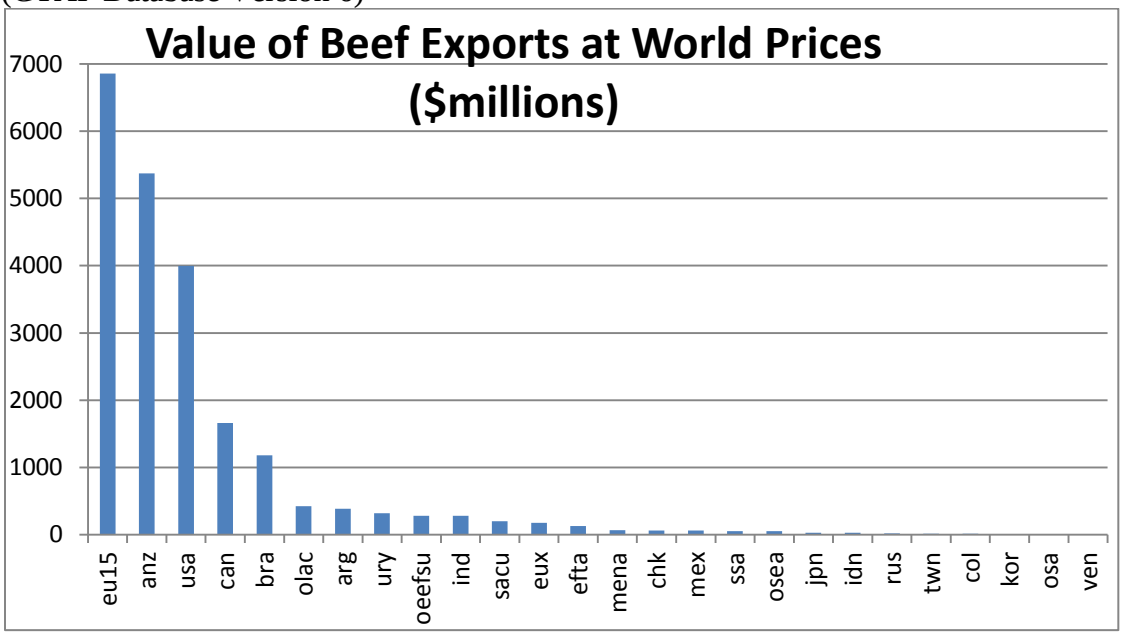
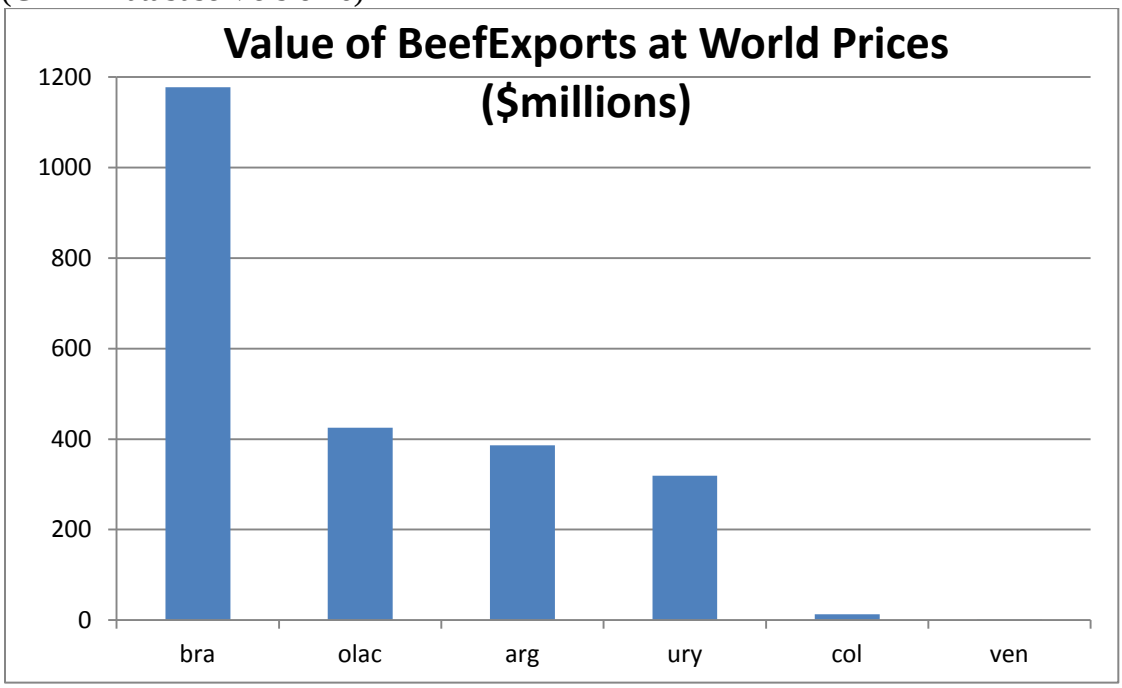


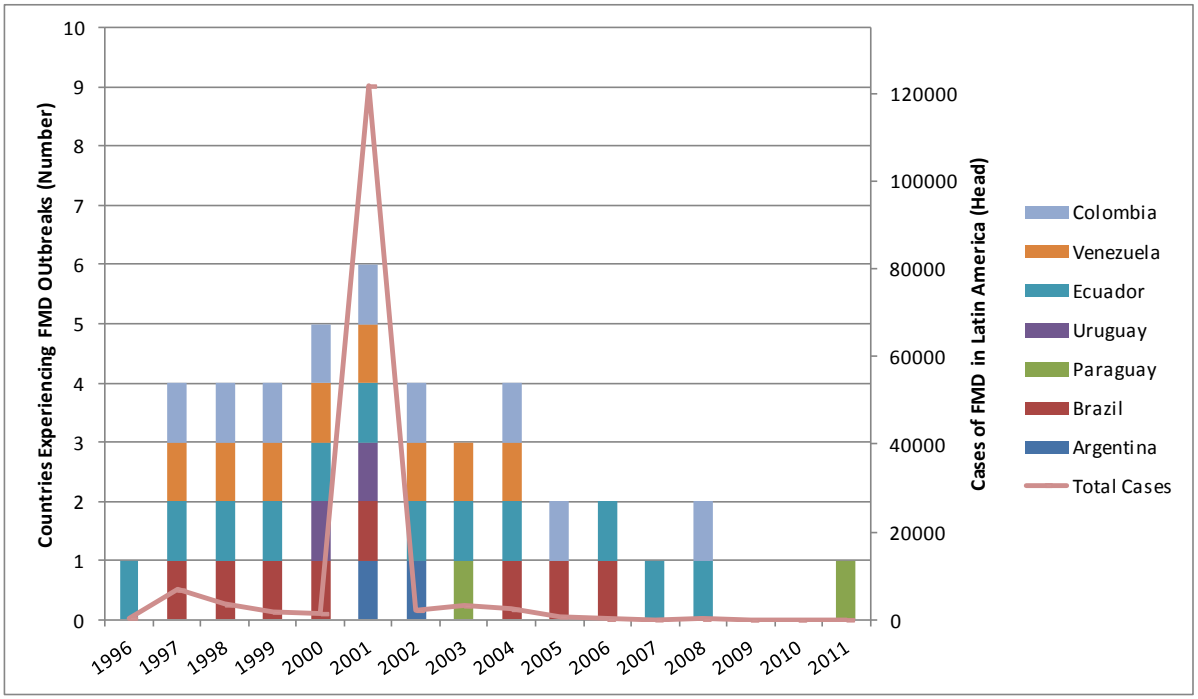
Figure 2. Value of Latin American Beef Exports in 2001
(GTAP Database Version 6)



FMD is intermittently found in several parts of the world, and is endemic in parts of Asia, Africa and South America. FMD is a viral, vesicular disease affecting cloven hoofed animals, causing blisters on the mouth and feet, fever and reduced appetite, and consequently reductions

in weight gain and milk production. While rarely lethal in adults, the death rate can be quite high in very young animals. The morbidity rate approaches 100% in susceptible populations and the disease has multiple avenues of transmission. FMD has been present in Latin America for many years, primarily types O and A[2]. Due to the lower surveillance intensity and reporting in LDCs, traditional mapping of FMD may underestimate true incidence of the disease. Reporting of FMD infection to the World Organization for Animal Health (OIE) by Latin American countries from 1997 to 2011 is illustrated in Figure 3. The instances of the disease hit a sharp peak in 2001 when Argentina and Uruguay experienced large numbers of outbreaks (2,394 and 2,063 herds of livestock, respectively). Pockets of disease still exist throughout Latin America as evidenced by the intermittent occurrence of reported FMD outbreaks. Argentina had multiple herds test positive for FMD type O in February 2006 and Brazil had herds test positive for type O in September and October 2005. As a consequence, FMD-free countries currently face the threat of FMD re-emergence, given the intensity of movements of livestock, wildlife, people and goods in Latin America.

Figure 3. Number of FMD outbreaks and corresponding Latin American countries where FMD occurred



[2] FMD has seven strains (A, O, C, SAT1, SAT2, SAT3, Asia1).

Under Article 20 of the General Agreement on Tariffs and Trade (GATT), countries may take appropriate Sanitary Phytosanitary (SPS) measures to ensure food safety and to protect plant and animal health, provided those measures are not being used to disguise protectionist agendas not related to health and safety. Trade responses to TADs induce two demand responses (Hagerman, et al., 2010). First, SPS trade sanctions by livestock and meat trade partners will persist until the country of outbreak is shown to be disease free for a pre-determined amount of time and often longer if another FMD-free source is available. The presence of FMD has limited, or at least interrupted, market access for Latin American countries in the international meat market and has consequently allowed for competitors to meet this demand. The second trade response is the domestic response to supply shifts. Supply normally shipped to other countries is instead moved into the domestic market, which may lead to lower domestic prices (Thompson, et al., 2002). Thus, the product from FMD infected regions of Latin America has been either consumed domestically or potentially traded regionally with surrounding countries.

In addition, movement restrictions within the FMD infected country will prevent normal livestock movements, thereby impeding production norms, (Thompson, et al., 2002) and disease outbreak related trade bans have been associated with increased international meat market volatility (Morgan and Prakash, 2006). Furthermore, the impact of production losses will likely increase the volatility of prices and production of agricultural commodities which may have implications on poverty and food security (Hertel, Martin and Leister, 2010).

Domestic policies in response to FMD typically follow one of two paths: eradication or management. Typically, countries choose to eradicate FMD if there is adequate support and resources to do so. Eradication through culling requires the extermination of all infected and potentially FMD exposed animals in a geographic region in order to kill the FMD virus, referred to as "stamp out." International market access is likely reinstated more quickly under stamp-out, yet the significant production and herd losses experienced as a result of mass culling may outweigh the benefits of the quicker resumption of trade. For this reason, eradication through stamp out may not hold the same incentives for LDCs. Brazil instated an eradication program of stamp-out plus movement restrictions in response to the August 2000 outbreak, resulting in the slaughter of over 11 thousand animals (over 70% cattle). Similarly, Uruguay responded to an

October 2000 outbreak of type O by using stamp-out, resulting in the slaughter of almost 7 thousand animals (Sutmoller and Casas Olascoaga 2002).

Eradication through vaccination, which is a progressive vaccination program to reduce susceptibility to disease below a critical level, takes more time. This method of eradication does more to maintain production and herd numbers in the region of infection, but comes at the cost of longer limitations on international market access. After a reintroduction of FMD in May 2001, Brazil elected to include vaccination and regionalization in the state where infection occurred (Sutmoller and Casas Olascoaga 2002). Similarly, when Uruguay suffered a reintroduction of FMD in April 2001, a week long period of stamp-out plus movement restrictions was followed by a more extensive seven month period of vaccination (Sutmoller and Casas Olascoaga 2002). In the April 2001 Argentinean FMD outbreak, the response program focused almost exclusively on FMD vaccination plus regionalization to ensure the state catering to export markets maintained an FMD-free without vaccination status (Rich, et al., 2005). The economic benefits of regionalization can be significant for areas where trade losses make up a large portion of total losses resulting from FMD (Paarlberg, et al., 2007, Rich, et al., 2005). These differences in response and eradication stem from variations in resources as well as the social and political context that exists within each country. The inclusion of these factors in policy and program evaluation and implementation will continue to be important in pursuing eradication efforts in LDCs (Ahuja 2004).

Modeling Framework:

When dealing with multiple, simultaneous outbreaks in multiple countries, the modeling framework employed must account for domestic production adjustments as well as changes in domestic consumption and trade flows. In this study, we focus on the changes in domestic and international prices, as well as trade effects that would have prevailed in a scenario that eliminates the production losses associated with FMD outbreaks in Latin America. We utilize historical data accounting for beef production losses in Latin American countries in tandem with a computable general equilibrium model to understand what the economic effects would have been, had FMD outbreaks in 2001 been prevented. The motivation for using differences from observed outbreak is to determine: (1) how much FMD presence in Latin America distorted

world beef prices in an environment that controls for other events impacting world meat markets at the same time and (2) how well a modeling framework such as this can be used to assess the value of FMD eradication in a region that may significantly impact the world beef market.

Recalling Figure 3, FMD occurrences in Latin America began to be reported to the World Organization for Animal Health (OIE) with increased frequency in the early 2000s. We therefore chose 2001 as our base year for consideration and begin our analytical framework with a modified application of the standard Global Trade Analysis Production (GTAP) model and database[3] (Hertel 1997) that focuses on the structural features representative of agricultural markets—GTAP-AGR. The GTAP-AGR model includes imperfect factor mobility between agricultural and nonagricultural sectors, a nested Constant Elasticity of Substitution (CES) production function for tradable commodities, and a Constant Difference of Elasticities (CDE) specification for household demand (Keeney, Hertel 2005). The model also includes detailed supply and demand elasticities specific to agricultural production and consumption as well as the Armington import demand specification to allow for product differentiation by region (Hertel et al. 2007). While there are 57 sectors included in Version 6 of the GTAP database, the cattle and cattle meat sectors also include sheep, goats, horses (and other livestock) in the initial database. In examining the database for Latin America, these sectors represent the beef cattle and cattle meat sectors quite well. In addition, since sheep and goats are also susceptible to FMD, we determined not to further disaggregate this sector. A positive production shock is imposed on cattle meat in each Latin American country, as shifts in the supply curve, by actual values of historically observed decreases in herd sizes from actual FMD outbreaks in each region that have been converted to meat equivalents. This allows for the analysis of changes in domestic and international prices along with trade impacts that would have potentially occurred had the production losses from FMD been prevented.

Data:

The number of head infected, dead or destroyed, and vaccinated in Argentina, Brazil, Colombia, Ecuador, Uruguay and Venezuela were collected from the World Animal Health Information Database (WAHID) archives (HandistatusII) for 2001. The OIE reports the number of cases of

[3] GTAP Database, Version 6

disease, head infected, head dead from disease, head slaughtered for disease control and head vaccinated; all except vaccination counts are included in Table 1.

Table 1. Historical Outbreaks in Latin America in 2001

Country	Outbreaks	Cases	Deaths	Slaughter	Vaccinated
Argentina	2,394	86,781	295	33	57,125,396
Brazil	37	1,558	10	11,763	156,101,114
Uruguay	2,057	32,686	0	5,088	11,773,000
Ecuador	22	574	3	0	3,553,721
Venezuela	4	184	0	0	10,266,185
Colombia	3	23	0	115	19,885,050
Source: World Animal Health Information Database, HandiStatusII					

In addition, country production data on the value of cattle meat produced in millions of US dollars (US$), beef yield in hectograms per animal, and average producer price in dollars per metric ton were collected from the FAOStat1 database (www.faostats.com). The production lost from FMD has two elements: loss from death and slaughter and reduction in productivity from sickness. Value of death loss is the number of head dead or slaughtered, transformed into the cattle meat equivalent, and multiplied by the average producer price within each country.

Table 2. Latin American Yields and Prices in 2001

Value Factors	Yield (Hg/animal)	Producer Price ($/tonne)
Argentina	2.124	1630.8
Brazil	2.037	1138.4
Paraguay	1.97	735.8
Uruguay	2.249	1202
Ecuador	1.979	2696
Venezuela	2.18	2506.5
Colombia	2.024	1606.3
Source: FAOStats		

Although the production losses could be estimated for multiple species, only cattle and cattle meat losses were examined since cattle comprised 99.3% of infections and 99.7% of vaccinations on average in the outbreak data. The reduction in productivity represents the lost production from animal sickness, namely animals will be slower to gain weight and produce less milk when infected with FMD. However, the surviving animals will recover and resume regular

weight gain and production. The average length of clinical infection of FMD was 4-6 days (Perez, Ward, and Carpenter 2004). Allowing for recovery time, a period of 10 days of reduced productivity was assumed to calculate production losses. The value of the final beef product is estimated by using the 2001 country yield and price information in Table 2. To estimate the cost of production, the value of final beef product is broken down into a daily profit, then reduced by the assumed profit margin to account for a daily cost of production for each of the 10 days the animal is sick. It is assumed that producers operate on a 10% profit margin and a proportion of the profit value is used as cost of production. The losses from death and production losses were then used to create a percentage change in production by country as shown in Table 3. Finally, it was assumed that no domestic beef demand change occurred as a result of the FMD outbreak and vaccination programs.

Table 3. Historical Percentage Change in Production (2001)

Beef Cattle	Value of Production Lost	Value (US$)	% National Value Lost
Argentina	Deaths	$ 1,021,826.66	0.0255%
	Slaughter	$ 114,306.03	0.0028%
	Sick but not killed/ dead	$ 2,966,385.14	0.0739%
Brazil	Deaths	$ 23,189.21	0.0003%
	Slaughter	$ 27,277,465.37	0.3512%
	Sick but not killed/ dead	$ 35,653.41	0.0005%
Paraguay	Deaths	$ 0	0.0000%
	Slaughter	$ 0	0.0000%
	Sick but not killed/ dead	$ 0	0.0000%
Uruguay	Deaths	$ 0	0.0000%
	Slaughter	$ 13,754,380.22	3.6101%
	Sick but not killed/ dead	$ 871,973.67	0.2289%
Ecuador	Deaths	$ 16,006.15	0.0032%
	Slaughter	$ 0	0.0000%
	Sick but not killed/ dead	$ 30,222.14	0.0060%
Venezuela	Deaths	$ 0	0.0000%
	Slaughter	$ 0	0.0000%
	Sick but not killed/ dead	$ 9,921.78	0.0009%
Colombia	Deaths	$ 0	0.0000%
	Slaughter	$ 373,882.39	0.0333%
	Sick but not killed/ dead	$ 737.93	0.0001%

Results:

Initial simulation results using the global modeling framework show the percentage changes in key variables for the beef sector resulting from shocks to meat production in Latin America. Shocks to beef production were implemented to represent the additional meat that would have been produced in each region, if there were no production losses associated with FMD during 2001. The production losses from FMD in 2001 were implemented in the modeling framework as shocks to the beef supply in the countries listed and are characterized in Table 4. Relatively small shocks to production are administered for Venezuela and Colombia, where smaller herd losses were experienced since FMD is endemic in both countries. Uruguay experienced the greatest herd losses in 2001, which is represented by a shock to production of nearly four percent in the model.

Table 4: Shocks to Beef Production in Latin America
(percentage points)

Country	Production Shock
Argentina	0.1022
Brazil	0.3519
Uruguay	3.8389
Venezuela	0.0009
Colombia	0.0001

In response to the small production increases that would have prevailed in an FMD free environment, the domestic producer price of beef would have decreased slightly in all countries, except for Colombia, where relatively small FMD-related production losses occurred in 2001 (Table 5). The quantity and value of exports from Venezuela and Colombia would decrease slightly, while exports from Argentina, Brazil and Uruguay increase. While the value of exports from Brazil and Uruguay increase, the value of exports from Argentina is slightly negative, resulting from the relatively larger decrease in the price of Argentine beef. Not surprisingly, the production impacts are most prominent in Uruguay, which had the largest FMD-related herd losses in 2001 and the largest shock to beef production in the model. The decrease in the producer price of beef in Uruguay would have been nearly three percent, while exports of Uruguayan beef would have increased by more than seventeen percent. Imports of beef increase slightly in all regions, except for Uruguay, where imports decrease by more than eight percent.

The changes in exports from each country can be further explained by examining the changes in bilateral trade for each Latin American country, included in Table 6.

Table 5: Changes in Key Variables in Latin American Beef Markets
(percentage points)

Country	Producer Price	Export Quantity	Value of Exports	Import Quantity
Argentina	-0.102471	0.040537	-0.061934	4.204209
Brazil	-0.345397	1.940975	1.595579	2.626244
Uruguay	-2.590167	17.43387	14.843704	-8.517289
Venezuela	-0.002247	-0.199554	-0.201801	0.27877
Colombia	0.00278	-0.584282	-0.581502	0.111959
Rest of Latin America	-0.005161	-0.525988	-0.531149	0.350364

Table 6: Changes in Bilateral Latin American Beef Exports
(percentage points)

Exporting Country / Importing Region	Argentina	Brazil	Uruguay	Venezuela	Colombia	Rest of Latin America
1 anz	0.69	2.46	19.23	-0.07	-0.11	-0.05
2 chk	0.36	2.11	18.64	-0.36	-0.40	-0.34
3 jpn	0.72	2.50	19.41	-0.01	-0.05	0.01
4 kor	0.67	2.55	18.50	-0.07	-0.11	-0.05
5 twn	0.74	2.63	19.91	-0.02	-0.05	0.01
6 idn	0.70	2.57	19.90	-0.03	-0.07	-0.01
7 osea	0.58	2.31	18.56	-0.15	-0.19	-0.13
8 osa	0.76	2.63	19.91	-0.01	-0.05	0.01
9 ind	0.72	2.59	19.88	-0.05	-0.09	-0.03
10 can	-0.30	1.49	17.52	-1.03	-1.07	-1.01
11 usa	0.53	2.31	18.51	-0.20	-0.24	-0.18
12 mex	0.70	2.47	18.63	-0.07	-0.11	-0.05
13 col	0.64	2.48	19.50	-0.08	-0.12	-0.06
14 olac	0.21	1.98	18.28	-0.52	-0.56	-0.50
15 ven	0.03	1.77	17.86	-0.70	-0.74	-0.68
16 arg	-4.20	-2.46	13.84	-4.97	-5.01	-4.95
17 bra	-4.36	-2.44	13.69	-5.08	-5.12	-5.06
18 ury	-8.56	-6.79	10.63	-9.30	-9.33	-9.27
19 eu15	0.30	2.06	18.31	-0.43	-0.47	-0.41
20 efta	0.56	2.32	18.81	-0.18	-0.22	-0.16
21 oeefsu	0.61	2.35	18.72	-0.11	-0.15	-0.09
22 eux	0.68	2.45	18.82	-0.06	-0.10	-0.04
23 rus	0.71	2.46	19.06	-0.02	-0.06	0.00
24 mena	-0.25	1.49	17.59	-0.97	-1.01	-0.95
25 sacu	0.62	2.40	18.46	-0.10	-0.14	-0.08
26 ssa	0.58	2.36	18.47	-0.14	-0.18	-0.12

The impacts of the production changes on the world beef market are included in Table 7. The global impacts on the beef market are minor, which is not surprising, given the relatively small shocks to Latin American beef production that were administered. The decrease in the world price for beef is negligible and the increase in world exports of beef is less than one percent.

Table 7: Percentage Changes in Mean World Price and World Exports in the Global Beef Market (percentage points)

	World Price	World Export Quantity
Beef	**-0.064041**	**0.118023**

Discussion:

Multiple outbreaks of foot-and-mouth disease in the early 2000s in Latin America caused production impacts as well as trade impacts for Argentina, Brazil, Uruguay, Venezuela, Colombia and Ecuador. Using historical data from these outbreaks and a modeling framework that includes price and quantity changes as well as changes in trade levels, the impact of production losses were isolated. The response policies of countries in 2001 primarily focused on movement restrictions and vaccination to achieve eradication, so slaughter levels were low as were the levels of death from disease, as would be expected. Despite the relatively small losses to production, eliminating the FMD presence in Latin America reduced producer level beef prices in Latin America with the exception of Colombia, where prices increased by a relatively small amount. Brazil and Uruguay showed the largest benefits in export quantity and value. Uruguay in particular showed the greatest impact from preventing the 2001 FMD outbreaks throughout Latin America, where export value increased almost 15%, export quantity increased 17%, and imports decreased by almost 9%. Bilateral trade among Latin American countries showed particular benefit for Uruguay. Uruguay's outbreak cost $6.1 million in eradication cost plus another $7.5 million in vaccination cost, as well as $230 million in trade restriction related costs (Sutmoller and Casas Olascoaga 2002).

This modeling framework can be used to assess the value of FMD eradication in a region that may significantly impact the world beef market, with the particular benefit of the framework being the simultaneous examination of production losses and consequent bilateral trade impacts for multiple countries. However, it must be acknowledged that these benefits come at the cost of lost detail and sensitivity at the production level when compared to a country level model.

Production losses represent only one of three loss categories that countries experience in the event of an FMD outbreak. In addition to the production loss, the country will experience an

increase in production cost from eradication programs and veterinary services plus trade losses resulting from the country losing FMD-free status. Another factor not discussed here is the willingness of producers to pursue eradication of FMD in Latin America. Livestock producers, particularly in disease endemic areas of LDCs, may be unlikely to pursue an optimal eradication program where disease is not recognized or considered "normal" (Tisdell, Harrison, and Ramsay 1999). Further work that is currently underway will take into account the increases in production costs associated with FMD prevention and eradication as well as the impacts of trade related policies that have interrupted meat trade in response to an FMD outbreak. Understanding the economic impacts of transboundary animal disease on international trade flows, particularly close trading partners, is an important extension of animal health economics modeling. This effort is an initial step towards fully accounting for the complexities involved in investigating the economic effects of transboundary animal disease in a global modeling framework.

References:

Ahuja, V. 2004. The economic rationale of public and private sector roles in the provision of animal health services. *Revue scientifique et technique/ Office international des epizooties* 23 (1):33-45.

Hagerman, A D, B.A. McCarl, and J H Mu. 2010. Economic Impact of a Livestock Attack. In *Wiley Handbook of Science and Technology for Homeland Security*, edited by J. G. Voeller.

Hertel, Thomas W. (editor), 1997. Global Trade Analysis: Modeling and Applications, New York; Cambridge University Press.

Hertel, T.W., Martin, W., and A.M. Leister, 2010. "Potential Implications of the Special Safeguard Mechanism (SSM): the Case of Wheat." World Bank Economic Review 24(20): 330-359.

Keeney, R., Hertel, T.W. 2005. 'GTAP-AGR: A Framework for Assessing the Implications of Multilateral Changes in Agricultural Policies.' GTAP Technical Paper No. 24.

Paarlberg, P L, A H Seitzinger, and J G Lee. 2007. Economic impacts of regionalization of a highly pathogenic avian influenza outbreak in the United States. *Journal of Agricultural and Applied Economics* 39 (2):325-333.

Perez, A., M. Ward, and T. Carpenter. 2004. Control of a foot-and-mouth disease epidemic in Argentina. *Preventive Veterinary Medicine* 65 (3-4):217-226.

Perry, B.D., and Delia Grace. 2009. The impacts of livestock diseases and their control on growth and development processes that are pro-poor. . *Philosophical Transactions of The Royal Society B* 364:2643-2655.

Perry, B.D., Tom F. Randolph, John McDermott, K.R. Sones, and P.K. Thornton. 2002. Investing in Animal Health Research to Alleviate Poverty. *International Livestock Research Institute* Nairobi.

Perry, B.D., and Karl M. Rich. 2007. Poverty impacts of foot-and-mouth disease and the poverty reduction implications of its control. *Veterinary Record: Journal of the British Veterinary Association* 160 (7):238-241.

Rich, Karl M., and B.D. Perry. 2011. The economic and poverty impacts of animal diseases in developing countries: New roles, new demands for economics and epidemiology. *Preventative Veterinary Medicine* 101:113-147.

Rich, Karl M., Alex Winter-Nelson, and N Brozovic. 2005. Modeling regional externalities with heterogeneous incentives and fixed boundaries: Applications to foot and mouth disease control in South America. *Applied Economic Perspectives and Policy* 27 (3):456-464.

Sutmoller, Paul, and Raul Casas Olascoaga. 2002. The successful control and eradication of foot and mouth disease epidemics in South America in 2001. *Evidence for the Temporary Committee on Foot-and-Mouth Disease of the European Parliment* 2 September.

Thompson, D, P Muriel, D Russell, P Osborne, A Bromley, M Rowland, S Creigh-Tyte, and C Brown. 2002. Economic costs of the foot and mouth disease outbreak in the United Kingdom in 2001. *Revue scientifique et technique/ Office international des epizooties* 21 (3):675-687.

Tisdell, C.A., S.R. Harrison, and G.C. Ramsay. 1999. The economic impacts of endemic diseases and disease control programmes. *Revue scientifique et technique/ Office international des epizooties* 18 (2):380-398.