Contagious Cargo: Health Externalities from Livestock Trade during Early Globalization

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A central idea in economics is that trade improves welfare by allowing countries with different comparative advantages to specialize. While the movement of goods across space is innocuous in many contexts, there are instances where trade can lead to various externalities. For example, the trade in agricultural products can lead to health or environmental externalities as diseases, pests, or invasive species are transported across locations. This gives rise to a tradeoff that is inherent to the trade in these goods where potential economic gains might come at the cost of disease transmission. Overall, the trade in agricultural products, where this externality is most salient, was a sizable 8% of total merchandise trade in 2023.[1] Understanding ways to effectively address the risks associated with trading these goods has important economic implications for many countries.

Governments recognize the risks associated with the trade in agricultural products and often enact trade restrictions on imports. The recent US response to an outbreak of screwworm in Mexico is a useful illustration of how governments implement trade barriers to prevent health externalities. Screwworm, a parasitic fly that lays eggs in open wounds of cattle, multiplies rapidly as successive generations hatch. This results in the death of the host in a matter of weeks. With no effective treatment, the fly poses a major threat to livestock. Once eradicated in the United States, screwworm has migrated northward from South America as warmer temperatures expand its range. In November 2024, the US government prohibited imports of live cattle from Mexico to prevent the fly from entering the United States.[2] While such trade barriers might have negative economic effects by raising the prices of animal products domestically, they might improve overall welfare by reducing the risk of widespread pest or disease outbreaks that would negatively impact domestic agriculture.

This paper explores the effectiveness of trade restrictions aimed to address health and environmental externalities from trade. I examine the historical trade in live animals during the first age of globalization in the late nineteenth century to both empirically and theoretically assess the health and economic consequences of trade restrictions aimed to reduce the spread of animal diseases. A key contribution of this paper is to highlight that trade restrictions are not guaranteed to solve health externalities. Their effectiveness depends crucially on the policy's design, and how the policy interacts with economic incentives and the underlying disease environment. Trade restrictions can have important equilibrium effects in contexts with multiple diseases that may transmit across species.

In the 1840s, Britain began removing tariffs that had effectively prohibited imports of a variety of agricultural products (Irwin, 1989; O'Rourke, 1997; Heblich et al., 2024). In the subsequent decades, several European countries started exporting over a million live animals to Britain annually, where they were often slaughtered for domestic consumption.[3] These

[1] A link to the Food and Agriculture Organization discussing the size of the trade in agricultural products can be found here.

[2] The following article summarizes the current risks associated with the cattle trade and the spread of screwworm: "Avian Flu Wiped Out Poultry. Now the Screwworm Is Coming for Beef." *New York Times*, July 28, 2025. A link to the article can be found here.

[3] For example, Figure 1 panel (a) shows that in the 1870s and 1880s Britain imported around a million

animals had to be transported live because refrigeration technologies that would have allowed them to be slaughtered prior to being shipped did not exist at the time (Zimmerman, 1962). British officials began linking trade in live animals to disease outbreaks among domestic livestock. The most severe of these episodes was an outbreak of rinderpest, a highly contagious and lethal disease, in 1865 that was imported from Russian cattle that killed approximately 6% of all domestic cattle in Britain. Parliament responded to the outbreak by passing a series of laws allowing British officials to regulate live animal imports and impose trade restrictions for the purposes of preventing disease transmission from foreign animals to domestic livestock. In subsequent decades, rinderpest and foot-and-mouth disease, two diseases that could transmit between species, motivated several trade restrictions by the British government.

This paper examines the consequences of trade restrictions implemented by the British on live sheep imports in the last quarter of the nineteenth century due to concerns that imported sheep were infected with foot-and-mouth and rinderpest. The primary trade restriction I study is the prohibition of European sheep imports that started with a ban on German sheep in 1889 and was extended to all continental European countries in 1892. I also analyze a second, less severe policy adopted at various times that required imported sheep to be slaughtered at the port of entry. This half measure allowed domestic consumers to still benefit from animal imports while reducing the likelihood foreign animals would contact domestic livestock. The first two empirical parts of the paper assess the health and economic effects of the restrictions using a difference-in-differences empirical strategy. The last part develops a model to illustrate how health externalities can reduce the gains from trade and analyze the welfare effects of various policies the British could have chosen.

There are several features of this context that make it particularly useful for examining health externalities from trade and the effectiveness of trade restrictions in addressing them. First, these trade restrictions were implemented in a data-rich environment. One contribution of the paper is to digitize a variety of historical data on disease, trade, and domestic agricultural production. As part of the effort to prevent disease spread, the British government collected detailed data on the number of outbreaks of several diseases among domestic animals. Officials also recorded the number of infected imported animals arriving at ports. I digitize these data, making it feasible to assess how domestic disease changed in response to the trade restrictions and link domestic disease outbreaks to infected imported animals. The primary disease I will focus on is sheep scab – a mite-borne disease that damages the skin and wool of sheep – because data on the disease is available spanning several decades around the trade restrictions. I also digitize data on foot-and-mouth disease, an important disease that motivated many of the trade restrictions adopted by British officials. The government also kept records of the trade in live animals and conducted annual agricultural censuses that provide information on the number of domestic livestock, which I digitize to complement the information on disease transmission. A second useful feature of the context is that the trade restrictions on sheep imports were implemented during a few key episodes between 1877 and 1892. This makes it possible to use a difference-in-differences empirical strategy to assess changes in outcomes before and after the trade restrictions were implemented. A final useful

sheep annually. For identification purposes, the paper focuses primarily on sheep imports, however, there was also a large international trade in cattle as well.

feature is that these restrictions were implemented as globalization was just starting to make health externalities from trade a consequential problem that governments needed to address. Therefore, this provides a particularly useful setting where the effects of trade restrictions can be estimated relative to the preexisting, largely laissez-faire, equilibrium. Whereas in the modern context, it is difficult to isolate the effects of trade restrictions given that existing trade agreements govern how countries can address disease risk from trade.

The paper starts by documenting changes in trade patterns in response to the restrictions. Figure 1 panel (b) shows the composition of countries exporting sheep to Britain over time. Before the import ban on European sheep, about 75% of Britain's sheep imports were exported from Germany and the Netherlands. The ban on European imports in 1889 forced British consumers to seek new trading partners. Between 1888 and 1895, the share of imported sheep from the Americas – primarily the United States, Canada, and Argentina – increased from approximately 10% to over 90% of total sheep imports. This trade substitution had important implications for disease transmission. After the import ban, the share of imported sheep infected with sheep scab increased from less than 1% in 1888 to 8% in 1895 (see Figure 2). In contrast, an earlier policy requiring sheep from key European trading partners to be slaughtered at the port of entry did not lead to substantial changes in trade patterns or disease among imported animals.

The next part presents the main empirical results on how the trade restrictions impacted disease transmission among domestic sheep. To assess the ban on European sheep, I use a difference-in-differences empirical strategy comparing the number of sheep scab outbreaks in counties closer to the main ports where sheep were imported to counties further away, before and after the ban. The results suggest that sheep scab outbreaks increased by approximately 45% after the ban. This is consistent with the trade substitution patterns in which Britain started to import sheep from countries with significantly higher prevalence of sheep scab after the import ban. The results from an event study specification, presented in Figure 3, suggest sheep scab outbreaks continue to worsen until 1896 which corresponds exactly with when Britain required port slaughter of sheep from the United States and Canada. This provides additional evidence linking high prevalence of disease among imported sheep from the Americas to disease transmission among domestic sheep in Britain. While the ban on European sheep increased the prevalence of sheep scab among domestic sheep, it was effective at keeping foot-and-mouth disease out of Britain. I also find that the earlier episode where port slaughter was required for continental Europe in 1877 was effective at reducing sheep scab outbreaks (see the event study analysis in Figure 4).

The last empirical section turns to the economic effects of the trade restrictions. I focus on two main outcomes: the price for meat paid by domestic consumers and wool production. To analyze meat prices, I digitize data from historical newspapers on meat prices in London and Liverpool around the ban on German sheep imports in 1889 and the policy mandating port slaughter on European sheep in 1877. Since it is likely that internal movement of livestock would equalize prices across regions in response to the trade restrictions, I do not use geographic variation to assess effects on prices. Instead, I use an empirical strategy that compares the price of mutton (sheep) to the price of beef before and after each policy was implemented. Given that the trade restrictions only targeted sheep and not cattle, we would expect the price of mutton to be differentially affected by the restrictions as long as mutton and beef were not perfect substitutes. In London and Liverpool, Mutton prices increased

by approximately 10% and 6% relative to beef prices in the months after the import ban on German sheep. In contrast, there was no change in meat prices in response to the 1877 port slaughter policy. Figure 5 shows the descriptive trends in beef and mutton prices for London around each of the two trade restrictions.

The second economic effect I analyze is how the ban on European sheep affected wool production. Wool was an important industry for Britain both to export as a raw material and to process into textiles and clothing products (Bowden, 1956). It is also possible that the ban affected wool production due to the increase in sheep scab among domestic sheep. Sheep scab has significant negative effects on a sheep's ability to produce wool as the mites cause skin complications (Rehbein et al., 2000). While data on wool production is not available during the period, data on wool exports is available for various ports throughout Britain. I show that wool exports decline at ports near counties in Britain that experienced higher sheep scab infection after the ban on European sheep. This provides evidence consistent with the higher prevalence of sheep scab caused by the ban also reducing wool production among domestic sheep.

In summary, the empirical portion of the paper shows that the import ban on European sheep led to a change in Britain's trading partners that increased sheep scab infection among domestic flocks. It also had negative economic effects by increasing the price of meat for domestic consumers and reducing domestic wool production. However, the ban was effective at keeping foot-and-mouth disease out of Britain, one of the ban's primary objectives. This episode highlights the importance of policy design when implementing trade restrictions to address health externalities given potential downstream general equilibrium forces. The results also highlight how less strict policies can be effective at mitigating the health externalities from trade. The 1877 port slaughter policy reduced sheep scab infections among domestic sheep and did not increase meat prices since the same exporters were still allowed to export animals for immediate slaughter.

Motivated by these facts, the last section develops a simple model combining domestic livestock production and consumption, international trade, and elements from an epidemiological model in which imported animals can spread disease to domestic livestock. A key use of the model is to assess the welfare implications of various trade policy scenarios, especially given that the trade restrictions influenced multiple diseases at once. In the model, a domestic household owns cattle and sheep, and consumes beef, wool, and mutton that is produced from these livestock. There are two diseases, one that can only infect sheep (sheep scab) and another that can transmit between species, capturing the important inter-species aspect of foot-and-mouth. The domestic country can import sheep from exporting countries at the risk of importing sheep with either disease that can potentially infect domestic livestock.

I calibrate the model using the data I digitized for the empirical analysis as well as other information from the history, epidemiology, and veterinary literature. I then use the calibrated model to compare the welfare implications of different trade policies. Table 1 presents welfare and other equilibrium values for several trade scenarios relative to autarky (in column 1). Steady state welfare is approximately .9% higher with free trade relative to autarky which shows that the model exhibits the basic Ricardian idea of gains from trade. However, when I introduce a health externality in which 3% of imported sheep are infected with sheep scab, the welfare gain relative to autarky declines to .3%. I then analyze a counterfactual that resembles the ban Britain implemented on European sheep.

In this scenario, the imported sheep now have a higher rate of sheep scab, capturing the substitution to sheep from the Americas, while still having no foot-and-mouth infection. Welfare in this counterfactual is .7% worse than autarky. I then compare this scenario to an alternative policy the British could have adopted where they continued to allow imported sheep from Europe. This would have kept sheep scab prevalence at pre-ban levels, yet increased the prevalance of foot-and-mouth disease among imported sheep that could infect domestic livestock (both sheep and cattle). In this scenario welfare is only .1% worse than autarky. This suggests that the ban implemented by Britain may have been worse overall than continuing to allow trade with Europe. However, in a counterfactual in which rinderpest is the second disease that could be imported from Europe, welfare is 2.9% worse than autarky due to the disease's severity and virulence. Overall, the model highlights how the welfare effects of trade restrictions depend on the underlying disease environment and how this interacts with trade incentives.

References

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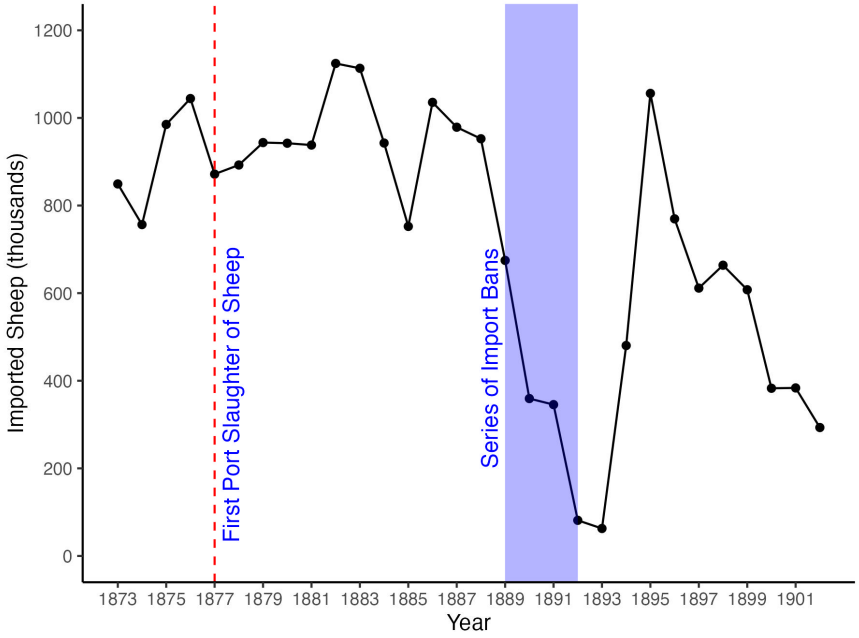
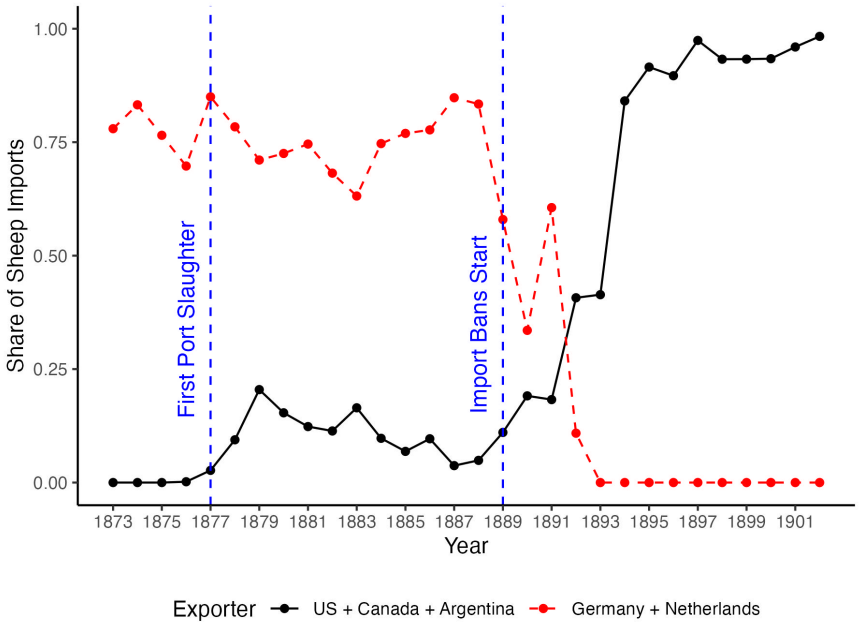
Figures & Tables

Figure 1: Sheep Imports to Britain Over Time

(a) The Number of Imported Sheep

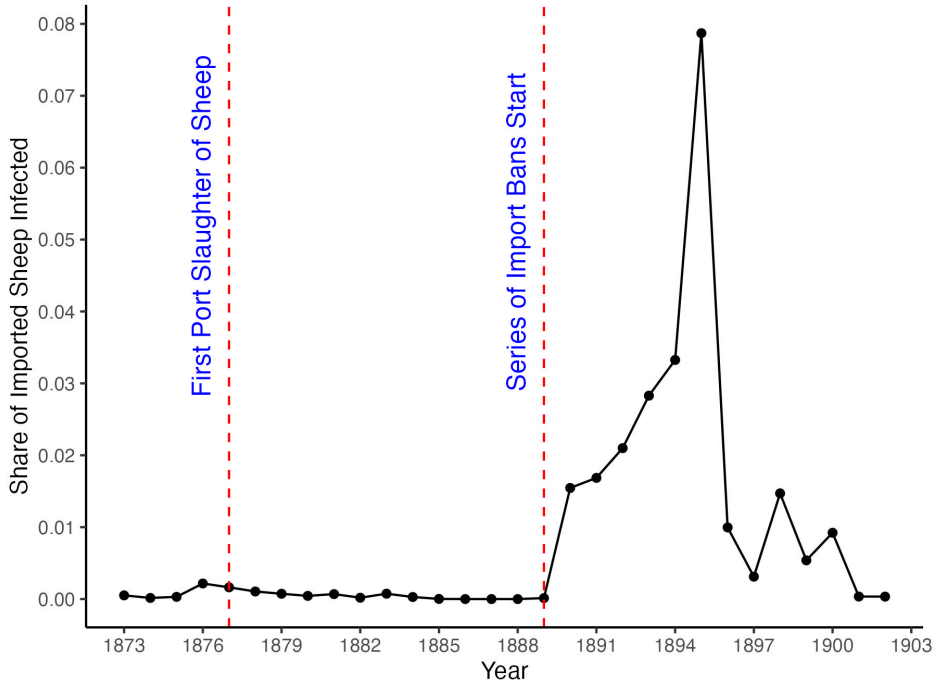


(b) The Share of Total Imports for the Main Exporters



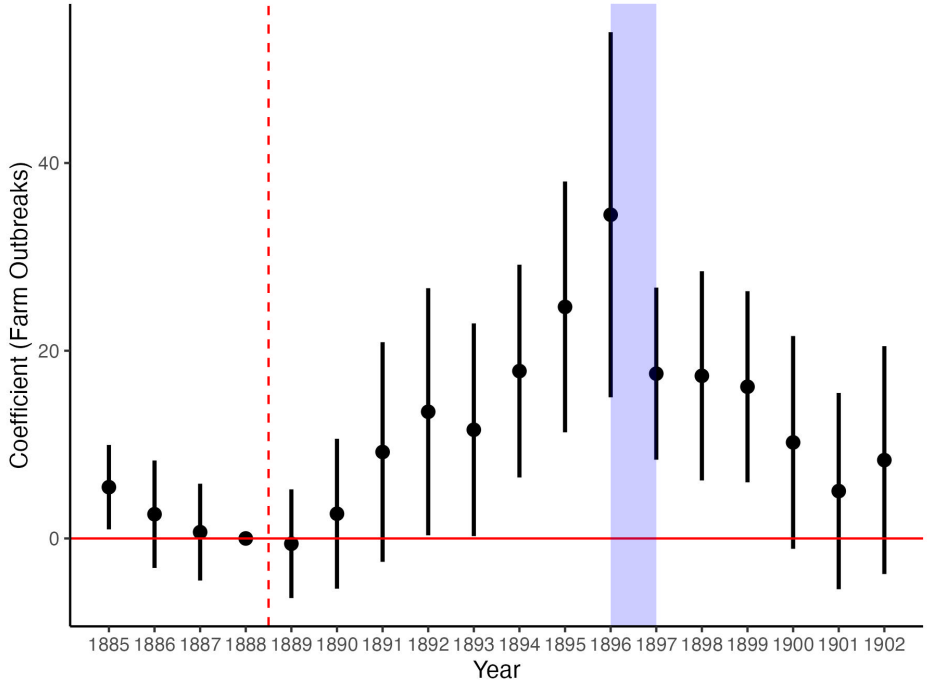
Note: This figure provides information on sheep imports to Britain over time. Panel (a) displays total sheep imports over time. Panel (b) displays the share of total sheep imports represented by the two key groups of exporters. The black, solid line displays the share of total imports comprised of sheep from the United States, Canada, and Argentina. The red, dashed line displays the share of total imports comprised of sheep from Germany and the Netherlands. The data are taken from various editions of the *Annual Report of the Veterinary Department of the Privy Council*.

Figure 2: Share of Imported Sheep Infected with Sheep Scab



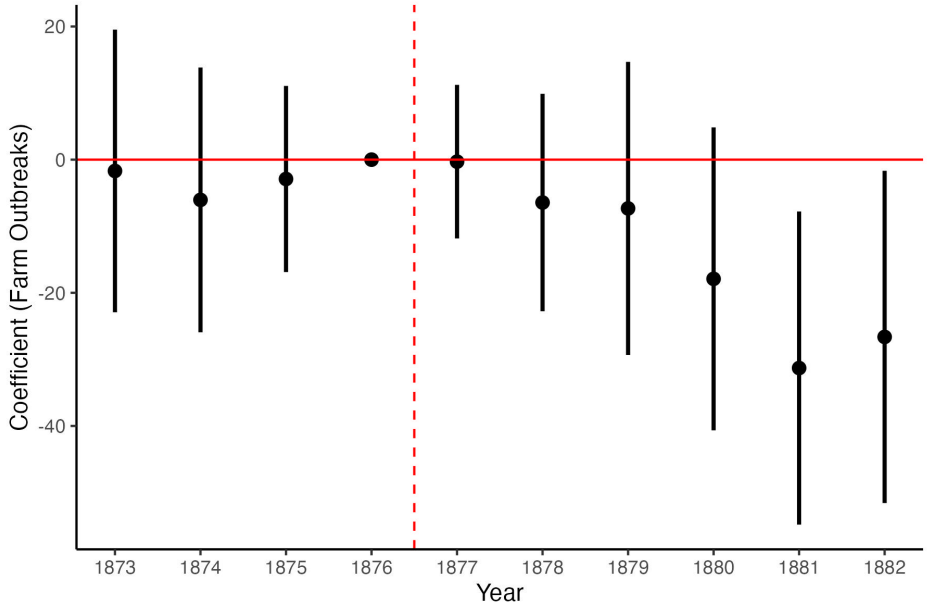
Note: This figure displays the share of imported animals that were infected with sheep scab over time. The dashed vertical lines indicate the years when the trade restrictions were implemented. The data are taken from various editions of the *Annual Report of the Veterinary Department of the Privy Council*.

Figure 3: Effect of the European Sheep Import Bans on Sheep Scab Outbreaks



Note: This figure presents the event study plot for the effect of the ban on European sheep imports on the number of sheep scab outbreaks. The red, dashed line corresponds to the period where import bans on European sheep begin to be implemented. The blue rectangle corresponds to the period where sheep from the United States and Canada were subjected to port slaughter (December 31, 1895) and the period where universal port slaughter of all animals entering Britain was implemented (January 1, 1897). The outcome is the number of sheep scab outbreaks at the county-level. Standard errors are clustered at the county-level.

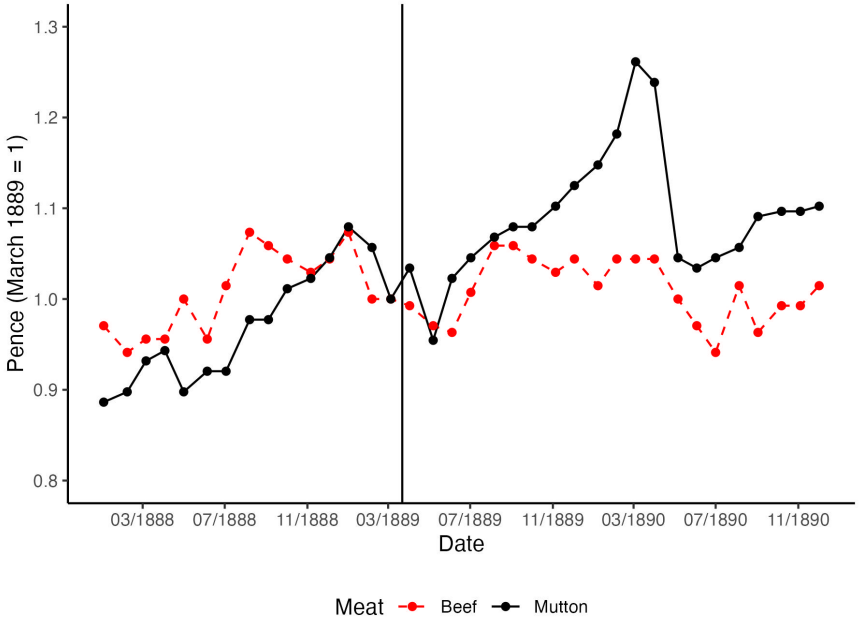
Figure 4: Effect of the 1877 Port Slaughter Policy on Sheep Scab Outbreaks



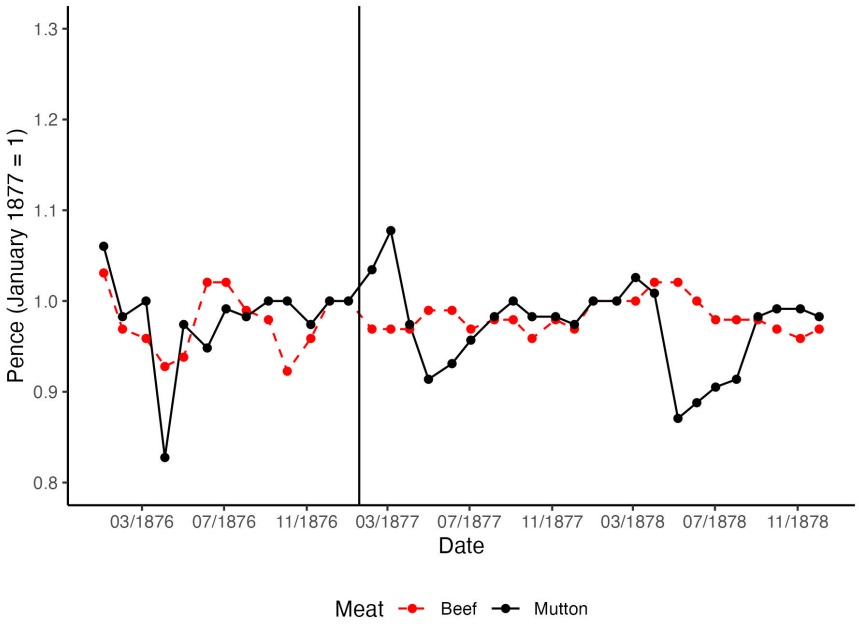
Note: This figure presents the event study plot for the effect of the 1877 policy mandating port slaughter of sheep from five European countries. The outcome is the number of sheep scab outbreaks at the county-level. The red, dashed line corresponds to when port slaughter was implemented. Standard errors are clustered at the county-level.

Figure 5: Comparison of Beef and Mutton Prices in London Around the Trade Restrictions

(a) Meat Prices Around the 1889 Ban on German Sheep Imports



(b) Meat Prices Around the 1877 Port Slaughter Restrictions



Note: This figure compares the price of beef and mutton at the Metropolitan Cattle Market in London around the two trade restriction episodes. Panel (a) shows the prices around the ban on German sheep imports that was implemented on March 22, 1889. The black, vertical line indicates the day the restriction was implemented. Panel (b) shows the prices around the mandatory port slaughter of sheep that was implemented on January 18, 1877. Similarly, the black, vertical line displays the date of implementation. The prices are collected monthly from *The Times*. The black, solid line displays the mutton price and the red, dashed line displays the beef price. Prices are normalized so the last month prior to the restriction equals one.

Table 1: Steady State Welfare of Different Trade Policies Relative to Autarky

	%Δ Welfare	%Δ Sheep	%Δ Cattle	%Δ Mutton	%Δ Wool	%Δ Beef	%Δ Good
Autarky	-	-	-	-	-	-	-
Trade	0.9	0	0	16.2	16.2	0	-7.1
Trade & Disease	0.3	-0.3	0	15.7	14.7	0	-7.2
Ban	-0.7	-0.9	0	14.9	12.1	0	-7.3
No Ban (FMD)	-0.1	-0.5	-0.1	15.1	14.4	-0.6	-7.2
No Ban (Rinderpest)	-2.9	-4.2	-3.9	13.8	13.1	-4.4	-8.2

Note: This table presents the model steady state for several policy scenarios relative to autarky. The baseline is autarky with no disease. Column (1) presents the percent change in welfare, defined as the percent change in the consumption of the outside of g_t necessary to make the household indifferent between the autarky equilibrium and the alternative equilibrium. Column (2) reports the percent change in domestic sheep relative to autarky. Column (3) reports the percent change in domestic cattle relative to autarky. Column (3)-(7) report the percent change in household consumption of each good relative to autarky. Row 2 presents the results where livestock imports are 80% of the price in autarky. Row 3 presents the results where livestock imports are 80% of the price in autarky and 3% of imported animals are infected with sheep scab. Row 4 presents the results where results where livestock imports are 80% of the price in autarky and 8% of imported sheep are infected with sheep scab. Row 5 presents the results where 3% of imported sheep are infected with sheep scab and 2% are infected with foot-and-mouth disease. Row 6 presents the results where 3% of imported sheep are infected with sheep scab and 2% are infected with rinderpest.