Disease Outbreak as a Determinant of International Trade

By

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Acknowledgments

To my Mother and Father,

To Jasper,

To Cassie and Deru,

To Griffin,

To Richard, Nick, Allison, and Jamie Rose,

To Isabella,

To Neil and Kevin,

To Professor David Lake and Konstantin Ash,

Overview

It began quietly enough in December of 2013, in an isolated Guinean village several miles from the Liberian border. Emile Omaouno, a two-year-old Guinean toddler, became violently ill.[1] What no one knew then was that he suffered from Ebola hemorrhagic fever, an extremely deadly and contagious condition that would soon sweep Guinea, Liberia, and Sierra Leone, with dramatic consequences for West Africa and the rest of the world. The human consequences of this disease are staggering. Thousands dead. Families torn asunder. Communities thrown into tumult. But the economic consequences of this outbreak have been equally dire. Labor shortages have threatened the all-important rice, maize, and cassava crops, causing food prices to soar. The production of lucrative commodities like oil, rubber, and cocoa has become excruciatingly slow. The price of everyday goods has increased dramatically in the face of tightening trade restrictions on the movement of goods and people. Foreign investment has fallen severely. Multinational corporations have scaled back operations. Tourism has all but ground to a halt. Airlines have cutoff service entirely to the afflicted nations.[2] Government revenues are dropping precipitously even as expenditures increase to combat the rampaging disease. The World Bank estimates that the cost of stopping the epidemic will be in the billions.[3] The economic effects of Ebola have been every bit as devastating as the human ones, and ultimately the severely crippled West African economy will beget human tragedies of its own. This is the modern nightmare of epidemic disease: human devastation coupled with economic isolation.

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[1] Stylianou, 2014.
[2] "FAO: Ebola Outbreak Putting West African Trade, Food Security in Jeopardy," 2014.
[3] Sy and Copley, 2014.

The last three decades have witnessed a steady increase in the number of communicable disease outbreaks in human populations around the world.[4] These outbreaks are often accompanied by widespread and sometimes irrational hysteria—witness the 2014 Ebola outbreak in West Africa or the 2009 H1N1, or "Swine Flu," outbreak. In light of the increasing frequency and public awareness of disease outbreaks, many researchers have identified communicable disease outbreak, transmission, and surveillance as an important area of study. While this has led to a growing body of research studying the effects of a variety of international and domestic factors on disease outbreaks, very little research has inverted this relationship by studying the effects of disease outbreaks on international systems. This thesis will seek to begin the process of examining how disease outbreaks affect the world economy.

The central question that this paper will seek to address is this: Does an outbreak of a communicable disease affect a country's international trade? To couch this question in more economic verbiage: is the advent of a communicable disease outbreak an important determinant of international trade? The answer to this question may be critically important both for nations coping with an outbreak and for international aid organizations seeking to assist these nations. Nations and aid organizations must constantly make decisions on how to direct a finite pool of resources to the greatest effect with incomplete information about the conditions on the ground. By identifying essential factors that can lead to economic shortfalls—in this case the outbreak of an infectious disease—these nations and aid organizations can be better informed as to how best to expend their limited resources. Recent research has corroborated the intuitive conclusion that economic downturns result in worse outcomes for disease outbreaks.[5] This means that a country

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[4] Smith et al. 2014.
[5] Suhrcke et al. 2011.

undergoing an economic shortfall while coping with the effects of an outbreak can expect to have higher transmission and mortality rates than it would if it had a healthy economy. Assuming that this is true, and assuming that a disease outbreak does in fact decrease international trade, my research question takes on an important meaning. We must consider the possibility of a vicious feedback loop for countries experiencing a disease outbreak. Consider the following hypothetical: an outbreak is reported in *Country X* thereby causing a decline in international trade involving said country, in turn this weakens the domestic economy of *Country X*, which in turn leads to a worse outcome of the disease outbreak, which could further damage the economy of *Country X*. If my findings suggest a negative effect on trade in the advent of an outbreak, it will establish the first leg of this causal relationship. In conjunction with other studies establishing the continued downward spiral of disease outbreak, my research may inform the response of nations and aid organizations to disease outbreaks. By addressing outbreaks quickly and thoroughly, countries and aid organizations may be able to cut off the feedback loop, mitigating both the magnitude of the outbreak and longterm economic damage.

In the following sections of this thesis, I will review the relevant literature on international disease outbreaks, explain my research design and hypotheses, present the findings of my research, examine the implications of these results, and identify potential areas for further research.

Literature Review

In this section I will provide a brief overview of the current state of research on communicable disease outbreaks and the gravity model of trade.

Communicable Disease Outbreaks:

The research most germane to my area of study involves the effects of economic downturns on outcomes of communicable disease outbreaks.[6] This research corroborates the intuitive conclusion that an economic downturn will negatively affect containment and treatment of disease outbreaks. According to Suhrcke et al., a weaker economy may lead to inadequate nutrition, less widespread immunization, infrastructure degradation, larger at risk populations (prisoners and homeless), a larger vector population, fewer doctors, and less access to drugs and treatment.[7] All of these economic effects may increase the infection and mortality rates of a disease outbreak. As detailed in the overview of this thesis, in conjunction with my research these findings raise the troubling possibility of a feedback loop between disease outbreaks and economic wellbeing.

Some researchers have linked international trade in wildlife with increases in infectious disease transmission.[8] This body of work suggests that international trade in wildlife introduces pathogens that are dangers to human and animal populations alike. Karesh et al. estimate that outbreaks caused by this sector of trade have caused hundreds of billions of dollars worth of

[6] Rechel et al., 2011. Suhrcke et al., 2011.
[7] Suhrcke et al., Pg. 3.
[8] Karesh et al., 2005.

damage to economies around the world. In terms of diseases that will be treated in this study, Ebola, SARS, and H5N1 outbreaks have all been linked to the international wildlife trade.

Another area of research involves the work of international organizations on monitoring and responding to communicable disease outbreaks. Aginam addresses the surveillance methods of the World Health Organizations, the World Trade Organization, and others.[9] In a similar vein, MacLehose et al. have focused on the European Union.[10] Of potential interest to the research addressed in this paper are studies seeking to measure the response of organizations that are significantly involved in international trade—the WTO, the EU—to the outbreak of communicable disease. By understanding how these organizations interact with outbreaks and interface with one another, we can begin to address how international organizations can help nations address potential economic shortfalls in the wake of a disease outbreak.

There are a number of studies on the economic consequences of outbreaks of foot-and-mouth disease. These studies are wide-ranging, looking at hypothetical and actual case studies in the United Kingdom,[11] Canada,[12] and California.[13] Superficially, these studies seem similar to the research conducted in this thesis, but because foot-and-mouth disease is primarily carried and transferred between livestock and only very rarely infects humans, these are not the sort of outbreaks that this study takes interest in.

It should be noted that there is also a growing body of literature that studies the relationship between international trade and chronic disease. Recent research suggests that the

[9] Aginam, 2002.
[10] MacLehose et al., 2001.
[11] Haydon et al, 2004.
[12] Krystynak and Charlebois, 1998.
[13] Carpenter et al., 2011.

growth of international trade with high-income countries has led to the spread of certain chronic diseases in many middle and low-income countries. In particular, unhealthy lifestyles—sugary and fatty foods, alcohol, and tobacco—have been transmitted from wealthy countries to less wealthy nations leading to an increase in chronic, non-communicable disease in those countries.[14]

The Gravity Model

The gravity model is a primary method used by economists to determine the relative weight of international trade determinants. In 1995, Trefler published *The Case of the Missing Trade and Other Mysteries*, which sought to tackle the theoretically sound but empirically inadequate Heckshcer-Ohlin-Vanek model.[15] The essential problem with the HOV-model, Trefler argued, was that it predicts significantly more international trade than actually occurs. Since then, many economists have sought to account for this "missing trade" by examining the negative effects of distance and relative economic size on bilateral international trade. These two factors are at the core of the gravity model. As with astral bodies, the larger and closer two nations are, the greater the gravitational effect is expected to be. In other words, nations are much less likely to trade with countries that are located a great distance away and/or that have small economies. The explanatory power of the gravity model is tremendous—Eaton and Kortum calculate that international trade would be 5 times greater in a world without gravity.[16] Gravity models often include a host of other variables that are expected to have some explanatory power

[14] Labonté et al., 2011. Beaglehole and Yach, 2003.
[15] Trefler 1995
[16] Eaton and Kortum, 2002. 1770.

on international trade.[17] The gravity model is a powerful and oft-used tool for calculating international trade determinants, hence its use in this study.

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[17] All of the variables included in the gravity model used in this study can be found in the Research Design section below.

Research Design and Hypothesis

In this section I will establish my hypotheses, introduce the datasets employed in this study, and explain how I will analyze the data in order to produce results that will support or contradict my hypotheses.

Hypotheses:

> **Hypothesis 1: The presence of a disease outbreak in a given country in a given year will depress international imports from and exports to that country in the following year.**

This hypothesis derives from the assumption that diseased nations will suffer from an internal loss of productivity due to sickness, hospitalization, quarantine, death, or the fear of these occurrences. This lost productivity could result in decreased production of goods and therefore exports. It could also result in decreased purchasing power due to lost earnings, thereby decreasing imports. Furthermore, potential trading partners may have reservations about trading with an afflicted nation for a bevy of reasons. Among these could be trepidation about disease containment and transmission during business interactions with citizens of the afflicted nation, fear of contaminated goods, and concern about domestic unrest in the afflicted nations. These concerns may be well-founded or entirely speculative, but they affect global trade in real ways.

> **Hypothesis 2: Instances in which both members of a dyadic trade pair are undergoing an outbreak will result in an even greater negative effect on imports and exports.**

If instances of an outbreak are likely to suppress exports from and imports to a given country, and both an importer and an exporter are undergoing a disease outbreak, it would logically follow that trade between two afflicted countries will be affected doubly.

Hypothesis 3: Trade with a nation's primary trade partners will be less affected than trade with less important trade partners.

This hypothesis is grounded in the notion that high volume trade relationships are more durable than others. Countries that trade significant amounts of goods with one another are likely to have more intertwined economies, more durable social and business connections, and may have enacted diplomatic trade agreements that facilitate or even require certain thresholds of trade. On the other hand, I hypothesize that countries that trade relatively little are more likely to limit international commerce in the face of a disease outbreak, possibly to the point of cutting off trade ties altogether.

Hypothesis 4: This negative effect on imports and exports will be exacerbated in the case of trade between contiguous nations.

I hypothesize that nations sharing a land border will suffer an even greater decline in trade in the event of an outbreak. This is due to increased fear of cross-border transmission. Countries contiguous to an afflicted nation are understandably more concerned about the possibility of transmission, and may increase the cost of trade through more rigorous customs and inspections in the event of an outbreak.

Hypothesis 5: The negative effect on trade will be greater in more impoverished countries.

I expect that countries with a lower Gross Domestic Product (GDP) per capita will experience greater decreases in both imports and exports than more wealthy countries. As a general rule, less wealthy countries have inferior infrastructural and institutional capabilities, resulting in a lesser capacity to respond effectively to a wide range of natural phenomenon.[18] I

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[18] Hendrix, 2010. Besley and Persson, 2010.

suspect that disease outbreaks will be no different, as a lesser ability to detect, monitor, treat, and contain outbreaks eventually manifests as a greater loss of domestic productivity and trade. I also suspect that the psychological deterrence of potential trade partners, as explained under Hypothesis 1, will be even more salient in the case of impoverished countries.

Hypothesis 6: The pathological characteristics of a disease will be important in determining its effect on trade.

This hypothesis reflects the seemingly self-evident conclusion that an outbreak of AIDS and an outbreak of anthrax are likely to affect trade differently in terms of magnitude and, potentially, direction. It is a fact that all diseases are not created equally, and, as can be seen in Appendix A, the range of diseases included in this study is extensive. Under this hypothesis, I will attempt to categorize similar diseases and test their effect on trade independently of other types of infections.

Data Sources:

I will test my hypotheses using two datasets. The first dataset I will use is the standard gravity model originally used by Head, Mayer, and Ries in their paper titled, "The Erosion of Colonial Trade Linkages After Independence." The original model spans from 1946 to 2006 and includes a host of control variables. Several of the control variables regarding colonial linkages that were used in the original study have been dropped from this study due to minuscule coefficients and issues of collinearity. The variables that have remained in the statistical model are as follows:[19]

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[19] Note that variables with the suffix "_o" relate to the country from which trade goods originate, while the suffix "_d" denotes the destination of the goods.

comcur — 1 for common currency
comleg — 1 for common legal origin
contig — 1 for contiguity
comlang_off — 1 for common official primary language
distw — weighted distance (pop-wt, km)
pop_o — Population, total in millions
gdp_o — GDP (current millions in US$)
gdpcap_o — GDP per capita (current in US$)
pop_d — Population, total in millions
gdp_d — GDP (current millions in US$)
gdpcap_d — GDP per capita (current in US$)
col_fr — 1 for trade from colony to hegemon
col_cur — 1 for pair currently in colonial relationship
gatt_o — 1 if origin is GATT/WTO member
gatt_d — 1 if destination is GATT/WTO member
rta — 1 for regional trade agreement in force
acp_to_eu — 1 for ACP to EU
eu_to_acp — 1 for EU to ACP
gsp — Global System of Preferences
gsp_rec — Global System of Preferences: reciprocal

The second data source I will use is a dataset published by Smith et al. which catalogues over 12,000 disease outbreaks between 1980 and July, 2013.[20] The dataset was generated using a Python script to parse the Global Infectious Disease and Epidemiology Network (GIDEON), turning prose reports on global disease outbreaks from GIDEON into a workable dataset. GIDEON gathers its information from a host of sources including Medline, national Health Ministries, Centers for Disease Control, the World Health Organization, texts, monographs, periodicals, journals, and user feedback.[21] This dataset includes the following variables:[22]

UID — A unique numerical ID assigned to each outbreak
Disease — The disease name, as listed in GIDEON

[20] See Appendix A for a list of all diseases included in the study.
[21] A complete list of the resources used by GIDEON is available here: http://www.gideononline.com/features/resources/
[22] List gathered from Smith et al README file, available from the Ramachandran Lab Data Repository, which can be found here: http://ramachandran-data.brown.edu/datarepo/request.php?request=explorePublicStudyTrial&StudyID=6&instit=BROWN&trialID=2

Nation — The nation where the outbreak occurred, as listed in GIDEON
Year — The year of the outbreak, or the first year if a range of years was given
Total Cases — Total number of cases for the given outbreak (outbreaks with no case data listed have a value of 9999)
Transmission Type — 0 for Non-vector borne, 1 for Vector Borne
Host Type — 0 for Zoonotic, 1 for Human-specific
Pathogen Taxonomy — 1 for Bacterium, 2 for Virus, 3 for Protozoon, 4 for Parasite, 5 for Fungus, 6 for Alga[23]

Methods of Analysis:

This section will explain the methods of statistical analysis that will be employed in this study. In the most elementary terms, I will incorporate a variable measuring disease outbreaks under a range of conditions into the gravity model and perform a regression. Depending on the coefficient of each regression, I will be able to weigh the relative importance of disease outbreaks on international trade vis-à-vis the other control variables in the gravity model. What follows is a more technical discussion of how I have prepared the dataset, introduced controls, and performed regressions.

This study will focus on the time period from 1980-2005, as this is the largest possible time period in which both disease outbreak and gravity model data are publicly available. I have introduced a one-year lead to the dependent variable, trade flow, in order to address a potential temporality flaw in this study. This problem arises from that fact that the Smith et al. dataset codes outbreaks in the year in which they began. This means that whether an outbreak occurs from January 1998 to February 1998, or from December 1998 to March 1999, the *Year* variable in Smith et al. will be coded as 1998. This means that measuring the advent of an outbreak

[23] There were no recorded outbreaks of alga during the period covered in this study.

against trade in the year of that outbreak opens the door to the possibility of measuring an outbreak against trade outcomes that were largely determined before the outbreak occurred. Measuring the effect before the cause would be a potentially fatal research design flaw. To address the issue of putting the proverbial cart before the horse, I will introduce a one-year "lead" on the *flow* variable. This means that a pandemic in *year X* will be measured against trade in *year X+1*. This "lead" should address any issues of temporality in this study.

I have also taken the natural log of the dependent variable, *flow*. This normalizes the variable which otherwise ranges massively from thousands to billions of dollars. I have also taken the natural log of the GDP and GDP per capita variables, again to normalize the distribution of widely varying values. Thusly, note that these variables are coded as *lgdp* and *lgdpcap* in the regressions.

The methodology of treating instances of zero trade is a problem inherent to the gravity model. In logging the monetary value of dyadic trade, instances of zero—the log of which is mathematically undefined—are dropped from the data set. While there is precedent in the literature for accepting these missing values as the cost of using the gravity model,[24] that method is potentially flawed in that it could potentially introduce selection bias, as only dyads with measured trade are included in the statistical model. This is particularly relevant in the scope of this study, as instances of trade falling suddenly to zero may be related to an outbreak in that year. There are a number of methods used to circumvent this particular problem. Head, Mayer, and Ries propose replacing zeroes with the smallest observed logged value, replacing all zeroes with $500, replacing all zeroes with $5,000, adding $1 to all values, or adding $1 million to all

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[24] Head, Mayer, and Ries, 2010.

values. After extensive testing of these options, I have added $1 million to all trade flows in order to retain all trade information in the final regressions. Of every method proposed, it results in the highest R^2 value, meaning the explanatory power of the model is greatest when using the logged value of trade plus one million. Just as importantly, it preserves nearly 200,000 observation of zero trade in the final statistical model. After leading the variable for trade (*flow*) by one year, adding one million to all values, and taking the natural log, the dependent variable that I use in the regressions is labeled somewhat clumsily as *log_flowp1plus1mil*.

I have introduced a number of geographic fixed-effect variables. These absorb some of the statistical noise from unobserved heterogeneity. In other words, variations in independent variables that are not otherwise controlled for in this model are “soaked up” in these variables. I have created dummy variables for the following geographic regions:

Central America
South America
The Middle East
West Africa
East Africa
Southeast Asia
Asia
Oceania

These variables should absorb uncontrolled similarities between nations in similar geographic areas, including natural resource wealth, reporting error, and regionally robust or weak trade. I have also introduced year fixed-effect variables for every year between 1980 and 2006. Again, these soak up the effects of independent variables from year to year that are not already controlled for in my model. Because of these fixed-effect variables, gradual increases in global population, GDP, and trade are not accidentally incorporated into other controls, including the outbreak variables at the heart of this study.[25]

Operationalization of Hypotheses:

Hypothesis 1: The presence of a disease outbreak in a given country in a given year will depress international imports from and exports to that country in the following year.

I test this hypothesis by incorporating a dummy variable gauging whether or not there was an outbreak in a given country in a given year—*varout*[26]—into the gravity model. By regressing the existence of an outbreak in a given year in a given country on international trade while controlling for the variables in the gravity model, I am able to measure the effects of the presence of an outbreak on international trade. If the coefficients of the outbreak variables are negative and the p-value suggests statistical significance, then we will have strong evidence that disease outbreaks have a negative impact on international trade.[27]

Hypothesis 2: Instances in which both members of a dyadic trade pair are undergoing an outbreak will result in an even greater negative effect on imports and exports.

To test this hypothesis, I include a dummy variable in every iteration of this regression that tests for instances in which both countries in a dyad undergo disease outbreaks in the same year. These variables are denoted by the suffix *_b*.

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[25] The introduction of fixed-effect variables is conventional when using the gravity model. Cheng and Wall, 1999.
[26] Followed by the suffix *_o*, *_d*, or *_b* depending on whether the outbreak occurred in the country from which trade originated, the destination of trade, or both.
[27] A more detailed discussion of the statistical methods used in this study is included below under the heading *Methods of Analysis*.

Hypothesis 3: Trade with a nation's primary trade partners will be less affected than trade with less important trade partners.

I test this hypothesis by ranking the trade partners of a given nation by total trade flow in a given year from 1 to *X*, where *X* is the number of nations with which there is a recorded trade value in the dataset. The basic regression can then be limited to observations of trade that are with a country's top ten trade partners, or those outside of the top ten. This gives us an admittedly broad understanding of the impact of disease outbreaks on major trade partners versus auxiliary ones.

Hypothesis 4: This negative effect on imports and exports will be exacerbated in the case of trade between contiguous nations.

To test this I have created two binary interaction variables, *outcontig_o* and *outcontig_d*, which are coded as one in instances in which a dyadic pair shares a land border and an outbreak is present in either the origin or the destination of trade, respectively.[28] In all cases in which either or both conditions are not true, the variables are coded as zero.

Hypothesis 5: The negative effect on trade will be greater in more impoverished countries.

I test this hypothesis with several regressions using a number of variables which measure the effect of disease outbreaks on trade only in countries falling below a certain GDP per capita threshold. The income thresholds that I use in this study are $456.25 and below, $730 and below, $1,500 and below, $2,500 and below, $5,000 and below, $10,000 and below, $20,000 and below, and all values above $20,000. The first two thresholds are the World Bank standards for extreme poverty and moderate poverty—$1.25 per day and $2 per day, respectively[29]—extrapolated over

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[28] These interaction variables are generated by multiplying the variable for disease outbreak (*varout*) with the variable for contiguity (*contig*).
[29] "Poverty Overview," 2014.

the course of an entire year. The other thresholds are incremental benchmarks selected to give a wider view of the issue at hand across a range of economic strata.

Hypothesis 6: The pathological characteristics of a disease will be important in determining its effect on trade.

I have also created outbreak dummy variables for nine ecological characteristics in order to ascertain which types of diseases have a greater or lesser effect on trade. The nine characteristics included in this study are listed and explained below:

Vector borne
Non-vector borne

These variables measure whether or not a disease is transmitted between hosts by another organism. Vector borne diseases include malaria, yellow fever, and chikungunya. Non-vector borne diseases include AIDS, all forms of hepatitis, and Ebola.

Zoonotic
Human-Specific

These variables measure the host type of a given disease. Zoonotic pathogens are capable of living and reproducing indefinitely in non-human populations. Human-specific pathogens are contagious only between humans, and are not capable of reproducing in non-human hosts. Zoonotic diseases include dengue, giardiasis, and rabies. Human-specific diseases include cholera, aseptic and bacterial meningitis, and adenovirus infection.

It should be noted that the distinction made between zoonotic and human-specific pathogens, while conventional in the field of epidemiology, ignores a more versatile third type of pathogen. A multi-host pathogen is capable of surviving and reproducing in both human and non-human hosts. In the dataset used in this study, multi-host pathogens are coded as zoonotic. Due to constraints on time and a lack of expertise in the field of epidemiology, it was not practical to individually code each disease in the dataset for multi-host pathology. This distinction could have a meaningful effect on this study, as human-specific and multi-host pathogens seem more likely to present obstacles to international trade on the basis that transmission between humans—including businessmen, diplomats, and longshoreman—is possible.

Bacterium
Virus
Protozoon
Parasite
Fungus
Alga

These distinctions denote the taxonomy of a given pathogen. They are listed here in order of decreasing frequency in the dataset. Bacterial diseases include tuberculosis, plague, and all categories of typhus. Viral diseases include influenza, rotavirus infection, and SARS. Protozoon diseases include sarcocystosis, rhinosporidiosis, and cyclosporiasis. Parasitic diseases include mercurial dermatitis, hookworm, and scabies. Fungal diseases include histoplasmosis, candidiasis, and zygomycosis. There were zero instances of recorded alga disease outbreaks during the time period covered in this study.

These categories are only a few of many ways to divide and categorize communicable diseases. For example, an outbreak of influenza is unlikely to manifest in trade in the exact way that an outbreak of Ebola would, despite both diseases being non-vector born, zoonotic, and viral. There are a number of other disease characteristics that would be relevant to include in this study, but which were not for various reasons. The fatality rate of a disease could help reconcile the wide variety of diseases even within pathological subsets. Unfortunately, fatality rates lack standardization, varying widely from one source to the next. Also, the fatality rate for many diseases is determined to a large degree by available treatment options and quality of care. An excellent example of this is rabies which, if caught early, is curable, but if left untreated for too long is almost unerringly a death sentence.[30] Another category that would be germane to this study is transmissivity. In epidemiology, this is measured by the basic reproduction number which measures the number of new cases a single case of a disease would be expected to generate if introduced to an uninfected population. As with fatality rates, this metric lacks standardization, varies widely depending on a number of factors, and is questionably relevant in terms of determining just how contagious a disease is in the traditional sense.[31] Another category that may be of note to this study is food borne disease. There is an argument to be made for excluding all food-borne illnesses from the dataset, due to the fact that, at first blush, their effect on trade ought to be predictably negative. However, I argue that this is not necessarily the case. In fact, only a relatively small portion of international commerce is in foodstuffs. Of these an even smaller fraction of livestock, poultry, or produce would be affected by an outbreak of any given food-borne disease. To the degree that food-borne diseases do affect international trade, I would argue that it is most likely due to the psychological aversion effects on potential trading partners and lost productivity due to a partially sickened workforce at home, and therefore that these diseases fall under the purview of this study.

[30] Jabr, 2011.
[31] For example, according to one study AIDS has a basic reproduction number of 19.7 in the San Francisco gay community, while another study suggests that during the 2014 West African outbreak, Ebola had a basic reproduction number of 1.51-1.59. However, there is little doubt that an Ebola patient is more likely to transmit the condition to those in their immediate vicinity than someone with HIV/AIDS. This example demonstrates the importance of transmissivity period along with time and place in determining a basic reproductive number. Dietz, 1993. Althaus, 2014.

Results

This section will present and explain the results of the statistical regressions used to test the hypotheses enumerated above. Again, all of these hypotheses are tested using standard regressions that control for the variables in the standard gravity model as well as a number of geographical and temporal fixed-effect variables. By comparing the relative size, direction, and statistical significance of each coefficient, this method allows us to gauge the relative effect of each control on trade in a given year. Converting these coefficients to dollar values is an inexact science, due to the fact that the dependent variable is a logarithmic function and that it has had a blanket addition of one million dollars added across all values. At the most basic level, a coefficient of 1 or -1 would result in roughly a tenfold increase or decrease in trade in a given year. Again, this is an imperfect measure. Any attempt to measure the real world cost of trade gained or lost from this study should be viewed as relative to the other controls in the gravity model, rather than as a strict dollar figure. It should be noted that comparing outbreak variables to other dichotomous variables is simpler than comparing them to variables with a greater range of values. For example, a variable such as weighted distance[32] (*distw*) appears to have a very small coefficient in the basic model,[33] but this is measuring the impact *per kilometer*, as opposed to a variable such as common official language (*comlang_off*), which is coded as either a zero or one in all cases.

> **Hypothesis 1: The presence of a disease outbreak in a given country in a given year will depress international imports from and exports to that country in the following year.**

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[32] The distance is weighted to reflect national population centers, as opposed to the shortest distance between two borders. For example, Russia and Mongolia share a land border, despite their respective population centers being thousands of kilometers apart.
[33] Appendix C

R-Squared: 0.670[34]

Variables	Coefficients	Robust Standard Error
Outbreak in exporting country	-0.089***	0.009
Outbreak in importing country	-0.147***	0.009
Outbreak in both exporting and importing countries	0.389***	0.013

Above are the results of the standard model used in this study, along with three binary variables for an outbreak in the exporting country (*varout_o*), the importing country (*varout_d*), or in both members of the dyad (*varout_b*). The R^2 value, 0.6705, tells us that the statistical model as a whole is explaining just over 67 percent of the variance we see in our dependent variable. This substantial value confirms the explanatory and predictive capabilities of the basic statistical model used herein. It should also be noted that this value is a slight but relevant increase over the R^2 value of the basic gravity model,[35] which is 0.6681, suggesting that the addition of the disease outbreak variables is a very small but still relevant explanatory factor in international trade.[36] For all three variables, the p-value is 0.000, meaning that the chance of these results being achieved with a set of random values is less than one in one-thousand. This establishes the statistical significance of these results and suggests that the findings are meaningful from an academic standpoint.

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[34] As is standard in studies such as this, each statistically significant coefficient is followed by an asterisk denoting the p-value of that particular finding. One asterisk denotes a p-value of less than 0.05, meaning that the finding would be generated by a random set of numbers at most five times out of 100. Two asterisks denote a p-value of at least 0.01. Three asterisks indicate the most significant findings with p-values of at least 0.001. The chance of these findings being the product of chance is less than one in 1,000. Coefficients without any asterisks are not statistically significant.
[35] Appendix B
[36] The introduction of disease variables does not significantly alter the magnitude or direction of any other independent variables included in the gravity model.

The coefficients themselves tell an interesting story. According to the first two coefficients listed above, an outbreak in either an exporting or an importing country results in a decrease in dyadic trade flows. This effect is more pronounced in the case of afflicted importers. These findings are in line with the first hypothesis explained in detail above. It stands to reason that traders are hesitant to do business with an afflicted nation, whether importing or exporting. While this hesitation may be well-founded in many cases, it may also be irrational, speculative, or even hysterical. Forgoing trade with a nation simply because it is undergoing an outbreak may be foolhardy in the case of outbreaks that are significantly contained geographically, limited to a portion of the population, or unlikely to be transmitted in the course of international commerce. This effect may also apply to consumers considering the purchase of something imported from an afflicted country. It is possible that there is a psychological barrier to purchasing any goods from such a nation, and that inability to sell goods to end-consumers may result in even the most rational traders choosing to by goods from non-afflicted countries.

Other than the consternation of potential trading partners and foreign consumers, the decline in trade in countries undergoing a disease outbreak may also be related to a dip in domestic productivity and wage-earning due to sickness and even death in the workforce. The results of such a decrease in economic productivity would affect both exports—fewer goods to sell due to falling productivity—and imports—citizens lose expendable income due to lost wages, healthcare expenses, etc.

Hypothesis 2: Instances in which both members of a dyadic trade pair are undergoing an outbreak will result in an even greater negative effect on imports and exports.

While the first hypothesis set forth in this paper is born out by the data in cases where one member of a dyad undergoes an outbreak, the second is decidedly not. The coefficient for dyads in which both members are undergoing a disease outbreak is 0.3887, a massive value that defies simple explanation. Keep in mind that these are not necessarily situations in which two countries have the same disease. It simply means these countries are undergoing an outbreak of *any* disease in the dataset. Not only is this effect inexplicably large—greater than the effect of a shared currency or official language—but it is persistent across nearly every regression presented in this study and nearly impervious to my attempts to explain it through controls and alternate statistical methodologies. At first I speculated that this could be driven by massive countries like the United States, China, Russia, Mexico, Canada and India frequently reporting outbreaks (due to the size of their populations and superior detection and reporting mechanisms) while trading massive amounts with one another. However, even without these countries, the results are similar. Across the large majority of outbreak variables I have regressed, this effect remains sizable and statistically significant. Applying Occam's Razor to this problem, one might conclude that countries figure that if they are both experiencing epidemics then they might as well trade with one another. While there may be some truth to this, it strikes me as an overly simplistic explanation. After all, what motivation does a country undergoing a syphilis outbreak have to increase exports to or imports from a country afflicted with dengue? This is a puzzle that I hope future research will continue to explore.

Hypothesis 3: Trade with a nation's primary trade partners will be less affected than trade with less important trade partners.

R-Squared: 0.849

Variables	Coefficients	Robust Standard Error
Top ten: exporter	0.028	0.029
Top ten: importer	-0.085**	0.026
Top ten: both	0.010	0.033

R-Squared: 0.638

Variables	Coefficients	Robust Standard Error
Non-top 10: exporter	-0.065***	0.008
Non-top 10: importer	-0.138***	0.008
Non-top 10: both	0.372***	0.012

The above regression measures the effect of an outbreak on trade with a given nation's top ten trading partners. Both the *origin* and *both* variables have minuscule coefficients and are statistically insignificant by a wide margin. This tells us that the outbreak of a disease essentially has no meaningful effect on either exports or trade with other afflicted countries among major trading partners. The data does suggest a negative effect on imports, even among a nation's top ten trading partners. Throughout the regressions presented herein, the prominent negative effect on imports in the event of an outbreak is a common thread.

On the other hand, the coefficients for all trading partners outside of the top ten tells a very different story. In this case, the negative effects on imports and exports are both statistically significant and pronounced. The effect on exports that we see in the general model has manifested, while the detrimental effect on imports already present in the top ten regression has increased significantly. This tells us that while high-volume trade relationships—presumably the result of historical familiarity, proximity, trade agreements, etc.—are durable in the face of disease outbreaks, marginal trade relations are much more susceptible to the effects observed in the general model.

It is also of note that the *both* variable, insignificant in the top ten regression, has reached very nearly the same level that it was in the basic regression (0.3723 compared to 0.3887). This tells us that the positive effect on trade between two afflicted nations exists almost entirely outside of a nations top ten trading partners. While this may not shed light on the puzzling nature of the *both* variable's positive coefficient, it does tell an interesting story about the behavior of afflicted nations.

Hypothesis 4: This negative effect on imports and exports will be exacerbated in the case of trade between contiguous nations.

R-Squared: 0.668

Variables	**Coefficients**	**Robust Standard Error**
Contiguous: exporter	0.156	0.086
Contiguous: importer	0.009	0.087
Contiguous: both	0.339***	0.101

In terms of imports and exports, this regression produces results that are not statistically significant. The minuscule coefficient and massive p-value of the imports variable tells us that the presence of a disease has very little to do with imports from contiguous nations. In terms of exports, we have a large coefficient, but a p-value that just misses statistical significance. If the result is true however, it tells an important story about afflicted nations increasing their exports to contiguous countries in times of disease outbreak. Again, no firm results can be drawn either confirming or denying this hypothesis, although the lack of significant results in a dataset of this size strongly suggests that contiguous countries do not trade less with one another in the event of an outbreak as conjectured in Hypothesis 4.

The one result that is statistically significant is the sizable coefficient attached to the *both* variable. This variable tells us that contiguous countries reliably trade more when they are both afflicted with an outbreak. One could surmise that contiguous countries are more likely to undergo outbreaks of the same exact disease, in which case an increase in trade could be related to sharing resources and coordinated containment and treatment efforts. However, subsequent testing of cases that match that particular criteria contradicts this conjecture. The *both* variable remains strong regardless of the particulars of each outbreak.

Hypothesis 5: The negative effect on trade will be greater in more impoverished countries.

GDP per capita over $20,000:
R-Squared: 0.673

Variables	Coefficients	Robust Standard Error
Over 20,000: exporter	0.298***	0.023
Over 20,000: importer	0.093***	0.025
Over 20,000: both	1.402***	0.061

GDP per capita below $20,000:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 20,000: exporter	-0.054***	0.008
Under 20,000: importer	-0.058***	0.009
Under 20,000: both	0.101***	0.011

GDP per capita below $10,000:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 10,000: exporter	-0.041***	0.009
Under 10,000: importer	-0.056***	0.009
Under 10,000: both	-0.004	0.013

GDP per capita below $5,000:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 5,000: exporter	-0.065***	0.010
Under 5,000: importer	-0.078***	0.009
Under 5,000: both	-0.006	0.015

GDP per capita below $2,500:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 2,500: exporter	-0.087***	0.009
Under 2,500: importer	-0.086***	0.008
Under 2,500: both	0.032	0.016

GDP per capita below $1,500:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 1,500: exporter	-0.117***	0.010
Under 1,500: importer	-0.100***	0.009
Under 1,500: both	0.072***	0.020

GDP per capita below $670:
R-Squared: 0.669

Variables	Coefficients	Robust Standard Error
Moderate poverty: exporter	-0.185***	0.012
Moderate poverty: importer	-0.142***	0.012
Moderate poverty: both	0.140***	0.027

GDP per capita below $456.25:
R-Squared: 0.669

Variables	Coefficients	Robust Standard Error
Extreme poverty: exporter	-0.191***	0.014
Extreme poverty: importer	-0.137***	0.014
Extreme poverty: both	0.179***	0.035

The table above tells a fascinating story about the importance of wealth in deterring the effects of an outbreak on trade. The first chart measures countries with a GDP per capita over $20,000. These are generally wealthy European and North American countries,[37] with robust healthcare systems, large economies, and numerous trade relationships. This regression tells us with a high degree of statistical certainty that nations in this GDP per capita slice actually experience an increase in trade in the event of an outbreak. This pattern is particularly pronounced in the case of exports, which spike significantly. The *both* variable for these countries is enormous, and suggests a massive surge in trade between wealthy countries undergoing an outbreak. As we will see below, the *both* characteristic is much smaller in all other GDP per capita slices, suggesting that a large proportion of the *both* coefficient in the general model is driven by these instances of large nations trading with one another. It is curious that a

[37] The exact sample changes from year to year, as the GDP and population of each country shift over time.

disease outbreak would spur greater trade in wealthier nations. This effect may be attributable to these nations trading treatments and potential cures with one another. It may also be that a coordinated government response to a crisis such as a disease outbreak actually stimulates the economy, as government money flows into treatment, research, and prevention measures.

The next regression measures the effect of an outbreak on countries with a GDP per capita below $20,000. Immediately, negative effects on imports and exports appear. This tells us that the cutoff for when a country begins experiencing the negative effects of an outbreak on trade is somewhere around the $20,000 mark. The *both* variable remains positive, but is less than one-tenth the magnitude that we saw in wealthier countries.

In the case of countries with a GDP per capita below $10,000, the coefficients for both imports and exports are slightly less negative than in the previous regression, although the values remain very similar. Meanwhile, the effect on the *both* variable is no longer significant, suggesting that this variable may have no explanatory power for trade between countries below this cutoff.

In the next regression, which measures countries below $5,000, we see a greater decline in imports and exports. The *both* variable remains statistically insignificant. This regression kicks off a series of results in which each GDP per capita slice portends more devastating effects on imports and exports than the last. The effect on countries with a GDP per capita below the World Bank standard for moderate poverty ($670 per year) and extreme poverty ($456.25 per year) are particularly alarming. The coefficient for each nearly doubles that of any other GDP per capita grouping. In the case of extreme poverty, the regression forecasts a drop in imports and exports that is roughly equivalent to 1,975 and 1,419 kilometers of weighted distance respectively.

Interestingly, for all groupings below $2,500, the negative effect on exports appears greater than that on imports. This is the inverse of what we have come to expect in the other regressions, which generally have a more negative-leaning coefficient for imports. It is also interesting that the *both* variable which became insignificant in the middle groupings becomes both significant and increasingly sizable in the lower income groupings.

Viewed as a whole, this set of results confirms the hypothesis that more impoverished countries suffer a greater decrease in trade in the event of a disease outbreak. While the *both* variable continues to confound—it has an enormous effect between wealthy countries, becomes insignificant in middling countries, then surges again in increasingly poor nations—the results on imports and exports are more readily explicable. Overall, the effect on both importers and exporters grow steadily more negative as we descend into lower and lower GDP per capita brackets. The most apparent explanation for this is that less wealthy countries lack the state capacity—hospitals and other medical facilities, doctors and other medical personnel, adequate systems of detection, roads and bridges to carry aid to backwater communities, government institutions to coordinate relief efforts, intellectual capital to develop treatments and cures, etc.—to respond effectively to an outbreak, and thereby mitigate the potential negative effects on trade and the economy at large. This lack of state capacity could cause a decline in domestic production, as the workforce is weakened. It could also present a legitimate deterrent for potential trade partners who are concerned about traveling to a given country, or who are nervous that end-consumer will have an aversion to goods produced in this country. No matter the specific reason for this decline, it has very real consequences for the citizens of these nations who may find themselves in both an afflicted country as well as an economically handicapped one. Foreign governments and international aid groups should keep this in mind when allocating resources to afflicted countries around the world.

Hypothesis 6: The pathological characteristics of a disease will be important in determining its effect on trade.

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Vector borne: exporter	0.015	0.009
Vector borne: importer	-0.011	0.008
Vector borne: both	-0.007	0.027

R-Squared: 0.670

Variables	Coefficients	Robust Standard Error
Non-vector borne: exporter	-0.048***	0.008
Non-vector borne: importer	-0.099***	0.008
Non-vector borne: both	0.352***	0.013

According to this statistical model, vector borne diseases have no statistically significant effect on trade. Meanwhile, non-vector borne diseases show results that track somewhat closely to those in our basic trade model—a negative effect on exports, a stronger negative effect on imports, and a very strong positive effect on *both*. This makes some intuitive sense. Diseases that are vector borne may be less likely (or perceived as less likely) to be transmitted through the course of trade, as they are generally transferred between humans by other organisms, as opposed to human contact. An outbreak of a disease like malaria, which only transmits directly between humans congenitally, through blood transfusions, organ transplants, or contaminated syringes,[38] may be less likely to deter a trader than something that is contagious directly between humans. In terms of the predictive capability of this study, this finding helps us weed out which diseases are most devastating to trade. In this case, we know that diseases that transmit directly between human hosts are likely to have strong negative effects on trade.

R-Squared: 0.669

Variables	Coefficients	Robust Standard Error
Zoonotic: exporter	-0.010	0.006
Zoonotic: importer	-0.071***	0.007
Zoonotic: both	0.243***	0.011

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Human specific: exporter	0.021***	0.006
Human specific: importer	0.020***	0.006
Human specific: both	0.143***	0.012

These results tell us that zoonotic diseases have a negative effect on imports, and an insignificant effect on exports. Interestingly, human specific diseases seem to have a slight positive effect on trade. This could be due to a government response that includes investment in treatment, inoculation, medicine, research, etc. Due to a variety of possible reasons—frequency of occurrence, severity of the disease, etc.—this government response may be less robust in the case of zoonotic diseases.

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[38] "Malaria Transmission," 2009.

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Bacterium: exporter	0.025***	0.006
Bacterium: importer	-0.023***	0.007
Bacterium: both	0.156***	0.011

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Virus: exporter	-0.005	0.006
Virus: importer	-0.017**	0.006
Virus: both	0.193***	0.013

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Protozoon: exporter	0.010	0.011
Protozoon: importer	-0.008	0.012
Protozoon: both	0.198*	0.078

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Parasite: exporter	0.074***	0.013
Parasite: importer	0.069***	0.014
Parasite: both	0.087	0.097

R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Fungus: exporter	0.117***	0.018
Fungus: importer	0.047*	0.020
Fungus: both	0.800***	0.172

These results break down the effect on trade of each disease taxonomy included in the dataset. The statistical significance falls below the commonly accepted academic threshold in a number of cases, but there are still some important takeaways from these regressions. The positive effect of the *both* variable remains strong across all regressions with the exception of parasitic diseases, for which it is statistically insignificant. Bacterial and viral diseases, by far the most common types of outbreaks, both have negative coefficients in the case of imports. This is in line with the many of the other findings presented herein. Interestingly, bacteria, parasites, and fungi all show positive coefficients in the case of exports. The could be related to government responses to disease spurring the larger economy, or due to displaced consumption—citizens who are sick buy less, so those goods are exported overseas.

With these caveats in place, I would like to reaffirm what may be the most important finding in this study. When the *both* variable is removed from the regressions, it has a significant positive effect on many variables. However, it does not significantly change the findings regarding the increasing effects of disease outbreaks in increasingly impoverished countries.

Discussion

While I have already explored many of the substantive findings and potential ramifications of this study above, this section will delve more deeply into what I find to be the most perplexing results: the strong coefficient for the *both* variable across nearly every regression. The nature of the regression used in this study is such that each independent variable controls against each other independent variable. Therefore, each instance of both countries undergoing an outbreak (in the standard model: *varout_b*) actually removes the statistical effect of that instance from the other outbreak variables (*varout_o* and *varout_d*). Coupled with the fact that there are a large number of instances of outbreak in both countries,[39] this indicates that absent the *both* variable many of the negative *origin* and *destination* coefficients would become positive. In other words, without the interaction term, the model would tell us that a disease outbreak generally results in increased exports and an insignificant effect on imports.[40] In this light, the findings of the general model presented under hypothesis one (and reflected in many of the other regressions) is that unilateral outbreaks drive trade down, joint outbreaks increase trade, and the net effect of outbreaks on trade is either positive or insignificant.

The finding that the net effect of disease on trade is positive, often significantly so, runs contrary to common sense. I have already presented several theories as to why this finding might manifest. It could be a result of afflicted nations figuring they might as well trade with one another if other nations are trading less with them. As mentioned above, I question the simplistic nature of this explanation. A more plausible explanation would be that robust responses from aid organizations and governments in fact stimulate a country's economy more than disease outbreak

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[39] Appendix D
[40] Appendix E

hurts it. If this is the case, this finding may be important to larger discussions of the ideal role of the government in stimulating the economy. While that particular issue is a massively important and politically contentious one that is largely outside the scope of this study, it should be noted that this potential explanation would reinforce the theory that government spending stimulates the economy in the short term. Another explanation posits that disease outbreaks tend to decrease the domestic supply of numerous goods, thereby increasing their value. Because the trade values are recorded in dollars instead of the quantity of goods bought and sold, it may be that the same or less volume of trade results in a higher monetary value. While it is impossible to verify this theory without data detailing either a globally standardized value for goods traded or the actual volume of goods traded, it would explain some this study's findings rather neatly. Specifically, it would help explain the increase in imports due to the soaring value of goods, as well as the *both* variable, as both countries experience inflated values for goods traded with one another. While I find some these theories to be compelling, absent further research untangling this relationship we can only speculate.

A portion of the explanation for this strange finding may be endemic to the broad nature of this study. The variety of diseases included in the statistical model used herein is expansive, even when narrowed down by different epidemiological characteristics.[41] Without an objective, standardized, and publicly available way of assessing both disease severity and transmissibility, it is nigh impossible to narrow down diseases according to the traits that we would expect to have the greatest effect on human behavior—in this case trade. It may be that outbreaks of the most severe diseases do in fact exert a negative effect on trade, but that less serious diseases

[41] Appendix A

stimulate trade. If this is the case, the broad nature of this statistical model may obscure the negative effect of the most serious conditions behind the positive effects of all the rest. It is my hope that future research will systematically quantify the severity and transmissibility of diseases, allowing more specific examination of the effects of disease outbreaks on trade.

While the majority of regressions are highly sensitive to the treatment of the *both* variable and experience significant positive change when it is removed, the findings regarding the increasing negative effect of disease outbreaks on poverty do not. Even without the *both* variable, these findings remain both strongly negative and statistically significant.[42] The fact that this finding is largely insensitive to the treatment of the *both* variable further confirms its importance as a statistical determinant. This is important for two reasons. First, it suggests that a large part of the positive *both* effect is contained in wealthy countries trading with each other, particularly those with a GDP per capita in excess of $20,000. Second, it reaffirms the conclusion that impoverished countries are more greatly affected economically by disease outbreak. This may be the most important finding uncovered in this study, as it can help inform international aid organizations and other altruistic parties as to where best to allocate finite resources. This strong negative relationship between disease and trade in the world's poorest countries should raise alarm bells for government agencies, aid groups, and future researchers alike.

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[42] Appendix F

Conclusion

This study began with the simple question of how disease outbreaks affect international trade. As is so often the case with simple questions, the answer is much more complicated than a simple yes or no. This study has confirmed the broad hypothesis that instances of an outbreak in either the importing or exporting member of a dyadic trade pair results in a loss of trade. Upon more nuanced inspection, this study finds that the direction and magnitude of this effect has a tremendous amount to do with the individual nations involved and the nature of the disease itself. This study has produced statistical results that suggest a number of conclusions. Instances in which both members of a dyad undergo a disease outbreak generally result in more trade than would otherwise be expected. Contiguity is not a significant factor in explaining the effect of disease on imports or exports. Trade relations with an afflicted nation’s top trading partners are less affected than those with peripheral partners. As a general rule, the more impoverished a nation is, the greater the negative effect on trade is for that nation. Finally, the specific pathology of a disease matters in terms of how it will affect trade. Specifically, bacterial and viral diseases exert negative effects on imports, while other disease types have either positive or statistically insignificant effects.

I have proposed a number of possible explanations for these results which are detailed above. I believe that positive effects observed in the event of an outbreak are likely due to increased trade in goods related to a specific outbreak (medicine, resources, food, miscellaneous aid, etc.), to an increase in government spending in times of medical emergency that, in turn, may lift the economy, or to an increase in the monetary value of trade goods as domestic production falls. This second proposal is supported by the positive effects of outbreaks in wealthy nations capable of staging a robust and prolonged campaign against a public health threat compared to negative effects in the type of impoverished country that lacks the resources for this. I believe that the observed negative effects on trade can be attributed to internal and external factors. Within a given country, a disease outbreak may weaken or kill members of the workforce. In turn, this may lessen domestic production outputs, leading to fewer goods to exports. Citizens may also lose wages due to illness, which could lessen their financial ability to purchase imported goods. Externally, consumers in other countries may have an aversion to purchasing goods from an afflicted nation, lessening exports. Traders may be concerned by the risk of contagion when conducting business with citizens of an afflicted country, whether or not these fears are rational. If true, this could drive a decrease in both imports and exports.

These findings are important for a number of reasons. There is inherent value in understanding the underlying precepts and tectonic forces that control global marketplaces. International trade is an important aspect of every nation's economic success, which in turn affects the lives of everyday citizens. Recognizing the determinants of the international marketplace allows governments, businesses, aid organizations, and everyday people to predict and prepare for an uncertain future. Recognizing the potential positive and negative effects of a given disease outbreak on the amount of actual capital flowing into and out of a nation can allow governments and aid organizations to fill the economic void that may follow an epidemic. In the introduction to this thesis, I proposed the possibility of a vicious cycle in which disease causes poverty which, in turn, causes more disease.[43] While the overall net positive effect suggests that in many cases this circle may not be as vicious as imagined, further testing confirms that

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[43] Suhrcke et al. 2011.

impoverished countries—those who can least afford economic calamity—are the most likely to face economic devastation in the wake of disease outbreak. Sun Tzu teaches that, “if you know your enemies and know yourself, you will not be imperiled in a hundred battles.” In this case, disease is the enemy. In some cases this deadly adversary exerts a predictable negative economic influence, in others a surprising positive one. In all cases, understanding the nature and effects of disease is a vital weapon in the struggle to improve the human condition.

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Appendix A - List of Diseases Included in Smith et al

ADENOVIRUS INFECTION
AEROMONAS & MARINE VIBRIO INFX.
AFRICAN TICK BITE FEVER
AIDS
AMOEBA - FREE LIVING
AMOEBIC COLITIS
ANAPLASMOSIS
ANGIOSTRONGYLIASIS
ANGIOSTRONGYLIASIS - ABDOMINAL
ANISAKIASIS
ANTHRAX
ASPERGILLOSIS
BABESIOSIS
BACILLUS CEREUS FOOD POISONING
BARMAH FOREST DISEASE
BARTONELLOSIS - CAT BORNE
BARTONELLOSIS - OTHER SYSTEMIC
BARTONELLOSIS - SOUTH AMERICAN
BLASTOCYSTIS HOMINIS INFECTION
BLASTOMYCOSIS
BOLIVIAN HEMORRHAGIC FEVER
BOTULISM
BRAINERD DIARRHEA
BRAZILIAN PURPURIC FEVER
BRUCELLOSIS
BUNYAVIRIDAE INFECTIONS - MISC.
CALIFORNIA ENCEPHALITIS GROUP
CAMPYLOBACTERIOSIS
CANDIDIASIS
CAPILLARIASIS - INTESTINAL
CERCARIAL DERMATITIS
CHANCROID
CHANDIPURA AND VESICULAR
STOMATITIS VIRUSES
CHIKUNGUNYA
CHLAMYDIA INFECTIONS, MISC.
CHLAMYDOPHILA PNEUMONIAE
INFECTION
CHOLERA
CLONORCHIASIS
CLOSTRIDIAL FOOD POISONING
CLOSTRIDIAL MYONECROSIS
CLOSTRIDIUM DIFFICILE COLITIS
COCCIDIOIDOMYCOSIS
CONJUNCTIVITIS - INCLUSION
CONJUNCTIVITIS - VIRAL
CRIMEAN-CONGO HEMORRHAGIC FEVER
CRYPTOSPORIDIOSIS
CUTANEOUS LARVA MIGRANS
CYCLOSPORIASIS
CYSTICERCOSIS
DENGUE
DERMATOPHYTOSIS
DIPHTHERIA
DIPHYLLOBOTHRIASIS
DRACUNCULIASIS
EASTERN EQUINE ENCEPHALITIS
Ebola
ECHINOCOCCOSIS - UNILOCULAR
EHRLICHIOSIS - HUMAN MONOCYTIC
ENTERITIS NECROTICANS
ENTEROVIRUS INFECTION
ERYSIPELOID
ESCHERICHIA COLI DIARRHEA
FASCIOLIASIS
FUNGAL INFECTION - INVASIVE
GASTROENTERITIS - VIRAL
GIANOTTI-CROSTI SYNDROME
GIARDIASIS
GLANDERS
GNATHOSTOMIASIS
GONOCOCCAL INFECTION
HANTAVIRUS INFECTION - OLD WORLD
HANTAVIRUS PULMONARY SYNDROME
HEPATITIS A
HEPATITIS B
HEPATITIS C
HEPATITIS D
HEPATITIS E
HERPES B INFECTION
HERPES SIMPLEX INFECTION
HERPES ZOSTER
HETEROPHYID INFECTIONS
HISTOPLASMOSIS
HISTOPLASMOSIS - AFRICAN
HOOKWORM
HUMAN HERPESVIRUS 6 INFECTION
INFLUENZA
JAPANESE ENCEPHALITIS
JAPANESE SPOTTED FEVER
KAWASAKI DISEASE
KINGELLA INFECTION
KYASANUR FOREST DISEASE
LARYNGOTRACHEOBRONCHITIS
LASSA FEVER
LEGIONELLOSIS
LEISHMANIASIS - CUTANEOUS
LEISHMANIASIS - MUCOCUTANEOUS
LEISHMANIASIS - VISCERAL
LEPROSY
LEPTOSPIROSIS
LISTERIOSIS

LYME DISEASE
LYMPHOCYTIC CHORIOMENINGITIS
LYMPHOGRANULOMA VENEREUM
MALARIA
MARBURG VIRUS DISEASE
MAYARO
MEASLES
MELIOIDOSIS
MENINGITIS - ASEPTIC (VIRAL)
MENINGITIS - BACTERIAL
MICROSPORIDIOSIS
MONKEYPOX
MUMPS
MYCOBACTERIOSIS - M. MARINUM
MYCOBACTERIOSIS - M. ULCERANS
MYCOBACTERIOSIS - MISCELLANEOUS NONTUBERCULOUS
MYCOPLASMA (MISCELLANEOUS) INFECTIONS
MYCOPLASMA PNEUMONIAE INFECTION
MYIASIS
NECROTIZING SKIN/SOFT TISSUE INFX.
NIPAH AND NIPAH-LIKE VIRUS DISEASE
NOCARDIOSIS
O'NYONG NYONG
OCKELBO DISEASE
OLD WORLD PHLEBOVIRUSES
ONCHOCERCIASIS
OPISTHORCHIASIS
ORBITAL AND EYE INFECTIONS
ORF
ORNITHOSIS
OROPOUCHE
PARAGONIMIASIS
PARAINFLUENZA VIRUS INFECTION
PARVOVIRUS B19 INFECTION
PEDICULOSIS
PERTUSSIS
PHARYNGITIS - BACTERIAL
PLAGUE
PLESIOMONAS INFECTION
PLEURODYNIA
PNEUMOCYSTIS - PNEUMONIA
POGOSTA DISEASE
POLIOMYELITIS
POWASSAN
PSEUDOCOWPOX
PYODERMAS (IMPETIGO, ABSCESS, ETC)
PYOMYOSITIS
PYTHIOSIS
Q-FEVER
RABIES
RAT BITE FEVER - STREPTOBACILLARY
RELAPSING FEVER
RESPIRATORY SYNCYTIAL VIRUS INFECTION
RESPIRATORY VIRUSES - MISCELLANEOUS
REYE'S SYNDROME
RHEUMATIC FEVER
RHINOSPORIDIOSIS
RICKETTSIA FELIS INFECTION
RICKETTSIALPOX
RIFT VALLEY FEVER
ROCKY MOUNTAIN SPOTTED FEVER
ROSS RIVER DISEASE
ROTAVIRUS INFECTION
RUBELLA
SALMONELLOSIS
SARCOCYSTOSIS
SARS
SCABIES
SCARLET FEVER
SCHISTOSOMIASIS - HAEMATOBIUM
SCHISTOSOMIASIS - JAPONICUM
SCHISTOSOMIASIS - MANSONI
SEPTICEMIA - BACTERIAL
SHIGELLOSIS
SINDBIS
SPOROTRICHOSIS
SPOTTED FEVERS - OLD WORLD
ST. LOUIS ENCEPHALITIS
STAPHYLOCOCCAL FOOD POISONING
STAPHYLOCOCCAL SCALDED SKIN SYNDROME
STREPTOCOCCUS SUIS INFECTION
STRONGYLOIDIASIS
SYPHILIS
TAENIASIS
TETANUS
TICK-BORNE ENCEPHALITIS
TOXIC SHOCK SYNDROME
TOXOCARIASIS
TOXOPLASMOSIS
TRACHOMA
TRICHINOSIS
TRICHOSTRONGYLIASIS
TRICHURIASIS
TROPICAL PHAGEDENIC ULCER
TRYPANOSOMIASIS - AFRICAN
TRYPANOSOMIASIS - AMERICAN
TUBERCULOSIS
TULAREMIA
TUNGIASIS
TYPHOID AND ENTERIC FEVER
TYPHUS - ENDEMIC
TYPHUS - EPIDEMIC
TYPHUS - SCRUB
VACCINIA AND COWPOX

VARICELLA
VENEZUELAN EQUINE ENCEPHALITIS
VENEZUELAN HEMORRHAGIC FEVER
VIBRIO PARAHAEMOLYTICUS INFECTION
WEST NILE FEVER
WESTERN EQUINE ENCEPHALITIS
YAWS
YELLOW FEVER
YERSINIOSIS
ZIKA
ZYGOMYCOSIS

Appendix B - Basic Gravity Model

Linear regression

Number of obs = 559727
F(62, 27664) = 836.77
Prob > F = 0.0000
R-squared = 0.6681
Root MSE = 1.247

(Std. Err. adjusted for 27665 clusters in dyadcode)

log_flo~1mil	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
camerica_o	.0815671	.0320635	2.54	0.011	.018721	.1444132
camerica_d	.0701555	.0330762	2.12	0.034	.0053246	.1349865
samerica_o	.0882219	.0285584	3.09	0.002	.032246	.1441977
samerica_d	-.2177423	.0273133	-7.97	0.000	-.2712777	-.1642069
mideast_o	-.4492739	.0272842	-16.47	0.000	-.5027522	-.3957956
mideast_d	-.2491465	.02551	-9.77	0.000	-.2991473	-.1991458
wafrica_o	.0485911	.027118	1.79	0.073	-.0045615	.1017437
wafrica_d	-.1037849	.0258916	-4.01	0.000	-.1545337	-.0530361
eafrica_o	.0442792	.02613	1.69	0.090	-.0069369	.0954953
eafrica_d	-.1073401	.0260836	-4.12	0.000	-.1584653	-.0562148
asia_o	.2940972	.0335237	8.77	0.000	.2283891	.3598053
asia_d	.0255699	.0353801	0.72	0.470	-.0437768	.0949166
seasia_o	.603461	.0402544	14.99	0.000	.5245604	.6823616
seasia_d	.2553467	.0383918	6.65	0.000	.1800968	.3305966
oceania_o	.5592379	.0420577	13.30	0.000	.4768027	.6416732
oceania_d	.2342458	.0415997	5.63	0.000	.1527083	.3157832
comcur	.2506931	.0607213	4.13	0.000	.1316762	.3697099
comleg	.1736884	.0161339	10.77	0.000	.1420652	.2053117
contig	1.159685	.0609677	19.02	0.000	1.040185	1.279185
comlang_off	.3255803	.0217696	14.96	0.000	.2829107	.3682498
distw	-.0000966	2.08e-06	-46.44	0.000	-.0001007	-.0000925
pop_d	.000615	.0000815	7.55	0.000	.0004553	.0007746
pop_o	.0011125	.0000719	15.48	0.000	.0009716	.0012534
lgdp_o	.4527133	.0051326	88.20	0.000	.4426531	.4627734
lgdp_d	.4079044	.0050114	81.40	0.000	.3980819	.4177269
lgdpcap_d	.1105056	.007069	15.63	0.000	.09665	.1243612
lgdpcap_o	.1844481	.0073818	24.99	0.000	.1699794	.1989168
col_fr	-.1979607	.1167791	-1.70	0.090	-.4268536	.0309321
col_hist	1.372045	.0791958	17.32	0.000	1.216817	1.527272
col_cur	-.7180254	.4553016	-1.58	0.115	-1.610439	.1743884
gatt_o	.0002522	.0147296	0.02	0.986	-.0286186	.0291229
gatt_d	.0297512	.0145566	2.04	0.041	.0012196	.0582828
rta	1.34425	.0334429	40.20	0.000	1.2787	1.4098
acp_to_eu	-.3773143	.0414952	-9.09	0.000	-.458647	-.2959817
gsp	.2618137	.0345678	7.57	0.000	.1940591	.3295682
eu_to_acp	-.4818718	.0352638	-13.66	0.000	-.5509906	-.412753
gsp_rec	.3793542	.0313668	12.09	0.000	.3178738	.4408346
_Iyear_1981	-.0690493	.005198	-13.28	0.000	-.0792376	-.058861
_Iyear_1982	-.0961235	.0059358	-16.19	0.000	-.107758	-.0844889
_Iyear_1983	-.0762863	.0062046	-12.30	0.000	-.0884475	-.064125
_Iyear_1984	-.1164961	.006697	-17.40	0.000	-.1296225	-.1033697
_Iyear_1985	-.0999086	.0070351	-14.20	0.000	-.1136976	-.0861195
_Iyear_1986	-.1461758	.0072556	-20.15	0.000	-.1603971	-.1319545
_Iyear_1987	-.1720398	.0076765	-22.41	0.000	-.1870863	-.1569934
_Iyear_1988	-.2143078	.0079484	-26.96	0.000	-.229887	-.1987286
_Iyear_1989	-.1708185	.0081131	-21.05	0.000	-.1867206	-.1549165
_Iyear_1990	-.2653567	.0089109	-29.78	0.000	-.2828225	-.247891
_Iyear_1991	-.2343357	.0089302	-26.24	0.000	-.2518394	-.216832
_Iyear_1992	-.3123092	.0094589	-33.02	0.000	-.3308491	-.2937693
_Iyear_1993	-.2281962	.0097241	-23.47	0.000	-.247256	-.2091365
_Iyear_1994	-.180068	.0102476	-17.57	0.000	-.2001538	-.1599822
_Iyear_1995	-.2887622	.0106528	-27.11	0.000	-.3096422	-.2678821
_Iyear_1996	-.3424588	.0108936	-31.44	0.000	-.3638108	-.3211069
_Iyear_1997	-.3765367	.0109003	-34.54	0.000	-.3979018	-.3551716
_Iyear_1998	-.3671142	.0109074	-33.66	0.000	-.3884933	-.3457352
_Iyear_1999	-.3278942	.0111716	-29.35	0.000	-.3497912	-.3059973
_Iyear_2000	-.3443034	.0114147	-30.16	0.000	-.3666767	-.3219301
_Iyear_2001	-.3339547	.0115556	-28.90	0.000	-.3566043	-.3113051
_Iyear_2002	-.3290744	.0118564	-27.76	0.000	-.3523135	-.3058353
_Iyear_2003	-.3877798	.0125617	-30.87	0.000	-.4124014	-.3631583
_Iyear_2004	-.4842537	.013841	-34.99	0.000	-.5113827	-.4571247
_Iyear_2005	-.5684358	.0146617	-38.77	0.000	-.5971736	-.5396981
_Iyear_2006	0	(omitted)				
_cons	-8.300985	.093325	-88.95	0.000	-8.483906	-8.118063

Appendix C - Gravity Model with Outbreak Variables

```
Linear regression                                 Number of obs =  559727
                                                  F( 65, 27664) =  836.49
                                                  Prob > F      =  0.0000
                                                  R-squared     =  0.6705
                                                  Root MSE      =  1.2426

                          (Std. Err. adjusted for 27665 clusters in dyadcode)
```

log_flo~1mil	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
varout_o	-.0887332	.0088131	-10.07	0.000	-.1060074	-.071459
varout_d	-.1469767	.0090515	-16.24	0.000	-.164718	-.1292353
varout_b	.3887311	.0126919	30.63	0.000	.3638544	.4136078
camerica_o	.0887072	.0318617	2.78	0.005	.0262568	.1511577
camerica_d	.0705817	.0329928	2.14	0.032	.0059143	.1352491
samerica_o	.0918419	.0283813	3.24	0.001	.0362132	.1474706
samerica_d	-.2194056	.0270887	-8.10	0.000	-.2725008	-.1663104
mideast_o	-.4303014	.0273065	-15.76	0.000	-.4838235	-.3767793
mideast_d	-.2428067	.0255704	-9.50	0.000	-.292926	-.1926873
wafrica_o	.0470561	.0269253	1.75	0.081	-.0057188	.099831
wafrica_d	-.1065995	.0256833	-4.15	0.000	-.15694	-.056259
eafrica_o	.0456445	.0258816	1.76	0.078	-.0050848	.0963738
eafrica_d	-.108009	.0258229	-4.18	0.000	-.1586232	-.0573949
asia_o	.2957077	.0332802	8.89	0.000	.2304769	.3609386
asia_d	.0246734	.0351325	0.70	0.483	-.044188	.0935348
seasia_o	.6081632	.039888	15.25	0.000	.5299807	.6863456
seasia_d	.2564022	.0381256	6.73	0.000	.1816741	.3311304
oceania_o	.5578235	.0414667	13.45	0.000	.4765468	.6391002
oceania_d	.2358288	.0408452	5.77	0.000	.1557701	.3158875
comcur	.2348854	.0603546	3.89	0.000	.1165875	.3531834
comleg	.1740705	.0160482	10.85	0.000	.1426153	.2055257
contig	1.164813	.0607845	19.16	0.000	1.045673	1.283954
comlang_off	.320541	.0215875	14.85	0.000	.2782283	.3628537
distw	-.0000965	2.06e-06	-46.76	0.000	-.0001005	-.0000924
pop_d	.0006306	.0000802	7.86	0.000	.0004733	.0007879
pop_o	.0011262	.0000707	15.92	0.000	.0009876	.0012648
lgdp_o	.4414275	.0051904	85.05	0.000	.4312541	.4516009
lgdp_d	.4030873	.0050593	79.67	0.000	.3931708	.4130037
lgdpcap_d	.1124693	.0070378	15.98	0.000	.0986749	.1262638
lgdpcap_o	.1888878	.0073386	25.74	0.000	.1745038	.2032719
col_fr	-.1976665	.1151245	-1.72	0.086	-.4233162	.0279832
col_hist	1.386596	.0779239	17.79	0.000	1.233861	1.539331
col_cur	-.7209592	.455033	-1.58	0.113	-1.612847	.1709281
gatt_o	-.0018364	.0146153	-0.13	0.900	-.0304832	.0268104
gatt_d	.0311919	.0144455	2.16	0.031	.002878	.0595059
rta	1.319556	.0330963	39.87	0.000	1.254685	1.384426
acp_to_eu	-.3632929	.0412748	-8.80	0.000	-.4441936	-.2823922
gsp	.2644243	.0341917	7.73	0.000	.1974069	.3314417
eu_to_acp	-.4688177	.0349781	-13.40	0.000	-.5373766	-.4002589
gsp_rec	.3791692	.030997	12.23	0.000	.3184134	.4399249
_Iyear_1981	-.066844	.0053217	-12.56	0.000	-.0772748	-.0564133
_Iyear_1982	-.0989326	.0063329	-15.62	0.000	-.1113453	-.0865199
_Iyear_1983	-.0759063	.0063476	-11.96	0.000	-.0883479	-.0634646
_Iyear_1984	-.1161913	.0070127	-16.57	0.000	-.1299366	-.1024461
_Iyear_1985	-.0992775	.0071536	-13.88	0.000	-.113299	-.085256
_Iyear_1986	-.1433775	.0074417	-19.27	0.000	-.1579636	-.1287913
_Iyear_1987	-.1687928	.0078107	-21.61	0.000	-.1841022	-.1534834
_Iyear_1988	-.2132538	.0082133	-25.96	0.000	-.2293524	-.1971553
_Iyear_1989	-.1682313	.0083176	-20.23	0.000	-.1845342	-.1519284
_Iyear_1990	-.2614058	.0090444	-28.90	0.000	-.2791332	-.2436784
_Iyear_1991	-.2308816	.0090591	-25.49	0.000	-.248638	-.2131253
_Iyear_1992	-.3127581	.0096158	-32.53	0.000	-.3316055	-.2939106
_Iyear_1993	-.2300282	.0098951	-23.25	0.000	-.2494232	-.2106332
_Iyear_1994	-.1829431	.0104616	-17.49	0.000	-.2034483	-.1624379
_Iyear_1995	-.2970338	.0109067	-27.23	0.000	-.3184115	-.275656
_Iyear_1996	-.3534779	.0111761	-31.63	0.000	-.3753837	-.3315721
_Iyear_1997	-.390973	.0112162	-34.86	0.000	-.4129573	-.3689886
_Iyear_1998	-.3832113	.0112706	-34.00	0.000	-.4053022	-.3611204
_Iyear_1999	-.338598	.0114351	-29.61	0.000	-.3610114	-.3161847
_Iyear_2000	-.3525961	.0116499	-30.27	0.000	-.3754305	-.3297618
_Iyear_2001	-.3472127	.0118896	-29.20	0.000	-.370517	-.3239085
_Iyear_2002	-.3386918	.0121018	-27.99	0.000	-.362412	-.3149717
_Iyear_2003	-.400375	.0128042	-31.27	0.000	-.4254719	-.3752781
_Iyear_2004	-.5108659	.0142149	-35.94	0.000	-.5387278	-.483004
_Iyear_2005	-.5920584	.0149191	-39.68	0.000	-.6213006	-.5628163
_Iyear_2006	0	(omitted)				
_cons	-8.168264	.0920086	-88.78	0.000	-8.348606	-7.987923

Appendix D - Tabulation of *varout_b*, *varout_o*, and *varout_d*

```
. tab varout_b
```

dummy: outbreak in both	Freq.	Percent	Cum.
0	482,799	78.25	78.25
1	134,217	21.75	100.00
Total	617,016	100.00	

```
. tab varout_o
```

outbreak dummy	Freq.	Percent	Cum.
0	329,573	53.41	53.41
1	287,443	46.59	100.00
Total	617,016	100.00	

```
. tab varout_d
```

outbreak dummy	Freq.	Percent	Cum.
0	329,889	53.47	53.47
1	287,127	46.53	100.00
Total	617,016	100.00	

Appendix E - Outbreak Regression without *Both* Variable

R-Squared: 0.642

Variables	Coefficients	Robust Standard Error
Outbreak in exporting country	0.127***	0.013
Outbreak in importing country	0.009	0.013

Appendix F - Poverty Regressions without *Both* Variable

GDP per capita over $20,000:
R-Squared: 0.670

Variables	Coefficients	Robust Standard Error
Over 20,000: exporter	0.434***	0.023
Over 20,000: importer	0.227***	0.024

GDP per capita below $20,000:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 20,000: exporter	-0.016*	0.008
Under 20,000: importer	-0.019*	0.008

GDP per capita below $10,000:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 10,000: exporter	-0.042***	0.008
Under 10,000: importer	-0.058***	0.008

GDP per capita below $5,000:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 5,000: exporter	-0.067***	0.008
Under 5,000: importer	-0.080***	0.008

GDP per capita below $2,500:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 2,500: exporter	-0.080***	0.008
Under 2,500: importer	-0.079***	0.007

GDP per capita below $1,500:
R-Squared: 0.668

Variables	Coefficients	Robust Standard Error
Under 1,500: exporter	-0.104***	0.009
Under 1,500: importer	-0.088***	0.008

GDP per capita below $670:
R-Squared: 0.669

Variables	Coefficients	Robust Standard Error
Moderate poverty: exporter	-0.167***	0.012
Moderate poverty: importer	-0.125***	0.011

GDP per capita below $456.25:
R-Squared: 0.669

Variables	Coefficients	Robust Standard Error
Extreme poverty: exporter	-0.175***	0.014
Extreme poverty: importer	-0.121***	0.014