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THE IMPACTS OF FOOT-AND-MOUTH DISEASE ON INTERNATIONAL PORK TRADE – AN EXTENSION OF GRAVITY MODEL

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THE IMPACTS OF FOOT-AND-MOUTH DISEASE ON INTERNATIONAL PORK TRADE – AN EXTENSION OF GRAVITY MODEL

DISSERTATION

A dissertation submitted in partial fulfillment of
the requirements for the degree of Doctor of Philosophy
in the College of Agriculture
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By

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ABSTRACT OF DISSERTATION

THE IMPACTS OF FOOT-AND-MOUTH DISEASE
ON INTERNATIONAL PORK TRADE – AN EXTENSION OF GRAVITY MODEL

Food safety scares affect consumption behavior, and food safety and animal health issues are increasingly impacting international agricultural trade. Foot-and-mouth disease (FMD) is a highly contagious viral-type disease, and has raised not only the concerns of animal health issue but also food safety issue. Over 58 countries in the world have experienced FMD outbreaks, and pork exports and imports among these countries are largely impacted. This dissertation focuses on how global pork trade is affected by FMD.

This dissertation consists of three parts: first, this study specifically focuses on the market of U.S. pork exports. Results show that disease-affected pork importers are potential traders with the U.S., and only importing countries with a vaccination policy are more likely to increase pork imports from the U.S. rather than those importers with a slaughter policy. Second, a further investigation focuses basic hypothesis on import demand of FMD-affected importers by using a gravity model with fixed-effects to show how pork trade is affected by FMD among 186 countries. Results confirm that pork export falls when an exporting country develops FMD. Exporters with a vaccination policy have larger negative impacts than those with a slaughter policy. Further, pork importers that develop FMD and institute a slaughter policy will import more pork, but importers with a vaccination policy import the same level of pork. Third, the findings of part one and two reveal that FMD-free pork exporters face different market opportunities when pork importers have FMD outbreaks. Hence, four major FMD-free pork exporters, such as Canada, U.S., Germany, and Spain, are further investigated. Results confirm that the impacts of foreign FMD have altered pork exporters differently. Germany has gained the most exports during foreign FMD outbreaks in pork importers; the U.S. is second; Spain is third; and Canada is fourth.

In sum, this dissertation contributes to the literature of gravity model when endogeneity and heteroskedasticity may coexist, when an extremely large number of zero observations are included, when single commodity for one specific exporter is analyzed, when a spatial econometric approach is compared, and when pork export market has been altered by foreign FMD outbreaks.

Keywords: foot-and-mouth disease, gravity model,
international trade, pork, spatial econometrics

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Dedicated to my family, especially Hui-Chu Su and Kathleen Yang.

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Chapter One

Introduction

1.1 Problem Statement

Food safety scares affect consumption behavior, and food safety and animal health issues are increasingly impacting international agricultural trade. Member countries of the World Trade Organization (WTO) can apply measures of the Sanitary and Phytosanitary (SPS) Agreement to ensure safe food for consumers and further to prevent the spread of pests or disease among animals and plants. Article 3 of the SPS Agreement permits WTO member governments to set their own standards and regulations on trade based on appropriate assessment of risks so long as the approach is consistent, not arbitrary, and scientifically based. The purposes of the SPS Agreement are to protect human or animal health from food-borne risk, from animal- or plant-carried diseases, and from pests or diseases. International markets are affected when one country applies the SPS Agreement to protect the health of domestic human, animal, and plant from diseases or risks.

In 2008, there were 153 WTO members who could apply the measures of the SPS Agreement. According to the WTO (2010), the SPS measures state that the agreement can apply "*to protect human or animal life from risks arising from additives, contaminants, toxins or disease-causing organisms in their food, beverages, feedstuffs; to protect human life from plant or animal carried diseases (zoonotics); to protect animal* *or plant life from pests, diseases, or disease-causing organisms; to protect a country from damage caused by the entry, establishment or spread of pests.*" These measures allow countries to violate the principle of non-discrimination (PND) that is a baseline principle in the international trading system. The first two provisions of the PND declare that foreign and domestic products should be equally treated and the same good among foreign countries should be treated identically. Although the measures of the SPS Agreement are allowed to violate the PND, countries should not have unreasonable food safety standards that can lead to welfare loss for domestic consumers (Yue, Beghin, and Jensen 2006; Yue and Beghin 2009; Calvin and Krissof 1998; Calvin, Krissof, and Foster 2007).

Some food safety standards can be unduly strict when the impacts of the disease or pests are trivial to domestic consumers or animals, so researchers have worked to highlight the impacts of food safety issues, such as apple trade between the U.S. and Japan. Yet, other measures of standard in food safety issues clearly address issues that impact domestic consumers or animals. One particular example is when a country has an outbreak of a high risk animal disease, such as Foot-and-Mouth Disease (FMD). In this case, FMD-free countries among WTO members can apply the SPS Agreement to avoid the intrusiveness of FMD via trade. International trade between importing and exporting countries can be stimulated or hindered after FMD outbreaks depending on several circumstances, such as domestic market conditions, the scale of FMD outbreaks, treatment policy adopted by government, etc. Therefore, the status of high risk animal diseases can be an important determinant in the activity of international trade among livestock products.

1.2 Background – FMD

FMD is a highly contagious viral-type disease which infects cloven-hoofed ruminant animals, such as cattle, goats, and pigs. FMD symptoms include fever, erosions, and blister-like lesion on the hooves, lips, mouth, teats, and tongue (APHIS 2007). Rushton (2009, p.200) mentions that the Office International des Epizooties (OIE) has a list of how FMD-affected countries control an FMD issue, which can be different depending on the disease status in the countries concerned:

- Countries with FMD usually have vaccination campaigns in order to control outbreaks.
- Countries close to the eradication of FMD usually adopt a slaughter policy for animals detected with FMD.
- Countries that are FMD-free but experience occasional outbreaks normally react by adopting a slaughter policy to eliminate infected animals and animals in contact with those infected.
- Countries that are FMD-free maintain stocks of vaccine for the possibility of outbreaks within their countries.

Slaughter and vaccination policies are the major treatments for FMD outbreaks. Since FMD severely impacts meat production and trade status (Mathews and Buzby 2001), there are strong reasons that some countries may adopt an effective treatment, like a slaughter policy, instead of following the procedures of the OIE list: safeguarding their reputation for their animals and meat products, maintaining their advantage in the market, and shortening economic loss period. Some countries with larger shares of animals and meat products in the market may necessarily execute a slaughter policy to get their industry back on track faster.

The international trade of an FMD-affected country can be either hindered or catalyzed depending on different scenarios. Therefore, this study focuses on the impacts of foreign FMD on international trade. As a contribution to understanding the impacts of FMD, this study investigates different ways for viewing FMD impacts. Since the U.S. has been FMD-free status for many decades, this study uses the example of the U.S. as a one-country viewpoint for the impacts of foreign FMD on U.S. exports. In a multiple-country viewpoint, FMD-free or FMD-affected exporting countries may interact differently with FMD-free or FMD-affected importing countries. This study uses 186 countries (including WTO and non-WTO members) for investigating the impacts of foreign FMD.

In swine species, about 58 countries were infected by FMD during 1996 to 2007. These FMD-infected countries reported a total of about 255 FMD outbreaks in swine species to the OIE from 1996 to 2007. Figure 1.1 simply exhibits that countries experienced FMD outbreaks during 1996 to 2007, and did apply a slaughter or vaccination policy. Many of these FMD-infected countries were eventually able to regain FMD-free status, yet others are still suffering from it. An FMD outbreak diminishes livestock production in all stages (due to slaughtering the disease-infected herds or lower herd health) and reduces consumption for meat products in the short-run (Yeboah and Maynard 2004; Roh, Lim, and Adam 2006). Hence, a persistent impact of FMD in a country can influence the domestic production, consumption, and trade.

In figure 1.2, world pork imports have seen a steady growth each year since 1996. The growth of U.S. pork exports has a similar trend with the growth of world pork imports. This growth has occurred despite various FMD outbreaks. The U.S. has been FMD-free for many decades, and the historical data show that the volume of U.S. pork exports has increased over 200 percent from 1996 to 2007. U.S. pork exports highlight the potential effects of FMD. The question is how can FMD outbreaks affect a country's production, consumption, exports, and imports? The following section and subsections will list the top 20 countries in pork production, consumption, exports, and imports, and further understand whether their growth of production, consumption, exports, and imports has specific connection with FMD.

1.3 Background – World Pork Markets

1.3.1 Pork Production

Table 1.1 lists the top 20 pork producers in the world, based on their ranking order in 1996, before the large outbreak of FMD. The total volume of pork production from these top 20 countries accounts for over 90 percent of world total pork production. Hence, these top 20 producers dominate world total pork production. Specially, China, the world's largest pork producers, covers almost 50 percent of total pork production from these top 20 pork producers during 1996 to 2007. The United States is the world's second-largest pork producer during 1996 to 2007.

Note that the asterisk sign indicates which pork producers had FMD outbreaks during 1996 to 2007. FMD outbreaks could create certain level of impacts on pork production. Except for China, Brazil, Philippines, and Viet Nam, countries with FMD status are not competitive pork producers during 1996 to 2007. These countries include:

France, Netherlands, Russian, Taiwan, United Kingdom, and South Korea. China, Brazil, Philippines, and Viet Nam didn't see reductions in pork production from FMD. They may not have suffered severe impacts from FMD because these four countries have larger territory and are able to control FMD through the surveillance in one region, so the influence of FMD may not severely spread all over the country. However, most countries are still affected by FMD outbreaks which influence long-term growth in pork production. The share of global pork production in France, Netherlands, Russian, Taiwan, United Kingdom, and South Korea declined during 1996 to 2007. Although pork production in Russia and South Korea has grown from 1996 to 2007, the shares of global pork production for these two countries have declined, so it shows the outbreaks have disadvantaged those producers. Indeed, FMD is one of the factors that influence pork production in a country.

1.3.2 Pork Consumption

Table 1.2 lists the top 20 pork consumers in the world, based on their ranking order in 1996, before the large outbreak of FMD. The ranking order of these top 20 pork consumers has not changed much during 1996 to 2007; meat consumption has been stable over time. The total volume of pork consumption from these top 20 countries accounted for about 86 percent of global pork consumption during 1996 to 2007. Total pork consumption of China, the world's largest pork consumers, covers almost 40 percent of these top 20 pork consumers from 1996 to 2007. The United States is the world's second-largest pork consumers from 1996 to 2007.

Note that the asterisk sign indicates which pork consumers (eleven countries) had FMD outbreaks during 1996 to 2007. All countries with FMD status, except for China, Viet Nam, Philippines, and South Korea, faced unstable growth in domestic pork consumption compared to global pork consumption between 1996 and 2007. These four countries saw no severe impacts from FMD outbreaks, and have similar growth trends to global pork consumption. Several factors, such as income and price, may dominate the impacts of FMD on pork consumption in these four countries. Although the impacts of FMD could affect meat consumption, this might be only a short-run influence. France, Taiwan, Netherlands, and Serbia and Montenegro, only slightly reduced their pork consumption during 1996 to 2007.

1.3.3 Pork Exports

Table 1.3 lists the top 20 pork exporters in the world, based on their ranking in 1996, before the large outbreak of FMD. Note that the asterisk sign indicates which pork exporters had FMD during 1996 to 2007. In general, the ranking order of these top 20 pork exporters has fluctuated a lot during 1996 to 2007; pork exports of an FMD-infected country are usually hindered from the disease because of import bans by disease-free countries. FMD-free importers have other choices to replace pork imports by FMD-affected exporters. The total volume of pork exports from these top 20 countries consists of almost 96 percent of global pork exports in 1996. In 2007, the total volume of pork exports from these top 20 countries declined to about 90 percent of global pork exports.

Many of these top 20 exporters had FMD outbreaks during 1996 to 2007. Notice that Canada, the United States, Germany, and Spain are FMD-free exporters and have largely increased their pork exports during 1996 to 2007. This could be a consequence of other major pork exporters facing FMD outbreaks. On the other hand, FMD-affected countries in these top 20 exporters faced slow or no-growth of pork exports during 1996 and 2007. The growth of pork exports can highly relate to the occurrences of FMD depending on the scale of FMD outbreaks and what policies are adopted to deal with FMD.

Pork exporters usually face different consequences after they report an FMD outbreak to the OIE, like reduced pork exports and lost market competition. Total pork exports of Netherlands cover almost 20 percent of these top 20 pork exporters in 1996, but in 2007 it diminished to about nine percent because Netherlands had FMD outbreaks in 2001. In addition, Taiwan had FMD outbreaks and lost most of their pork exports and market competition due to FMD in 1997. United Kingdom and South Korea have experienced a similar situation with Taiwan. Although some countries, like France and Ireland, had FMD outbreaks during 1996 to 2007, their pork exports were only affected for a few years. France and Ireland were able to regain their pork export market, but their volumes were not as high as in 1996. Some countries, such as Brazil and China, had FMD during 1996 to 2007, but it didn't seem to influence their exports, which may relate to their larger territory that can successfully contain an outbreak within a quarantined area to isolate the disease from FMD-free zones. Indeed, FMD-affected countries can easily regain FMD-free status with a prompt controlled measure, surveillance, and cooperation with the OIE. In a few years FMD-affected countries can become FMD-free and import bans can be removed. However, competition and availability of pork exports from many FMD-free countries has improved from 1996 to 2007, like Canada, the United States, Germany, Spain, Austria, Italy, Mexico, and Finland.

1.3.4 Pork Imports

Table 1.4 lists the top 20 pork importers in the world, based on their ranking in 1996, before the large outbreak of FMD. Note that the asterisk sign indicates which pork importers had FMD during 1996 to 2007. In general, the ranking order of these top 20 pork importers has changed during the period based on many factors such as income, domestic and international pork prices, FMD outbreaks, and the related policies. Further, the total volume of pork imports from these top 20 countries accounted for over 96 percent of global pork imports in 1996, but it declined to about 83 percent in 2007. This decrease is partially explained by FMD outbreaks during 1996 to 2007.

There are eight pork importers that had FMD outbreaks during 1996 to 2007, but, except for France, Greece, and Argentina, pork importers had not only increased their pork imports but also increased their import market share in 2007 compared to 1996. All importers with FMD status, except Argentina, increased their pork imports during 1996 to 2007. Most importing countries with FMD status increase their pork imports after an FMD outbreak, but this is not always the case.

FMD-affected countries can adopt two different policies, vaccination and slaughter, to deal with FMD outbreaks. Although pork exports and imports exhibit some correlation with FMD outbreaks in Tables 1.3 and 1.4, it is not clear there is a positive or negative effect on trade. It is important to understand the consequences of FMD outbreaks on exporting and importing countries; especially countries can adopt a vaccination or slaughter policy.

1.4 The Illustration of FMD Impacts on Exporters and Importers

This section illustrates the impacts of FMD on international pork trade. First, the impacts of foreign FMD-affected exporters on FMD-free exporters and importers will be demonstrated. Second, the impacts of foreign FMD-affected importers on FMD-free exporters and importers will be illustrated. If an FMD-free exporter reports an outbreak to the OIE, their exports will be hindered because of import bans. In addition to the policy dealing with FMD outbreaks, the country can adopt either a slaughter or vaccination policy. The central goal of a slaughter policy is to strengthen the efficacy in controlling FMD outbreaks, so all disease-infected animals are slaughtered to prevent additional outbreaks from FMD, so a slaughter policy can create a larger decline in supply. The central goal of a vaccination policy is to protect healthy animals from infection. Since a vaccinated animal cannot be distinguished from an infected animal, countries with a vaccination policy usually face the FMD stigma for a longer period. Pork exports of an FMD-infected country still can be hindered at least one to two years no matter which policy is applied.

Figure 1.3 demonstrates the occurrence of FMD outbreaks in foreign major exporters when the domestic market is still FMD-free. When one of the major pork exporters has an FMD outbreak, the aggregate supply curve shifts from AS to AS’, which leads the world price of pork to increase from P to P'. As a result, FMD-free pork exporters would be stimulated to export more ($\overline{Q_d Q_s}$ to $\overline{Q_d^{'} Q_s^{'}}$) due to a higher world price level, and FMD-free importers might import less ($\overline{Q_d Q_s}$ to $\overline{Q_d^{'} Q_s^{'}}$) because world price is higher.

Figure 1.4 illustrates the occurrence of an FMD outbreak in a major importer, and the domestic markets remains FMD-free. When one of the major pork importers has an FMD outbreak, the aggregate demand curve shifts from AD to AD', which leads world price of pork to fall from P to P'. Consequently, FMD-free pork exporters would export less ($\overline{Q_d Q_s}$ to $\overline{Q_d^{'} Q_s^{'}}$) because world aggregate demand has fallen in the short-run, and FMD-free importers would import more ($\overline{Q_d Q_s}$ to $\overline{Q_d^{'} Q_s^{'}}$) because world price is lower.

A pork exporter can be an importer as well, so foreign impacts of FMD have a dynamic effect, and the world price level could be volatile if FMD outbreaks occur in many places in the world. Since pork exports from FMD-affected exporters are limited, this study focuses on two things: first, foreign FMD impacts on FMD-free exporters; second, the reaction of FMD-affected importers when they have an FMD outbreak. Figure 1.3 and 1.4 show that foreign FMD could lead the world pork price level to increase or decrease, so FMD-free exporters can gain or lose pork exports. Hence, the following chapters will analyze the impacts of foreign FMD on exporters and imports.

In addition to the reaction of FMD-affected importers after an outbreak, figure 1.5 demonstrates the impacts of FMD on pork importers depending on either a slaughter (figure 1.5a) or vaccination (figure 1.5b) policy is applied. For economic impacts, an FMD outbreak causes a production shortage and demand shrinkage during the short-run period (Yeboah and Maynard 2004; Paarlberg et al. 2008). Both supply and demand will decline as an FMD outbreak occurs in a country. A constant change on the demand level in figure 1.5a and 1.5b is assumed. The slaughter policy will cause a large decrease in supply (shift from S to S' in figure 1.5a), but supply will not fall as much under the vaccination policy (shift from S to S' in figure 1.5b). FMD-infected importers with a slaughter policy would likely increase their imports in the short-run (from $\overline{Q^s Q^d}$ to $\overline{Q^{s'} Q^{d'}}$ in figure 1.5a), so FMD-infected importers may import more if they adopt a slaughter policy. It is not clear whether FMD-infected importers with a vaccination policy would increase or decrease their imports in the short-run (from $\overline{Q^s Q^d}$ to $\overline{Q^{s'} Q^{d'}}$ in figure 1.5b), so FMD-infected importers may not specifically import more if they adopt a vaccination policy. However, the empirical analysis is needed to confirm whether pork importers will import more under a slaughter policy than under a vaccination policy.

1.5 Organization of Study

This topic has received our attention on how foreign FMD impacts alter international pork trade and affect international pork markets of FMD-free exporters. Chapter two of this dissertation focuses on the impacts of foreign FMD outbreaks on one FMD-free exporter, the U.S. Chapter three investigates the foreign FMD impacts on international pork trade among 186 countries. Chapter four of this dissertation discusses findings from chapter two and three and illustrates FMD impacts on market competition among major pork exporters, such as Canada, USA, Germany, and Spain. Chapter Five provides a summary, policy implications, conclusion, and recommendation for further research.

Table 1.1: World Major Pork Producers (Unit: MT)

Top 20 Countries	shares for 1996	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	shares for 2007
China*	0.431	31580	35963	38837	40056	39660	40517	41231	42386	43410	45553	46505	42878	0.456
USA	0.106	7764	7835	8623	8758	8596	8691	8929	9056	9313	9392	9559	9962	0.106
Germany	0.050	3635	3564	3834	4103	3982	4074	4110	4239	4323	4500	4663	4985	0.053
Spain	0.032	2356	2401	2744	2893	2905	2989	3070	3190	3076	3168	3235	3439	0.037
France*	0.029	2161	2219	2328	2353	2312	2315	2346	2339	2293	2274	2011	2031	0.022
Poland	0.028	2064	1891	2026	2043	1923	1849	2023	2190	1956	1956	2098	2151	0.023
Netherlands*	0.022	1624	1376	1725	1711	1623	1432	1377	1253	1289	1297	1265	1290	0.014
Brazil*	0.022	1600	1540	1690	1835	2010	2230	2565	2560	2600	2710	2830	2990	0.032
Denmark	0.020	1494	1521	1629	1642	1625	1716	1759	1762	1810	1793	1749	1802	0.019
Russian*	0.020	1449	1314	1279	1310	1341	1287	1367	1481	1433	1334	1444	1640	0.017
Italy	0.019	1410	1396	1412	1472	1479	1510	1536	1590	1590	1515	1559	1603	0.017
Taiwan*	0.017	1269	1030	892	822	921	962	935	893	898	911	846	828	0.009
Japan	0.017	1266	1283	1285	1277	1269	1245	1236	1260	1272	1245	1247	1250	0.013
Canada	0.015	1130	1156	1282	1439	1509	1593	1709	1730	1780	1765	1748	1746	0.019
Belgium	0.015	1070	1033	1085	1005	1042	1062	1041	1026	1054	1013	1001	1061	0.011
U. K.*	0.014	1004	1091	1135	1042	899	777	774	716	708	706	697	739	0.008
Mexico	0.012	895	940	950	994	1030	1058	1070	1035	1064	1103	1109	1152	0.012
South Korea*	0.012	865	873	992	950	1004	1077	1153	1149	1100	1036	1000	1043	0.011
Philippines*	0.012	860	901	933	973	1008	1064	1095	1145	1145	1175	1215	1250	0.013
Viet Nam*	0.010	735	810	790	925	990	1069	1209	1257	1408	1602	1713	1832	0.019
World Total	0.904	73257	77006	82272	85310	84559	85657	88077	89773	91240	93635	95325	93957	0.912

Sources: FAOSTAT and USDA/FAS

Note: * indicates countries had FMD outbreaks during 1996 to 2007.

Table 1.2: World Major Pork Consumers (Unit: MT)

Top 20 Countries	shares for 1996	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	shares for 2007
China*	0.403	31687	36188	38932	39158	40082	40807	41497	42576	43351	45460	46460	43173	0.436
USA	0.097	7614	7640	8475	8680	8424	8425	8721	8849	8917	8806	8820	9161	0.092
Germany	0.056	4377	4261	4555	4543	4418	4296	4373	4466	4496	4468	4498	4589	0.046
Russian*	0.031	2423	1939	2173	2281	1943	1905	2162	2317	2133	2104	2309	2574	0.026
Japan	0.029	2264	2066	2062	2190	2245	2300	2414	2420	2603	2644	2482	2556	0.026
Spain	0.028	2190	2222	2530	2608	2591	2621	2655	2698	2465	2475	2557	2716	0.027
France*	0.026	2063	2082	2186	2226	2251	2250	2175	2299	2070	2134	1925	1960	0.020
Italy	0.026	2041	2012	2164	2277	2300	2445	2464	2505	2513	2476	2591	2659	0.027
Poland	0.024	1899	1663	1793	1877	1835	1804	1845	1915	1832	1828	1933	1957	0.020
Brazil*	0.023	1809	1962	2280	2271	2417	2297	2219	2422	2397	1902	2081	2093	0.021
U. K.*	0.018	1439	1412	1456	1488	1444	1515	1502	1572	1573	1585	1665	1699	0.017
Viet Nam*	0.013	1048	1090	1161	1249	1335	1465	1639	1786	1996	2281	2495	2552	0.026
Philippines*	0.013	1043	1099	1136	1203	1236	1294	1365	1425	1389	1461	1613	1673	0.017
Mexico	0.012	951	993	1069	1128	1234	1278	1317	1329	1417	1411	1430	1461	0.015
South Korea*	0.011	901	913	889	1045	1075	1025	1150	1291	1183	1239	1410	1493	0.015
Taiwan*	0.011	897	865	967	934	965	973	958	934	948	944	869	844	0.009
Canada	0.010	804	802	906	968	933	955	948	862	921	814	825	902	0.009
Ukraine	0.010	792	699	679	640	680	592	599	626	599	545	589	707	0.007
Netherlands*	0.010	792	744	820	803	827	748	744	585	534	580	615	538	0.005
Serbia and Montenegro*	0.009	669	627	623	658	636	572	639	590	553	582	571	657	0.007
World Total	0.862	78573	82069	87908	89344	89710	90549	92687	95071	95614	97803	100331	99083	0.868

Sources: FAOSTAT

Note: * indicates countries had FMD outbreaks during 1996 to 2007.

Table 1.3: World Major Pork Exporters (Unit: MT)

Top 20 Countries	shares for 1996	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	shares for 2007
Netherlands*	0.209	777	621	845	907	985	869	687	626	659	688	691	710	0.086
Denmark	0.171	634	766	778	829	899	877	977	1033	1129	1174	1216	1233	0.149
Belgium	0.116	429	402	448	442	440	487	503	452	492	522	545	566	0.068
Taiwan*	0.072	268	50	2	1	1	2	2	2	2	1	1	2	0.000
France*	0.071	262	300	303	356	513	392	357	366	410	418	430	418	0.051
Canada	0.062	231	286	320	435	520	605	700	713	702	724	741	723	0.087
USA	0.058	217	302	396	416	489	580	670	650	705	816	878	962	0.116
Germany	0.038	140	169	263	410	418	499	525	582	691	796	900	1026	0.124
Spain	0.035	132	159	184	267	287	306	335	411	487	542	552	619	0.075
U. K.*	0.033	123	136	164	177	134	31	63	54	66	75	84	87	0.011
Ireland*	0.018	66	75	90	89	82	82	95	84	79	84	81	91	0.011
Hungary	0.017	64	84	67	85	94	87	85	89	82	79	77	101	0.012
Brazil*	0.013	47	49	67	68	96	224	424	429	398	544	410	507	0.061
Austria	0.011	41	52	65	80	78	87	104	89	113	126	134	148	0.018
South Korea*	0.009	35	49	90	81	17	8	4	6	2	6	5	1	0.000
Sweden	0.007	25	36	27	31	13	12	13	17	25	27	22	19	0.002
China*	0.006	24	92	106	56	51	78	145	134	134	108	115	94	0.011
Italy	0.006	21	22	27	46	44	34	37	49	65	57	54	58	0.007
Mexico	0.004	13	25	31	37	40	42	41	35	34	38	43	52	0.006
Finland	0.002	9	19	16	16	12	15	22	28	32	34	41	39	0.005
World Total	0.957	3716	3219	4574	5223	5192	5393	5999	6448	7068	7701	7910	8265	0.902

Source: UN COMTRADE

Note: * indicates countries had FMD outbreaks during 1996 to 2007.

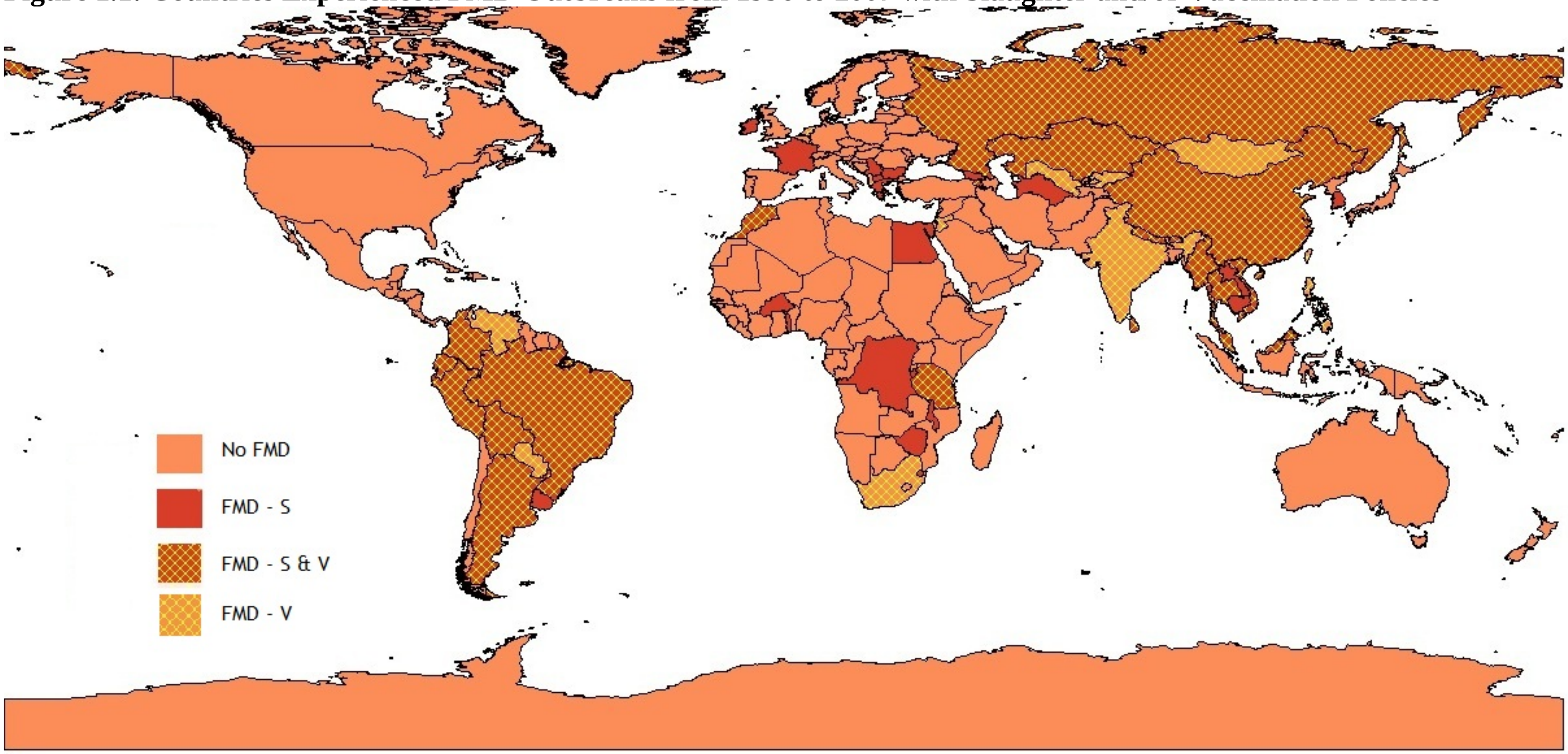
Table 1.4: World Major Pork Importers (Unit: MT)

Top 20 Countries	shares for 1996	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	shares for 2007
Germany	0.225	862	798	932	913	713	692	903	808	842	946	941	926	0.117
Italy	0.175	670	656	779	744	755	848	818	830	832	857	905	942	0.119
Japan	0.170	653	512	505	600	651	709	778	753	864	873	725	761	0.096
France*	0.077	294	286	323	329	322	300	281	299	304	302	320	342	0.043
Russian*	0.069	263	309	282	444	213	372	602	535	455	563	626	672	0.085
USA	0.048	184	191	217	266	321	325	367	401	376	360	342	335	0.042
U. K.*	0.042	159	142	156	202	241	240	279	376	382	431	450	466	0.059
Greece*	0.029	110	109	135	142	521	453	162	167	158	199	209	184	0.023
Hong Kong*	0.016	60	84	128	133	161	171	179	200	211	169	179	198	0.025
Portugal	0.015	57	65	70	81	96	113	108	107	110	104	115	135	0.017
Belgium	0.014	54	70	72	66	50	59	64	52	61	57	59	59	0.007
Netherlands*	0.014	54	63	44	75	73	71	104	179	204	179	213	205	0.026
Spain	0.013	50	68	75	88	80	70	67	71	59	59	80	93	0.012
Austria	0.012	46	43	50	67	87	72	70	66	87	107	116	131	0.017
South Korea*	0.011	41	61	53	125	139	98	123	122	175	261	311	339	0.043
Mexico	0.010	37	59	109	143	202	208	235	269	334	304	322	325	0.041
Poland	0.010	37	29	57	42	35	17	44	46	102	170	164	242	0.031
Canada	0.007	27	39	41	39	40	53	54	54	63	87	91	110	0.014
Argentina*	0.006	25	31	40	36	38	36	9	29	23	16	17	23	0.003
Denmark	0.005	20	38	24	36	42	29	31	37	42	52	61	38	0.005
World Total	0.965	3836	3857	4396	4966	5363	5501	5996	6214	6645	7245	7470	7900	0.826

Source: UN COMTRADE

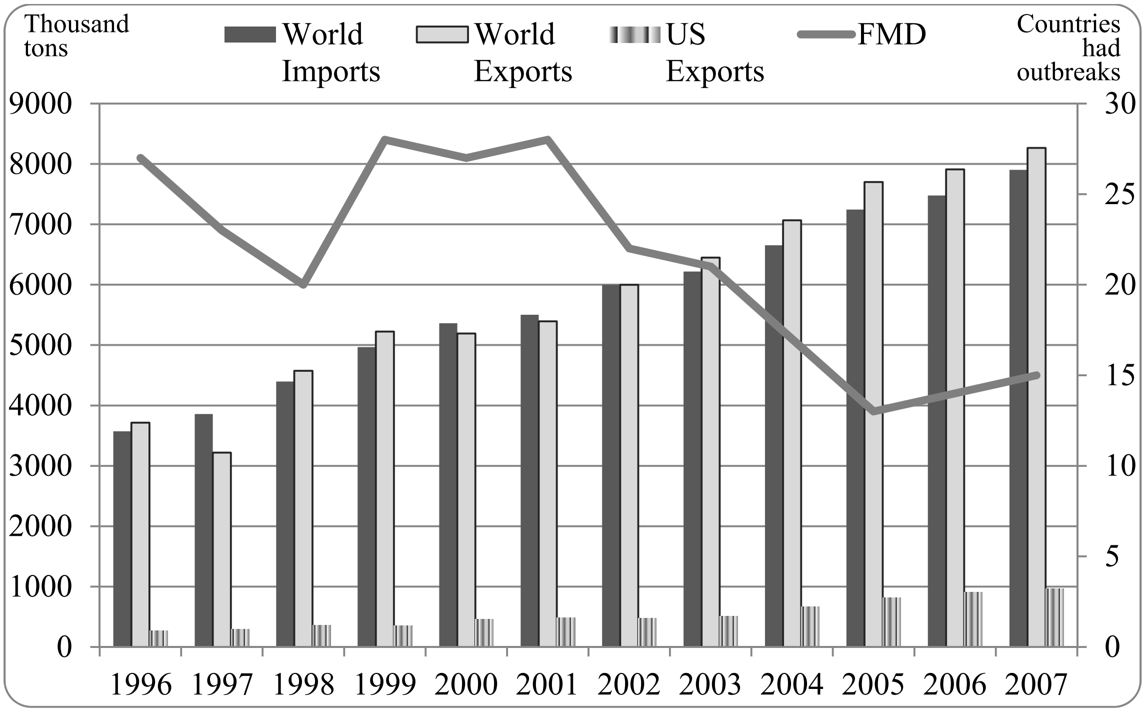
Note: * indicates countries had FMD outbreaks during 1996 to 2007.

Figure 1.1: Countries Experienced FMD Outbreaks from 1996 to 2007 with Slaughter and/or Vaccination Policies



Note: S represents that countries adopted slaughter policy; V represents that countries adopted vaccination policy.
This figure was generated by Open GeoDa software.

Figure 1.2: Pork Trade versus U.S. Pork Exports and FMD Outbreaks, 1996-2007



Sources: UN Commodity Trade Database and Office of International Epizootics.

Figure 1.3: Foreign FMD-Affected Exporters Impact FMD-Free Countries

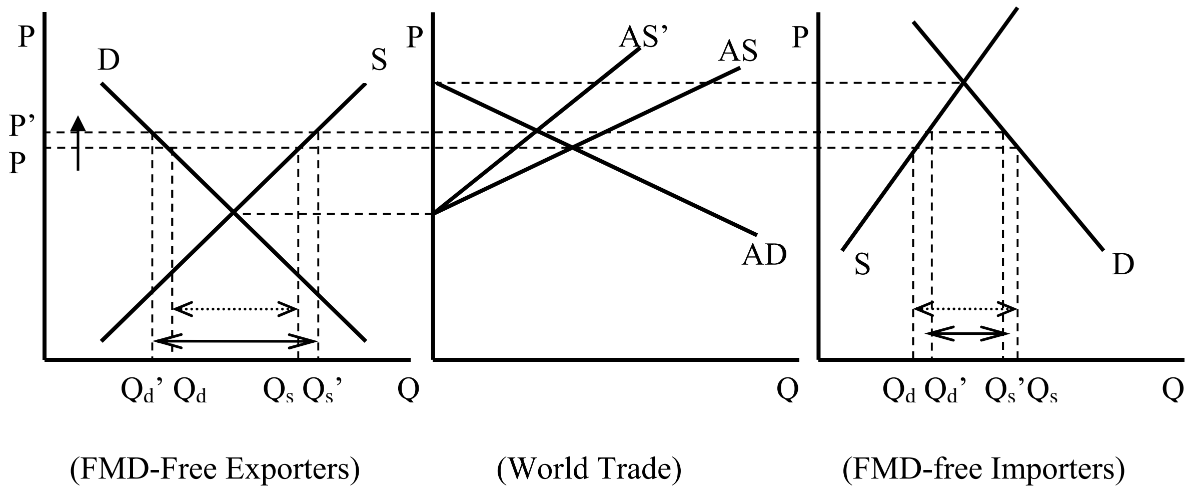
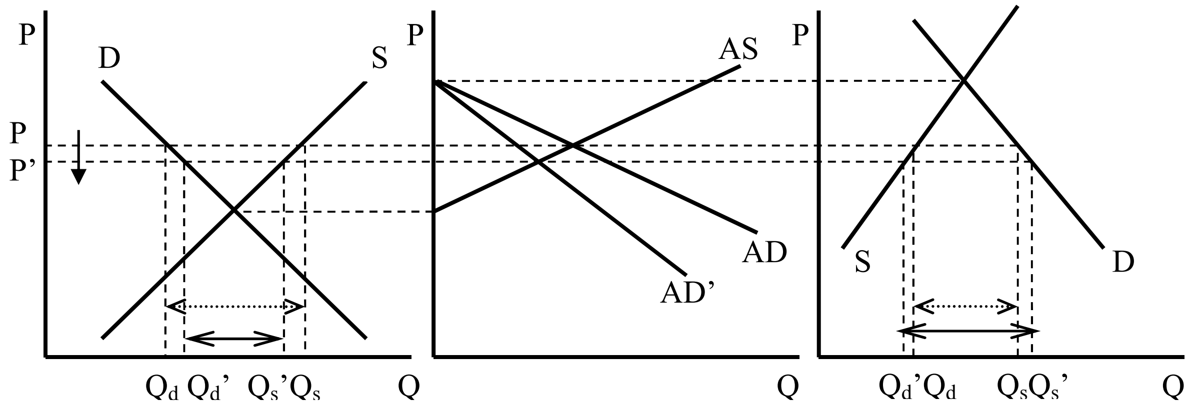
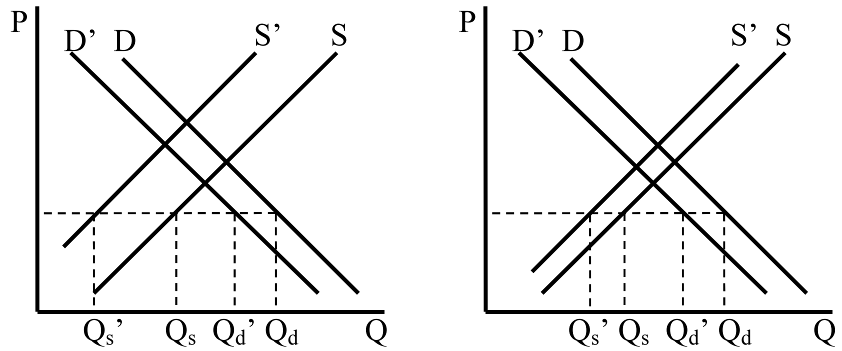


Figure 1.4: Foreign FMD-Affected Importers Impact FMD-Free Countries



(FMD-Free Exporters) (World Trade) (FMD-free Importers)

Figure 1.5: FMD-Affected Importers between Slaughter and Vaccination Policy



(1.5a, Slaughter Policy) (1.5b, Vaccination Policy)

Chapter Two

FMD-Free Pork Exporters – the Case of the U.S.

2.1 Introduction

Foot-and-Mouth Disease (FMD) is a highly contagious disease that affects cloven-hoofed animals such as cattle, goats, and pigs. A serious FMD outbreak can create tremendous negative impacts on animal health, domestic meat production, and agricultural economic activity. FMD-free countries usually adopt a zero-tolerance policy to avoid the introduction of FMD through international trade. The risk of FMD is one of the reasons that led to the Sanitary and Phytosanitary (SPS) measures that are applied to protect human and livestock from health risks.

During 1996 to 2007, at least 58 countries were reported as FMD-affected regions, with a total of 255 outbreaks (figure 1.2). Many of these 58 countries were ultimately able to become FMD-free regions through slaughtering infected animals, but other countries still suffer from FMD outbreaks. An FMD outbreak reduces animal production (due to slaughtering or reduced production from the herds) and shrinks demand in the short-run due to food-safety scares (Yeboah and Maynard 2004; Roh, Lim, and Adam 2006).

There are two basic policies that can be applied by an FMD-affected country: a slaughter policy and a vaccination policy. A slaughter policy (where all infected animals and others around them are slaughtered to prevent the disease from spreading) is generally more effective in controlling the disease than a vaccination policy. A slaughter policy, however, usually results in a larger supply disruption. Vaccination saves the animal's life, but time is needed for recovery, which means a production shortage for a while. Countries that adopt a vaccination policy are still considered FMD-affected by the Office of International Epizootics (OIE) because vaccinated animals cannot be distinguished from infected animals. Therefore countries which adopt a vaccination policy prolong the impacts of FMD occurrences.

These FMD policies have an impact on international pork exports. Pork exports can either be stimulated or depressed from FMD outbreaks. Pork exports from FMD-free countries are expected to increase when an FMD-infected importing country adopts a slaughter policy that creates a supply shortage for a long time, especially if the outbreak leads to a supply shock for a longer period than the time demand decreases in the importing country. However, if the situation is reversed, then pork imports could fall. In sum, if demand can return to its original level within a short time, then pork imports should not be hindered, assuming other factors constant. Even if pork demand returns to its original level within a short time, it is still possible that pork imports increase due to consumer preferences for FMD-free pork. In sum, pork exporters can benefit when importing countries report an FMD outbreak. Exporters can maintain international markets as long as FMD-free status is maintained.

World pork imports have seen a steady growth each year since 1996 (figure 1.2). The growth of U.S. pork exports has a similar trend with the growth of world pork imports. This growth has occurred despite various FMD outbreaks. The U.S. has been

FMD-free for many decades, and the historical data show that the volume of U.S. pork exports has increased over 200 percent from 1996 to 2007. U.S. pork exports highlight the potential effects of FMD. The first objective of this article is to test whether U.S. pork exports increase to countries with FMD.

FMD-affected countries have applied either a slaughter or vaccination policy to deal with the FMD outbreaks. The second objective is to investigate the impacts of these different policies on U.S. pork exports. The data sources utilized in this study do not mention whether the zero-trade flows are truly zero or missing values. Zero observations in trade data can contain important information on low levels of trade (Eichengreen and Irwin 1998) but missing values don't, so this study provides estimates including and excluding zero observations. Cragg's (hurdle) model is applied to study the zero trade issue further.

There are other factors that may affect U.S. pork exports, like contiguity, common official language, and colonized relations from the past. The common official language and colonized relations from the past reveal countries that may be likely to trade with each other due to similar culture. Neighboring countries may easily have more trade than non-neighboring countries. These factors are commonly discussed and examined in the gravity model. We use two different methods, a spatial econometric model and a gravity model, to investigate these factors and the effects of FMD, and compare and contrast the performance of these two models.

Regional trade agreements (RTAs) are also important factors that can influence U.S. pork exports. The U.S. has two RTAs: the Dominican Republic-Central America-United States Free Trade Agreement (CAFTA-DR) and the North American Free Trade

Agreement (NAFTA). The U.S. also has many agreements with individual countries, such as Free Trade Agreements (FTAs) and Economic Integration Agreements (EIAs). These agreements not only create beneficial welfare gains from trade, but also induce more potential trade (Grant and Lambert 2008; Lambert and McKoy 2009). These agreements have been beneficial to pork exporters and importers; hence, we have included the effects of RTAs in the analysis of U.S. pork exports. Overall for the specific topic of FMD outbreaks in importing countries, the objectives of this study focus on investigating how the impacts of foreign FMD outbreaks influence U.S. pork exports.

2.2 Literature Review and Background

Many researchers have investigated FMD outbreaks and found that they can dramatically affect consumer behavior, prices, production, and trade. Yeboah and Maynard (2004) found that consumers reacted negatively to FMD and reduced their consumption in the short-run. Roh, Lim, and Adam (2006) addressed the negative impacts of FMD on hog, pork, and beef prices for Korea during 2000 and 2002. Paarlberg et al. (2008) determined that FMD leads hog and pork prices to fall for three to five quarters depending on the severity of the outbreak. FMD outbreaks continue to impede agricultural trade between many countries (Jarvis, Cancino, and Bervejillo 2005). There is no question that FMD outbreaks can lead to severe impacts on domestic supply and demand.

Gravity and spatial econometric models are applied in this study. The gravity model is often applied to international and regional trade, population migration, commodity flows, etc. The theoretical development of the gravity model, which is often used to explain origin-destination (OD) flows, has progressed in recent years (Baldwin and Taglioni 2006). The theoretical development of the spatial econometric model holds its advantage in regionalized research when spatial autocorrelation might exist in related data. Hence, this study uses gravity and spatial econometric models to investigate U.S. pork exports, and further compares both findings.

2.2.1 The Gravity Model

Researchers have used the gravity model for over 40 years to study economic problems. The theoretical underpinnings of the gravity model have been improved in recent years (Baldwin and Taglioni 2006). Anderson (1979) was the first to provide a formal theoretical foundation for the gravity equation. Anderson and van Wincoop (2003) further point out that proper estimation of the gravity equation (to avoid omitted variables bias) must recognize endogenous multilateral price (resistance) terms for both the exporter and importer countries. Anderson and van Wincoop (2003) and Baier and Bergstrand (2007) illustrated the gravity equation with multilateral price term as:

$$(2.1)\ \ln\left[\frac{X_{ij}}{GDP_i GDP_j}\right] = \alpha_0 + \alpha_1 D_{ij} - \ln P_i^{1-\sigma} - \ln P_j^{1-\sigma} + \varepsilon_{ij}$$

Which subject to $j = 1 \ldots N$ equilibrium conditions:

$$(2.2)\ P_j^{1-\sigma} = \sum_{i=1}^{N} P_i^{\sigma-1} \left(\frac{GDP_i}{GDP_W}\right) \cdot e(\alpha_1 D_{ij})$$

where X_{ij} is the value of the merchandise trade flow from exporter *i* to importer *j*; GDP_i (GDP_j) is the level of gross domestic product (GDP) in country *i* (*j*); D_{ij} includes all factors that might create or reduce trade resistance, such as distance, adjacent countries, and official language, between countries *i* and *j*; $P_i^{1-\sigma}$ and $P_j^{1-\sigma}$ are exporter and importer price indices (i.e., multilateral resistance terms); σ is the elasticity of substitution between varieties (i.e., countries); GDP_W denotes world GDP, which should be constant across countries. Anderson and van Wincoop (2003) and Feenstra (2004) point out that an alternative method for specifying resistance terms in cross sectional data that is easier computationally is to run an estimation of equation (2.1) using country-specific fixed effects.

Santos-Silva and Tenreyro (2006) argue that even if the gravity equation is controlled by fixed effects, heteroskedasticity is still quantitatively important in a gravity equation. Hence, they propose an augmented gravity equation in levels using a Pseudo-Maximum-Likelihood (PML) estimator, which can also handle zero trade observations. Using Monte Carlo simulation, Santos-Silva and Tenreyro (2006) examine and compare the fitted values between the least squares (LS) and the PML estimators, and their results show that the Poisson PML (PPML) estimator is relatively robust and well behaved among different estimators. Their original dependent variable for their simulation was always positive, but they updated their simulation with a non-negative dependent variable and showed that the PPML estimator is still well behaved (Santos-Silva and Tenreyro 2009). Westerlund and Wilhelmsson (2009) also examine the effects of zero trade on the estimation of the gravity model using a Monte Carlo simulation and panel data structure. They also suggest using the Poisson fixed effects estimator.

Sun and Reed (2010) were the first to apply a PPML estimator with bilateral and time fixed effects to deal with FTA variables in agricultural trade. The main challenge in

Sun and Reed (2010) is potential endogeneity problems with the FTA variable, which may involve reverse causality between higher trade volumes and trade agreements. This endogeneity problem can cause bias in estimated coefficients and underestimate the parameters of interest (Lee and Swagel 1997). Although one traditional solution for endogeneity problems involves using instrumental variables (IV), Baier and Bergstrand (2007) conclude from previous cross-section studies that IV estimation is not a reliable method for addressing the endogeneity bias of the FTA (binary) variable in a gravity equation. Another method demonstrated by Baier and Bergstrand (2007) and Grant and Lambert (2008) to deal with the endogeneity problem is using panel data with bilateral and country-and-time fixed effects, because their FTA_{ijt} (RTA_{ijt}) involves more correlations among countries i (j) and time.

Dealing with zero trade observations is a common issue in gravity models. In general, it is not a serious problem when the analysis involves multiple (aggregated) commodities. Since our study only focuses on pork exports for the U.S., our data involves a large number of zero trade values (about 56% in our data). The data sources don't mention whether zero trade flows are truly zero or simply missing. Santos-Silva and Tenreyro (2009) conclude that a dependent variable with a large proportion of zeros does not affect the performance of their PPML estimator, making it an ideal estimator for the study of U.S. pork exports.

Since two estimators, i.e., spatial econometric and gravity PPML, are compared in this study, it is reasonable to exhibit and compare results between including and excluding zero observations. Furthermore, the Cragg's model is applied to show the major differences between participation and outcome questions. The Cragg's model is set up to answer two simple questions: first, whether countries would like to import pork from the U.S. (i.e., a participation question); second, if countries are likely to import pork from the U.S., then how much would they like to import (i.e., an outcome question). The Cragg's (probit plus truncated regression) model allows major differences between participation and outcome questions.

2.2.2 The Spatial Econometric Model

During the mid-20th century, spatial econometric approaches originated to overcome violations in sampling models caused by spatial proximity (Arbia 2006). Many people have contributed to spatial statistical techniques since that time. Before the 1970s, spatial autocorrelation was important with such concepts as spatial interaction, spatial interdependence, or spatial dependence. Spatial autocorrelation was first noted by Cliff and Ord (1968). Paelinck and Klaassen (1979) used the term "*spatial econometrics*" for this particular methodology. Cliff and Ord (1973) suggested that when one accounts for a relationship between nearby spatial units of the same variable, it is necessary to recognize the consequences of spatial autocorrelation, which means one spatial unit is correlated with nearby spatial units. Hence, using traditional statistics to examine problems that involve spatial autocorrelation will result in misspecification and biases.

Spatial econometric methods have been applied in many different fields, such as geology, agricultural studies, epidemiology, regional sciences, archaeology, sociology, and political science. The motivations for applying spatial regression are due to the potential existence of time-dependence, omitted variables, spatial heterogeneity, and model uncertainty (LeSage and Pace 2009). The major interlinked relations for these motivations are the spatial regression structure involving the violation of the assumption that errors are independently and identically distributed (*iid*). Depending on the nature of the spatial dependence, ordinary-least square (OLS) regression will result in inefficient estimates or biased and inconsistent estimates.

Why are spatial data special? Anselin (1990) pointed out that researchers should treat spatial data differently from other types of data because the spatial effects (processes) can confuse understanding of the spatial data. Spatial effects divide into two parts: spatial heterogeneity and spatial dependence. Anselin (1988, p. 11) stated that spatial dependence is "… the existence of a functional relationship between what happens at one point in space and what happens elsewhere." In other words, there is a lack of independence among observations; the errors for spatial unit *i* may be related to the errors in a neighboring unit *j*. The result is measurement errors due to the presence of spatial dependence. Anselin and Getis (1992, p. 24) state that spatial heterogeneity "… occurs when there is a lack of spatial uniformity of the effects of spatial dependence and/or of the relationships between the variables under study." In other words, it is typified by regional differentiation; lack of homogeneity leads to inconsistency across the study due to the effects of the size, shape, and configuration of spatial units. Therefore, a spatial econometric model not only concerns distance differentiation and how the neighbor effects impact measurement error, but also concerns how the effects of size, shape, and configuration of spatial units complicate measurement error.

2.2.3 Gravity Model Verses Spatial Econometric Model

Sen and Smith (1995) labeled the gravity model as a "*spatial interaction model*" because the regional interaction of commodity trade is a function of regional size measures, which typically use GDP. The gravity model (spatial interaction model) implies that countries are more likely to trade with each other as the size of their economy increases. The gravity model further uses distance as an explanatory variable that will release the spatial dependence concerns in the sample of origin-destination (OD) flows between pairs of regions (LeSage and Pace 2009). Nevertheless, the gravity model has been challenged on how effectively it captures spatial dependence in interregional flows. LeSage and Pace (2009) mention that the typical sample for a gravity model involves $n^2 = N$ bilateral (OD) pairs with each OD pair being an observation. The sample of a typical spatial econometric model involves n regions with each region being an observation. Hence, in order to compare a spatial econometric model with a gravity model, the samples of both models should be compatible.

Several issues are raised by LeSage and Pace (2009) on the empirical modeling of OD flows using a spatial econometric interaction model, such as spatial weights, zero flows, multilateral resistance effects, etc. This article focuses on U.S. pork exports to 181 countries. When the sample for the spatial econometric model is adjusted to OD flows, the spatial weight matrices need adjusting as well. For the zero trade flows issue, our models will examine cases where zero trade flows are included and excluded. Furthermore, in order to explain the price differential effects (multilateral resistance) between countries, researchers have applied time- and/or country-fixed effects in the gravity model. LeSage and Pace (2009, p. 234) point out that the fixed effects in a spatial autoregressive structure can be viewed as "introducing additional exogenous information that augments the sample data information," and conventional fixed effects in gravity models only introduce additional parameters but do not augment sample data information. Hence, the conventional fixed effects are unlike the fixed effects in a spatial autoregressive structure for which the fixed effects also contain some information of spatial weight matrices. Based on these issues and previous efforts from researchers, it is feasible to compare the gravity model with the spatial econometric model.

2.3 Data Description and Empirical Models

2.3.1 Data Description

The data for the annual value of U.S. pork exports are derived from the United Nations Commodity Trade Statistics Database (http://comtrade.un.org). Real GDP (*RGDP*) is derived from the FAS/USDA (http://www.ers.usda.gov/Data/Macroeconomics/) in U.S. dollars. The *FMD* records are collected from 1996 to 2007 from the OIE (http://www.oie.int/hs2/report.asp?lang=en). The indicators of distance, contiguity, colonial relations, and common language are taken from the Centre d'Etudes Prospectives et d'Informations Internationales (http://www.cepii.fr/anglaisgraph/bdd/distances.htm). The calculation of distance, referenced by latitude and longitude of the largest population in the country, uses the great circle formula[1]. The *RTA* variable for the U.S. shows if an importing country has a regional trade agreement with the U.S. This

[1] The great circle formula uses the shortest distance between any two points on the surface of a sphere.

data came from the WTO website. The spatial weight matrix applied is an inverse distance matrix instead of a contiguity matrix because many countries are not contiguous. This matrix also makes the comparison with the gravity model clearer.

For each variable, the definition and statistical summary are presented in table 2.1. Total annual U.S. pork exports to the 181 importing countries[2] averaged almost $8 million (U.S.). The real GDP of these countries averaged $165 billion (U.S.) annually. The average distance from the largest urban area to the U.S. is about 9,400 kilometers. Fifty-three of the importing countries include English as an official language (about 30% of the observations). Only one country has a colonial linkage with the U.S. (Philippines). From 1996 to 2007 over 58 countries had FMD outbreaks (about 12 percent of the observations). About 14 countries (about three percent of the observations) had an RTA with the U.S.

2.3.2 Empirical Frameworks

The analysis provides several comparisons to address questions posed earlier: no fixed effects versus country and time fixed effects; a spatial econometric model versus a gravity model; and use of the full data versus omitting zero trade observations. This article will also apply the PPML estimator for the gravity model. The spatial econometric model will be focused on a spatial Poisson regression model with the generalized linear model (GLM) procedure, in contrast with the PPML estimator. The PPML model equations of the gravity model are:

[2] Countries list is shown in Appendix I.

(A) No time or country fixed effects – Gravity Model

$$\text{(2.3)}\ \ln X_{jt} = \alpha_0 + \alpha_1 \ln(RGDP_{jt}) + \alpha_2 \ln(Dist_j) + \alpha_3 (Lang_j) + \alpha_4 (Col45_j) + \alpha_5 (Contig_j) + \alpha_6 (RTA_{jt}) + \alpha_7 (FV_{jt}) + \alpha_8 (FS_{jt}) + \varepsilon_{jt}$$

(B) Country and time fixed effects – Gravity Model

$$\text{(2.4)}\ \ln X_{jt} = \alpha_j + \alpha_t + \alpha_0 + \alpha_1 \ln(RGDP_{jt}) + \alpha_6 (RTA_{jt}) + \alpha_7 (FV_{jt}) + \alpha_8 (FS_{jt}) + \varepsilon_{jt}$$

In equations (2.3) and (2.4), *t* denotes time and *j* denotes importing country; $\ln X_{jt}$ is the log of pork export value from the U.S. to importing country *j* in time *t*; α_j is country fixed effects to account explicitly for specifying multilateral price terms; α_t is time fixed effects to capture the potential effects that are also changing by time. $RGDP_{jt}$ is the real gross domestic product of the importing country as a proxy for economic size. $Dist_j$ is the distance between the U.S. and importing country *j* used as a proxy for transportation costs. Other geographic and preference similarities, such as sharing a common language $(Lang_j)$, having colonial linkages since 1945 $(Col45_j)$, and two countries that are contiguous $(Contig_j)$, are commonly used in gravity equations. RTA_{jt} is a dummy variable indicating the existence of a regional trade agreement between the U.S. and importing country *j*. The variable $FV_{jt} (FS_{jt})$ denotes an interaction dummy variable indicating the importing country *j* under FMD status adopted either a vaccination (or a slaughter policy). The ε_{jt} is assumed to be a log-normally distributed error term.

For the spatial econometric model, a spatial Cliff-Ord-type model, which allows for spatial lags in the dependent variable, the exogenous variables, and the disturbances, is often examined and discussed (Cliff and Ord 1973 and 1981; Arraiz et al. 2010). The model can be set up as:

(2.5) $y_n = \rho W_n y_n + x_n \beta + u_n$, $u_n = \lambda M_n u_n + \varepsilon_n$

where y_n is a $n \times 1$ vector of observations on the dependent variable, x_n is a $n \times k$ matrix of observations on exogenous variables (same independent variables in the gravity model), W_n and M_n are $n \times n$ matrices of spatial weights that parameterize the distance between neighbors, u_n is a $n \times 1$ vector of spatially correlated disturbances, ε_n is a $n \times 1$ vector of independent and identically distributed disturbances, λ and ρ are scalar parameters that measure the dependence of y_i on nearby y and the spatial correlation in the errors, and β is a $k \times 1$ vector of parameters. This type of spatial econometric model includes spatial lag and spatial error factors in the model; spatial spillover effects are allowed to exist in the endogenous variables, exogenous variables, and disturbances.

The tests of spatial autocorrelation indicate any potential spatial effects in the data. It is questionable that the amount of pork trade from the U.S. to country A is affected spatially by the amount of trade to country B. For instance, U.S. pork exports to Denmark are not likely affected by U.S. pork exports to Japan. The influence of spillovers in endogenous variables can be minimal[3], but the influence from spatial correlation in error terms may still exist. For this special case, this study applies a spatial error model (SEM).

[3] The global (Moran's I and Geary's c) tests for spatial autocorrelation were performed. The results of the global tests reveal that spatial autocorrelation on U.S. pork exports is very minimal (Moran's I (0.036) and Geary's c (0.961)).

The SEM can be set up as:

(C) No time or country fixed effects – Spatial Model

(2.6) $y_n = x_n\beta + u_n$, $u_n = \lambda M_n u_n + \varepsilon_n$

where the notation is identical to Equation (2.5). In the PPML estimator, a fixed effects (country and time) spatial error model can be written as:

(D) Country and time fixed effects – Spatial Model

(2.7) $y_n = \alpha_n + x_n\beta + u_n$, $u_n = \lambda M_n u_n + \varepsilon_n$

where α_n is a $n \times 1$ vector of observations on country and time fixed effects. And the parameters can be estimated by using maximum likelihood in a generalized linear spatial Poisson model. The matrix x_n is $n \times k$ and contains all other exogenous variables from Equation (2.3) with the variable $Dist_j$ removed.

2.4 Empirical Results

The empirical results contain the following comparisons: models with and without fixed effects; spatial econometric versus gravity model; and full sample size versus deleting zero observations. The results reported in table 2.2 use 2172 observations; results reported in table 2.3 delete zero trade flows, so there are 941 observations. The results in tables 2.2 and 2.3 present a side-by-side comparison of a spatial econometric model versus a gravity model; they also include fixed effects versus no fixed effects. The Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log likelihood are used to measure goodness of fit for each model. Lambda (λ) is an estimated parameter for spatial autocorrelation in the error term; a significant lambda (λ) indicates that the estimation process can be biased if an OLS estimator is used.

2.4.1 Overall Comparisons

Table 2.2 presents the empirical results with full sample size. Lambda (λ) is significantly different from zero in the spatial Poisson model, and the results of AIC, BIC, and log-likelihood indicate that the spatial Poisson model with fixed effects is statistically better than the one with no fixed effects. The gravity PPML estimator without fixed effects has a better goodness of fit than the one with fixed effects, based on the results of AIC and BIC among the gravity models. In general, the empirical results between spatial Poisson and gravity PPML estimators are very similar, except for the $Contig_j$ coefficient which is not consistent in these two estimators and does not have the expected sign in the gravity PPML estimator. Hence, the spatial Poisson model performs better than the gravity PPML estimator in the comparison of full sample size.

Table 2.3 presents the empirical results excluding zero observations. Lambda (λ) is significantly different from zero in the spatial Poisson model with no fixed effects, and the results of AIC, BIC, and log-likelihood reveal that the spatial Poisson model with no fixed effects has better goodness of fit measures than the one with fixed effects. In addition, the results of AIC and BIC show that the gravity PPML estimator with no fixed effects performs better than the one with fixed effects. There may be concerns with endogeneity for the gravity PPML estimator with no fixed effects, but the coefficient for

RTA is very close for models with and without fixed effects. Hence, endogeneity may not be a problem in this particular case of U.S. pork exports.

A comparison of tables 2.2 and 2.3 show the impact of excluding zero observations. Results indicate that the gravity PPML estimator with no fixed effects and excluding zero observations is statistically better. Note that the spatial Poisson model with no fixed effects performs better than the gravity PPML model based on the AIC and BIC. The spatial Poisson is also preferred when the models including and excluding zero observations are compared (tables 2.2 and 2.3). This suggests that spatial analysis (using the Poisson model) fits U.S. pork export patterns better. The comparison further shows that models excluding zero observations fit the data better.

Comparing results for each variable in tables 2.2 and 2.3 reveal an expected and consistent outcome between spatial Poisson and gravity PPML models. The only coefficient which differed in sign between models was for $Contig_j$, where the expected sign is positive, but the result is negative for the gravity PPML estimator with no fixed effects (table 2.2). The spatial econometric models in tables 2.2 and 2.3 are not affected by this issue and reveal empirical results that are consistent with expectations. The only two contiguous countries to the U.S. are Canada and Mexico; which are also members of NAFTA. Thus, this variable does not have much distinction from the RTA variable. The empirical results of both models (gravity PPML and spatial Poisson) with no fixed effects in table 2.3 are similar to table 2.2, so we utilize these results for side-by-side comparisons for each variable.

2.4.2 Side-by-Side Comparisons

In comparing the spatial Poisson and gravity PPML models in table 2.3 with no fixed effects, both models have coefficients for $RGDP_{jt}$, RTA_{jt}, and FV_{jt} that consistently have the expected signs and are significantly different from zero. These results indicate that U.S pork exports are likely to increase if the importing country has a higher standard of living, has a trade agreement with the U.S., and applies a vaccination policy when they have an FMD outbreak. A slaughter policy in FMD-infected countries does not have a significant impact on U.S. pork exports. This may reflect the countries that follow a slaughter policy, which are mostly European (France and the Balkans) and some African countries. The U.S. has no free trade agreement with those countries and they are usually supplied by other European exporters (Denmark and Netherlands). Coefficients for $Contig_j$ in the spatial Poisson model and coefficients for $Col45_j$ and $Dist_j$ in the gravity PPML model are also significant at the 1% level, indicating that U.S. pork exports are influenced by contiguity, colonized relations, and distance.

The coefficient for FV_{jt} indicates that FMD-affected importing countries with a vaccination policy are likely to enhance pork imports from the U.S. As mentioned in the introduction, consumer demand is often the key factor to reflect whether pork imports increase during an FMD outbreak. Consumers may focus on safer FMD-free pork from the U.S. as their consumption recovers after the FMD outbreak. Persistent FMD would reduce pork production and stimulate potential imports.

In table 2.4, the Cragg's (hurdle) model assumes importing countries pass through two stages. In the first stage, the participation question, which is the binary decision of yes (1) or no (0), identifies countries that import pork from the U.S. In the second stage, the outcome question focuses on those countries which pass through the first stage, and explains the quantity of pork imports from the U.S. The participation question is modeled with a basic probit estimation, and the outcome question is modeled with spatial Poisson and gravity PPML estimators.

The empirical results of the probit estimator (the participation question) in table 2.4 reveal whether or not an importing country imports pork from the U.S. All coefficients in the probit estimator have the expected signs and are significant at the 1% level (column 2 of table 2.4), except for the coefficient FV_{jt} with 10% significance level. More importantly, the coefficient for FS_{jt} indicates that FMD-affected importing countries with a slaughter policy are more likely to participate in pork trade with the U.S. than those with a vaccination policy.

The outcome question in the second stage exhibits how much pork these participating countries import from the U.S. The coefficients for FS_{jt} in table 2.4 from the PPML and spatial estimators are not significantly different from zero; on the contrary, the FV_{jt} coefficients are positive and significantly different from zero for the outcome question. Basically, the result of the FV_{jt} coefficients is expected in the participation and outcome question. This implies that importing countries with a vaccination policy have intended to import pork from the U.S., and have positive imports when they had FMD. The result of the FS_{jt} coefficients in the participation question is expected, but the results in the outcome question show that countries with a slaughter policy don’t significantly increase imports from the U.S. when they have FMD. This is an interesting outcome, and needs further study on pork exporting markets. Competition among pork exporters might put the U.S. at a disadvantage in some FMD markets because of distance or other factors. An interesting question would be: which pork exporters cover those markets?

A vaccination policy may prolong the impact of FMD because vaccinated animals cannot be distinguished from infected animals. The link between FMD and consumer health is minimal, but the concern of food safety from FMD issue may raise potential demand to decrease. Once the concern of food safety issue is clear, domestic consumption may be stimulated for pork from FMD-free countries. These results reveal that counties with a vaccination policy are the major importers which have increased their imports from the U.S. when FMD outbreaks were reported.

2.5 Conclusions

This study provides several comparisons: models with and without fixed effects; spatial econometrics versus gravity model; and full sample size versus deleting zero observations. In the comparison between spatial econometric and gravity models, the expected sign and the significance level of coefficients are very similar and highly consistent among the models with no fixed effects and no zero observations. In general, the spatial econometric model is better than the gravity model based on AIC and BIC. The gravity PPML model exhibits a consistent result when excluding fixed effects and zero observations. However, the spatial econometric models reveal more consistent and robust results in every comparison. This study confirms factors that impact U.S. pork exports, such as real GDP, distance, colonized relations, contiguous countries, regional trade agreement, and FMD outbreaks with a vaccination policy. Therefore, the FMD outbreak can not only create tremendous negative impacts domestically on meat production, but also create positive impacts on FMD-free regions.

This study contributes to the literature on the impacts of FMD outbreaks on trade. The findings of this study reveal that the impacts of foreign FMD outbreaks can increase U.S. pork exports. The empirical results for U.S. pork exports exhibit positive impacts from the vast majority of importing pork countries with FMD outbreaks. However, most of that increase in pork imports comes from countries with a vaccination policy.

The first and second stages of Cragg's model show several major differences beyond the zero trade issue. The first stage of Cragg's model confirms that FMD-affected importing countries are potential customers for U.S. pork. When countries adopt a slaughter policy there is a higher potential to import U.S. pork than for countries that with a vaccination policy. However, in the second stage of Cragg's model, these high potential importers with a slaughter policy did not significantly increase U.S. pork imports; only importers with a vaccination policy had significantly larger U.S. pork imports. This may imply that international markets for pork exports are quite competitive and other major pork exporters are able to cover the markets for countries with a slaughter policy. It would definitely require further research on this point. Further, U.S. pork exports may be disadvantaged by distance or other factors relative to other pork exporters. This finding encourages further study on the competitive environment among those major pork exporters when foreign FMD outbreaks impact on international trade.

The empirical results between the gravity and spatial econometric models are very comparable. The estimated parameters with and without fixed effects are very similar and consistent for the gravity and spatial econometric models, and we find the gravity model fits better when zero observations and fixed effects are not included. This might be related to the special case when a single commodity is analyzed and issues of endogeneity are less pronounced than they are in aggregated data. However, the spatial econometric models reveal more consistent and robust results in every comparison.

Zero trade flows may still be an issue in future studies. Some previous literature includes zero trade flows because measured zero trade may not be truly zero. Since our data sources don't mention whether the zero trade flows are truly zero value or missing, this study compares the spatial econometric and gravity models when including and excluding zero trade flows. Our final results with no zero trade flows and no fixed effects exhibit similar results compared to the results of the probit model. This implies that excluding zero trade flows is less likely to change the empirical results.

Table 2.1: Definitions and Sample Statistics of Variables (Range from 1996 to 2007; n = 181; N = 2172)

Variables	Description of variables	Mean	Std. Dev.	Min.	Max.
Exports (X_{jt})	Annual total value of U.S. pork exports (thousands)	7,877	6,640	0	1,100,000
RGDP ($RGDP_{jt}$)	Annual real GDP for each importing countries (U.S. dollar 2005 base – billions)	165	481	0.052	4468
Distance ($Dist_j$)	The shortest distance from the largest population regions to the U.S. (Kilometers)	9,369	3,470	1,154	16,357
Com-Language ($Lang_j$)	Binary variable=1 if importing countries use same official language with the U.S.	0.292	0.455	0	1
Col45 ($Col45_j$)	Binary variable=1 if importing countries had colonial linkage with the U.S. since 1945	0.005	0.074	0	1
Contiguity ($Contig_j$)	Binary variable=1 if importing countries have land connected with the U.S.	0.011	0.104	0	1
RTA (RTA_{jt})	Binary variable=1 if importing countries had RTA relations with the U.S.	0.030	0.172	0	1
FMD*V (FV_{jt})	Binary variable=1 if importing countries had FMD outbreaks and applied a vaccination policy	0.069	0.255	0	1
FMD*S (FS_{jt})	Binary variable=1 if importing countries had FMD outbreaks and applied a slaughter policy	0.047	0.212	0	1

Table 2.2: The Comparison between Spatial and Gravity Models – Full Sample Size

Dependent variable: X_{jt}	No Fixed Effects		With Fixed Effects (α_j, α_t)	
	Spatial Poisson	Gravity PPML	Spatial Poisson	Gravity PPML
$RGDP_{jt}$	0.261 ***	0.264 ***	0.297 ***	0.261 ***
	(0.012)	(0.010)	(0.171)	(0.011)
$Dist_j$	.	–1.056 ***	.	.
		(0.039)		
$Lang_j$	0.279 ***	0.329 ***	.	.
	(0.057)	(0.048)		
$Col45_j$	0.474 **	0.881 ***	.	.
	(0.238)	(0.075)		
$Contig_j$	0.047	–2.004 ***	.	.
	(0.178)	(0.142)		
RTA_{jt}	0.487 ***	0.410 ***	0.476 ***	0.412 ***
	(0.131)	(0.093)	(0.106)	(0.047)
FV_{jt}	0.171 **	0.181 ***	0.262 ***	0.267 ***
	(0.084)	(0.068)	(0.095)	(0.053)
FS_{jt}	0.013	0.268 ***	0.077	0.143 *
	(0.113)	(0.094)	(0.122)	(0.076)
N. of sample	2172	2172	2172	2172
AIC	6.826	8.137	5.862	8.300
BIC	14872.280	17725.180	13340.090	18635.430
Log likelihood	–7405.405		–6258.985	
Lambda (λ)	0.722 ***		0.733 ***	

Note: * 10% significance, ** 5% significance, and *** 1% significance;
Parentheses represent standard errors.

Table 2.3: The Comparison between Spatial and Gravity Models – Excluding zeros

Dependent variable: X_{jt}	No Fixed Effects		With Fixed Effects (α_j, α_t)	
	Spatial Poisson	Gravity PPML	Spatial Poisson	Gravity PPML
$RGDP_{jt}$	0.095 ***	0.048 ***	0.099 ***	0.123 ***
	(0.007)	(0.003)	(0.036)	(0.048)
$Dist_j$		–0.110 ***	.	.
		(0.010)		
$Lang_j$	0.035	0.015	.	.
	(0.033)	(0.012)		
$Col45_j$	0.164	0.119 ***	.	.
	(0.117)	(0.029)		
$Contig_j$	0.455 ***	0.014	.	.
	(0.095)	(0.038)		
RTA_{jt}	0.128 *	0.073 **	0.059 ***	0.074 ***
	(0.071)	(0.030)	(0.019)	(0.023)
FV_{jt}	0.121 ***	0.047 **	0.013	0.014
	(0.045)	(0.024)	(0.015)	(0.016)
FS_{jt}	–0.050	–0.004	0.020	0.024
	(0.062)	(0.030)	(0.015)	(0.019)
N. of sample	941	941	941	941
AIC	4.338	4.722	4.971	4.732
BIC	4120.792	4487.479	5375.944	5054.300
Log Likelihood	–2033.008		–2194.992	
Lambda (λ)	0.593 ***		–0.239	

Note: * 10% significance, ** 5% significance, and *** 1% significance;
Parentheses represent standard errors.

Table 2.4: Cragg's Model for Participation and Outcome Questions

	Participation Question		Outcome Question			
	Probit Estimator		PPML Estimator		Spatial Estimator	
Dependent Variable:	dy[a]		X_{jt}		X_{jt}	
$RGDP_{jt}$	0.299	***	0.048	***	0.095	***
	(0.016)		(0.003)		(0.007)	
$Dist_j$	–1.565	***	–0.110	***	.	
	(0.080)		(0.010)			
$Lang_j$	0.602	***	0.015		0.035	
	(0.077)		(0.012)		(0.033)	
$Col45_j$	Omitted		0.119	***	0.164	
			(0.029)		(0.117)	
$Contig_j$	Omitted		0.014		0.455	***
			(0.038)		(0.095)	
RTA_{jt}	0.622	***	0.073	**	0.128	*
	(0.234)		(0.030)		(0.071)	
FV_{jt}	0.235	*	0.047	**	0.121	***
	(0.131)		(0.024)		(0.045)	
FS_{jt}	0.534	***	–0.004		–0.050	
	(0.152)		(0.030)		(0.062)	
N. of observations	2172		941		941	
LR χ^2	844.160		6820.297			
AIC	0.974		4.722		4.338	
BIC	2120.686		4487.479		4120.792	
Log Likelihood	–1033.510				–2033.008	

Note: * 10% significance, ** 5% significance, and *** 1% significance;
Parentheses represent standard errors.
[a] The dependent variable (*dy*) is a binary response between 0 and 1

Appendix I – List of 181 Countries

Afghanistan	Chad	Haiti	Mongolia	Suriname
Albania	Chile	Honduras	Morocco	Swaziland
Algeria	China	Hong Kong	Mozambique	Switzerland
Andorra	Colombia	Iceland	Namibia	Syrian Arab Rep.
Angola	Comoros	India	Nepal	Taiwan
Antigua and Barbuda	Congo	Indonesia	New Caledonia	Tajikistan
Argentina	Costa Rica	Iran	New Zealand	United Rep. of Tanzania
Armenia	Côte d'Ivoire	Iraq	Nicaragua	Thailand
Australia	Croatia	Israel	Niger	Togo
Azerbaijan	Cuba	Jamaica	Nigeria	Tonga
Bahamas	Dem. Rep. of the Congo	Japan	Norway	Trinidad and Tobago
Bahrain	Djibouti	Jordan	Oman	Tunisia
Bangladesh	Dominica	Kazakhstan	Pakistan	Turkey
Barbados	Dominican Rep.	Kenya	Panama	Turkmenistan
Belarus	Ecuador	Kiribati	Papua New Guinea	Uganda
Belize	Egypt	Korea	Paraguay	Ukraine
Benin	El Salvador	Kuwait	Peru	United Arab Emirates
Bermuda	Equatorial Guinea	Kyrgyzstan	Philippines	Uruguay
Bhutan	Eritrea	Laos	Qatar	Uzbekistan
Bolivia	Ethiopia	Lebanon	Russian Federation	Vanuatu
Bosnia and Herzegovina	EU-27	Lesotho	Rwanda	Venezuela
Botswana	Fiji	Liberia	Saint Lucia	Viet Nam
Brazil	Gabon	Libya	Saint Vincent and the Grenadines	Yemen
Brunei Darussalam	Gambia	Macedonia	Samoa	Zambia
Burkina Faso	Georgia	Madagascar	Serbia and Montenegro	Zimbabwe
Burma	Ghana	Malawi	Seychelles	
Burundi	Greenland	Malaysia	Sierra Leone	
Cambodia	Grenada	Mali	Singapore	
Cameroon	Guatemala	Mauritania	Solomon Islands	
Canada	Guinea	Mauritius	South Africa	
Cape Verde	Guinea-Bissau	Mexico	Sri Lanka	
Central African Rep.	Guyana	Rep. of Moldova	Sudan	

Chapter Three

FMD Impacts on International Pork Markets – 186 Countries

3.1 Introduction

Food safety scares affect consumption behavior, and food safety and animal life issues are increasingly impacting international agricultural trade. Member countries of the World Trade Organization (WTO) can apply measures of the Sanitary and Phytosanitary (SPS) Agreement to ensure safe food for consumers and further to prevent the spread of pests or disease among animals and plants. Foot-and-mouth disease (FMD) is a highly contagious viral-type disease which infects cloven-hoofed ruminant animals, such as cattle and pigs. FMD symptoms include fever, erosions, and blister-like lesion on the hooves, lips, mouth, teats, and tongue (APHIS 2007). In swine species, about 58 countries were infected by FMD during 1996 to 2007, but the volume of the international pork exports still grew from 3.7 to 8.3 million tons (figure 3.1). The volume of pork imports has steadily grown from 1996 to 2007, but the volume of pork exports exhibits a drop during 1997 and 2000. The pork market and its supporting industries in importing and exporting countries were influenced by FMD, but some countries (and firms) were gaining market share but others were not.

These FMD-infected countries reported a total of about 255 FMD outbreaks in swine species to the Office International des Epizooties (OIE) from 1996 to 2007. Many of these FMD-infected countries were eventually able to regain a position of FMD-free regions, yet others are still suffering from it. An FMD outbreak diminishes livestock production in all stages (due to slaughtering the disease-infected herds or lower herd health) and reduces consumption for meat products in the short-run (Yeboah and Maynard 2004; Roh, Lim, and Adam 2006). If consumption can return to its original level within a short period of time, pork imports in an importing country may not be hindered, which implies pork exports in an exporting country could be stimulated, assuming other factors constant.

International pork trade can be hindered or stimulated by FMD outbreaks. Pork exports of an FMD-free country usually increase when the consumption levels of FMD-infected importing countries return to normal in the short-run. Yet, the FMD-infected importers may not necessarily increase imports in the short-run until their consumption level recovers. Further, pork exports of an FMD-infected country are usually hindered from the disease because of import bans by disease-free countries. Therefore, the first objective of this study is to investigate whether an FMD outbreak in a pork exporter negatively impacts trade.

An FMD-infected country can apply either a slaughter or vaccination policy to protect domestic animals. The central goal of a slaughter policy is to strengthen the efficacy in controlling FMD outbreaks, so all disease-infected animals are slaughtered to prevent additional outbreaks from FMD spreading. A slaughter policy can create a larger decline in supply. The central goal of a vaccination policy is to protect healthy animals from infection. Since a vaccinated animal cannot be distinguished from an infected animal, countries with a vaccination policy usually face the FMD stigma for a longer period. Pork exports of an FMD-infected country still can be hindered at least one to two years no matter which policy is applied. However, pork imports can have two different consequences when an FMD-infected importing country adopts a slaughter versus vaccination policies.

It is important to understand the effects of an FMD outbreak for a pork importing country when two different policies are adopted: a slaughter policy (figure 1.5a) and a vaccination policy (figure 1.5b). FMD outbreaks create impacts on supply and demand (Yeboah and Maynard 2004; Paarlberg et al. 2008). Both supply and demand will decline as an FMD outbreak occurs in a country. A constant change on the demand level in figure 1.5a and 1.5b is assumed. The slaughter policy will cause a large decrease in supply (shift from S to S' in figure 1.5a), but supply will not fall as much under the vaccination policy (shift from S to S' in figure 1.5b). FMD-infected importers with a slaughter policy would likely increase their imports in the short-run (from $\overline{Q^s Q^d}$ to $\overline{Q^{s'} Q^{d'}}$ in figure 1.5a), so the first hypothesis is that FMD-infected importers will import more if they adopt a slaughter policy. It is not clear whether FMD-infected importers with a vaccination policy would increase or decrease their imports in the short-run (from $\overline{Q^s Q^d}$ to $\overline{Q^{s'} Q^{d'}}$ in figure 1.5b), so the second hypothesis is that FMD-infected importers will not specifically import more if they adopt a vaccination policy. The second objective is to test these two hypotheses and further to confirm whether FMD-infected exporters face an impeded pork trade under these two different policies.

Regional trade agreements (RTAs) are also important factors that have influenced agricultural trade in the last three decades (Baier and Bergstrand 2007; Grant and Lambert 2008; Lambert and McKoy 2009; Sun and Reed 2010). Among 186 countries, 157 exporting countries had an RTA relation with another country during 1996 to 2007. The RTA factor in this study[4] covers: Free Trade Agreements (FTAs), Economic Integration Agreements (EIAs), Preferential Trade Agreements (PTAs), and Customs Union (CU). In total, these agreements consist of 25 different trading groups (see Appendix II for definitions): AFTA, CAN, APTA, CACM, CAFTA-DR, CARICOM, CEFTA, CEZ, CIS, COMESA, EAC, EAEC, EFTA, EU27, MERCOSUR, NAFTA, PAFTA, PICTA, SAARC, SACU, SADC, SAFTA, SAPTA, SPARTECA, and TPP. Hence, the RTA factor can potentially stimulate international pork trade, so the third objective is to test whether an RTA increases pork trade among its members.

Because the analysis is for a single commodity and includes so many countries, the trade data consists of many zero trade flows (over 96% of the observations are zero). The data sources are not clear whether the zero trade flows are missing or truly zero values. If zero trade flows are excluded, it is possible that important information is being lost on low levels of trade (Eichengreen and Irwin 1998), which leads to biased estimation due to heteroskedasticity. We apply a gravity model which has performed well for measuring the impacts when a large number of zeros are included. In addition, a Heckman model is used to investigate the effects of including zero observations in the estimation.

Recent developments in the gravity model have overcome two challenges identified by the literature. The first challenge involves possible endogeneity problems due to omitted variables. Numerous studies have shown that fixed effects can account for multilateral resistance (price) terms (Anderson and van Wincoop 2003; Feenstra 2004; Baier and Bergstrand 2007; Grant and Lambert 2008; Sun and Reed 2010). Hence, the

[4] A list of all RTAs (in force) can be retrieved from: http://rtais.wto.org/UI/PublicAllRTAList.aspx

endogeneity problems due to omitted variables can be controlled. The second challenge is the presence of heteroskedasticity with zero-valued trade and the log-linearized gravity equation. Santos-Silva and Tenreyro (2006 and 2009) have demonstrated that the Poisson Pseudo-Maximum Likelihood (PPML) model is a very suitable estimator for the large number of zero trade flows under such situations. This study contributes to the literature when an extremely large number of zero observations are used in the gravity model with the PPML estimator. Further, an extremely large number of zeros may lead to the variance exceeding the mean (called overdispersion). The consequences of overdispersion are a violation of the assumption of homoscedasticity and misleading inferences. This study also applies a negative binomial (NB) estimator, which has more advantages in dealing with overdispersion, to contrast the results with the PPML estimator. Therefore, the fourth objective is to apply the PPML estimator with fixed effects and the NB estimator to further distinguish the impacts of FMD and RTA on international pork trade.

Several other factors may also affect pork exports, such as common official language, past colonial connections, and religious beliefs. Countries with a common language and past colonial connections are more likely to trade with each other due to similar culture. Muslims and Jews are prohibited to consume pork, so countries with larger groups of Muslims and Jews are not likely to import pork. The last objective is to identify the influence of these factors on pork trade. This study contributes to basic understanding of the impacts of FMD outbreaks in international pork trade, the role of RTAs, and other important factors, while analyzing their difference influences in FMD-infected and FMD-free countries.

3.2 Literature Review

Numerous studies have found that FMD outbreaks can dramatically influence consumption behavior, market prices, production in all stages, and meat products' trade. Yeboah and Maynard (2004) discovered that consumers responded negatively to FMD outbreaks and decreased their consumption level in the short-run. Roh, Lim, and Adam (2006) estimated the negative effects of FMD outbreaks on cattle, beef, hog, and pork prices in Korea during 2000 and 2002. Costa, Bessler, and Rosson (2011) found that beef, pork, and chicken export prices in Russia declined after its FMD outbreak due to the imposition of an import ban. These prices reverted to normal after the import ban was overturned. Paarlberg et al. (2008) identified the impacts of FMD outbreaks, which caused pork and hog prices to decline. All prices ended up recovering after three to five quarters based on standard- and high-outbreak scenarios. Jarvis, Cancino, and Bervejillo (2005) concluded that FMD outbreaks still impede agricultural trade among many countries. Past FMD research demonstrates that FMD outbreaks can create dramatic impacts on supply and demand in the short-run.

3.2.1 The Gravity Model

The gravity model is widely used to examine bilateral trade flows (Anderson 2008). Numerous studies reveal how to measure the impacts of regulations, policies, and standards on food trade using this model (Swann, Temple, and Shurmer 1996; van Beers and van den Bergh 1997; Peridy, Guillotreau, and Bernard 2000; Wilson and Otsuki 2004; Anderson and van Wincoop 2004; and Anders and Caswell 2009). Recent research has recognized possible endogeneity problems due to omitted variables (Anderson and van Wincoop 2003) and the presence of heteroskedasticity when using log-linearized specifications of the gravity model (Santos-Silva and Tenreyro 2006) or when excluding zero observations (Hurd 1979).

The first formal theoretical foundation of the gravity equation was provided by Anderson (1979). Due to the omitted bias concern (prices) in the gravity equation, Anderson and van Wincoop (2003) point out that a proper gravity equation must recognize endogenous multilateral prices terms for bilateral trade countries. Anderson and van Wincoop (2003) and Feenstra (2004) suggest using country-specific fixed effects as an alternative method in specifying multilateral price terms for computational ease. Baier and Bergstrand (2007) confirm that country-specific fixed effects are not able to eliminate the endogeneity bias if an FTA coefficient is included, so they used country-and-time fixed effects under a panel setting to explain time-varying multilateral resistance terms, such as RTAs. Grant and Lambert (2008) also demonstrate the gravity model with a series of fixed effects showing RTA impacts on member trade. These studies show that properly applied fixed effects can avoid endogeneity problems due to omitted variables.

It is common to use log-linearized specifications in a gravity model equation. Santos-Silva and Tenreyro (2006) point out that heteroskedasticity can be quantitatively important in a gravity equation because Jensen's inequality, i.e., $E(\ln y) \neq \ln E(y)$, is neglected. When observations of the dependent variable include zeros, the problem of heteroskedasticity leads to biased estimation, even if the gravity equation is controlled by fixed effects. Hurd (1979) indicates the problem of heteroskedasticity can be enlarged if zeros are excluded. Santos-Silva and Tenreyro (2006) propose an augmented gravity equation in levels using a Pseudo-Maximum-Likelihood (PML) estimator, which can handle zero-valued trade, so the problem of heteroskedasticity can be avoided.

Santos-Silva and Tenreyro (2006) use Monte Carlo simulation to show that the Poisson PML (PPML) estimator is relatively robust and adequately behaved among different estimators including ordinary least square (OLS), Tobit, non-linear least square (NLS), and PPML. Their simulations show that the PPML estimator is still well behaved among different estimators when the dependent variable is non-negative (Santos-Silva and Tenreyro 2006; Santos-Silva and Tenreyro 2009). Westerlund and Wilhelmsson (2009) also examine the effects of zero trade with the gravity model using a Monte Carlo simulation under a panel data structure. They had up to 83% of the values equaling zero for the dependent variable in their simulations. They also suggest using the Poisson fixed effects estimator. Hence, this study contributes to the literature on the extremely large number of zero observations in the gravity model and the PPML estimator.

Sun and Reed (2010) were the first to use the PPML estimator with fixed effects in the gravity model to deal with FTA variables on agricultural trade. The potential endogeneity problems with the FTA variable involve reverse causality between higher trade volumes and trade agreements (Sun and Reed 2010). Their application of fixed effects shows that the endogeneity problem from omitted variables can be controlled. The endogeneity problem involves bias and underestimates the parameters (Lee and Swagel 1997). Finding instrumental variables (IV) is an alternative traditional solution for endogeneity problems, but Baier and Bergstrand (2007) conclude that IV estimation is not a reliable approach for dealing with the endogeneity bias. They propose a gravity model with country-and-time fixed effects under a panel data structure to account for the endogeneity problem. Hence, this study will apply a PPML estimator in a gravity model with country-and-time fixed effects under a panel data structure.

3.3 Data Description and Empirical Models

3.3.1 Data Description

Bilateral trade data (X_{ijt}) in U.S. dollars from 1996 to 2007 for pork exports are derived from the United Nations Commodity Trade Statistics Database (http://comtrade.un.org). The sample period of the data is three-year intervals (from 1996 to 2005 plus 2007, the last year of data) in order to reduce computational time and eliminate possible autocorrelation. There are 172,050 observations $(186 \times 185 \times 5)$ that include 165,675 zeros (over 96% of the sample). Pork exports are Harmonized System (HS) coding 0203, i.e., meat of swine, fresh, chilled, and frozen. The records of FMD outbreaks and control policies from 1996 to 2007 come from the OIE (http://www.oie.int/hs2/report.asp?lang=en). Real gross domestic product (RGDP) in U.S. dollars is obtained from the FAS/USDA (http://www.ers.usda.gov/Data/Macroeconomics). Distance, colonial relations, and common official language are collected from the Centre d'Etudes Prospectives et d'Informations Internationales (http://www.cepii.fr/anglaisgraph/bdd/distances.htm). The RTA variable shows if the exporting country has a RTA relationship with the importing country and is collected from the WTO website.

The definition and statistical summary of variables are shown in table 3.1. Annual total value of pork exports among 186 importing countries (shown in Appendix III) averaged $0.4 million (U.S. dollars). The average real GDP for these countries is $224 billion (U.S. dollars) annually. The average distance between the largest urban areas for the countries is 7,936 kilometers. Almost 16% of the observations represent that countries use the same official language. Only 0.7% of the observations reveal that countries have past colonial connections. From 1996 to 2007 over 58 countries had FMD outbreaks (about 12 percent of the observations). Over six percent of the observations have trading countries with an RTA connection.

3.3.2 Empirical Framework

This study employs a gravity model with the PPML estimator by controlling several different fixed effects for comparisons. Each result of the PPML estimator will contrast with the results of a NB estimator. We specify the empirical models for the first objective as:

(A) Only time fixed effects

$$(3.1)\ \ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2 \ln(RGDP_{jt}) + \alpha_3 \ln(Dist_{ij}) + \alpha_4 (Lang_{ij}) + \alpha_5 (Col45_{ij}) + \alpha_6 (\mathrm{Muslim}_{\mathrm{j}}) + \alpha_7 (FMD_{it}) + \alpha_8 (FMD_{jt}) + \alpha_9 (RTA_{ijt}) + \varepsilon_{ijt}$$

(B) Time and bilateral country pair fixed effects

$$(3.2)\ \ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_{ij}^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2 \ln(RGDP_{jt}) + \alpha_7 (FMD_{it}) + \alpha_8 (FMD_{jt}) + \alpha_9 (RTA_{ijt}) + \varepsilon_{ijt}$$

(C) Bilateral country pair and country-and-time fixed effects

$$(3.3)\ \ln\left[\frac{X_{ijt}}{(RGDP_{it})(RGDP_{jt})}\right] = \alpha_0 + \alpha_{ij}^{\theta} + \alpha_{it}^{\theta} + \alpha_{jt}^{\theta} + \alpha_9 (RTA_{ijt}) + \varepsilon_{ijt}$$

In equations (3.1) to (3.3), t denotes time, i denotes exporting country and j denotes importing country; $\ln X_{ijt}$ is the log of pork export value from exporting country i to importing country j in time t; α_t^θ are time fixed effects; α_{ij}^θ denote bilateral country pair fixed effects; α_{it}^θ and α_{jt}^θ denote country-and-time fixed effects to account explicitly for the time-varying multilateral price terms. Both $RGDP_{it}$ and $RGDP_{jt}$ are real gross domestic product of the exporting and importing countries, respectively, as a proxy for economic size. $Dist_{ij}$ is the distance between exporting country i and importing country j used as a proxy for transportation costs. Other geographic and preference similarities, such as sharing a common language $(Lang_{ij})$, past colonial connections since 1945 $(Col45_{ij})$, and religion in importing country j (Muslim_j), are commonly used in gravity equations. RTA_{ijt} is a dummy variable indicating the existence of a regional trade agreement between the exporting country i and importing country j. The variable FMD_{it} (FMD_{jt}) denotes a dummy variable indicating the exporting country i (importing country j) with FMD. The ε_{ijt} is assumed to be a log-normally distributed error term.

Equation (3.1) presents a basic gravity model with time fixed effects, and further identifies whether the coefficients of variables, i.e., $Dist_{ij}$, $Lang_{ij}$, $Col45_{ij}$, and Muslim_j, have the expected signs. Equation (3.2) has time and bilateral country pair fixed effects which account for all time-invariant bilateral barriers, so $Dist_{ij}$, $Lang_{ij}$, $Col45_{ij}$, and Muslim_j, are excluded and explained by fixed effects. Equation (3.3) not only has bilateral country pair fixed effects but also country-and-time fixed effects which account for multilateral resistance (price) terms. The variables FMD_{it} (FMD_{jt}) are excluded and explained by the fixed effects. The income coefficients are restricted to unity in equation (3.3), which is consistent with the theoretical gravity model in Anderson and van Wincoop (2003).

(D) Policy effects with time fixed effects

$$(3.4)\ \ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2 \ln(RGDP_{jt}) + \alpha_3 \ln(Dist_{ij}) + \alpha_4 (Lang_{ij}) + \alpha_5 (Col45_{ij}) + \alpha_6 (\text{Muslim}_j) + \alpha_7 (FV_{it}) + \alpha_8 (FV_{jt}) + \alpha_9 (FS_{it}) + \alpha_{10} (FS_{jt}) + \alpha_{11} (RTA_{ijt}) + \varepsilon_{ijt}$$

(E) Policy effects with time and bilateral country pair fixed effects

$$(3.5)\ \ln X_{ijt} = \alpha_0 + \alpha_t^{\theta} + \alpha_{ij}^{\theta} + \alpha_1 \ln(RGDP_{it}) + \alpha_2 \ln(RGDP_{jt}) + \alpha_7 (FV_{it}) + \alpha_8 (FV_{jt}) + \alpha_9 (FS_{it}) + \alpha_{10} (FS_{jt}) + \alpha_{11} (RTA_{ijt}) + \varepsilon_{ijt}$$

The empirical models for the second objective are expressed in equations (3.4) and (3.5). The variables $FV_{it} (FV_{jt})$ denote an interaction dummy variable indicating when the exporting country *i* (importing country *j*) with FMD adopts a vaccination policy; the variables $FS_{it} (FS_{jt})$ denote an interaction dummy variable indicating when the exporting country *i* (importing country *j*) with FMD adopts a slaughter policy. The other variables are defined previously. Equations (3.4) and (3.5) identify the parameters of vaccination and slaughter policies for FMD-infected countries. The specifications of equation (3.4) and (3.5) are the same as equations (3.1) and (3.2), respectively, except for the parameters related to FMD. The model specifications controlling for both country-and-time and bilateral country pair fixed effects in identifying vaccination and slaughter policies are the same as in equation (3.3).

3.4 Empirical Results

The empirical results contain several comparisons, such as the PPML estimator versus NB estimator, models with different fixed effects, FMD impacts on exporters versus importers that vary between slaughter and vaccination policies, and treatment of zero-valued trade. The empirical results of the NB estimator are only for comparing the coefficient signs and significant levels to the results of the PPML estimator, since the NB estimator varies with the scale of the dependent variable. The NB estimator has a well-known advantage in dealing with overdispersion, and it is important to make sure that the PPML estimator generates similar signs and significance levels when there is an extremely large number of zero observations.

The empirical results are reported in Tables 3.2 and 3.3; each coefficient has its expected sign and is significantly different from zero. Coefficients for $RGDP_{it}$ and $RGDP_{jt}$, are close to unity which allows us to restrict to them when we apply the bilateral country pair and country-and-time fixed effects in Table 3.2. The coefficients $Dist_{ij}$, $Lang_{ij}$, $Col45_{ij}$, and $Muslim_j$ have the expected signs and are significant at the 1% level in Table 3.2 and 3.3 when time fixed effects are controlled. Comparing to the results of the NB estimators, the estimated parameters for these variable are significant at the 1% level and have expected signs. The larger distance between countries means higher transportation costs, so the negative sign is expected. Among international pork traders, if countries have a common official language and colonial connections, then they are more likely to have pork trade with each other. Religious beliefs, i.e., Muslims and Jews, have an important role and negatively impact international pork trade.

In Table 3.2, the estimated parameters for FMD_{it} have the expected negative sign and are significantly different from zero for all of the estimation techniques, indicating FMD has negative impacts on pork exporters. This result confirms that FMD-infected exporters reduce shipments when they were confirmed as an FMD-infected region. Estimated parameters for FMD_{jt} have the expected signs and are significantly different from zero when time fixed effects are used; further, the estimated parameters are similar between the PPML and NB estimators. When bilateral country pair and time fixed effects are used these coefficients are positive, but not significantly different from zero. The NB estimation shows result very similar to the PPML model. FMD-infected importers may not increase pork imports with an outbreak. However, these results do not distinguish between slaughter and vaccination policies.

In Table 3.3, the estimated parameters for FV_{it} have the expected signs and are significant at the 1% level for all of the estimation techniques. The estimated parameters for FS_{it} have the expected signs and are significant at the 1% level for all of the estimation techniques, except for the NB estimator with time fixed effects. Any pork exporter with FMD faces lower pork exports no matter which policy, slaughter or vaccination, is adopted. However, an FMD-infected exporter with a vaccination policy encounters a larger negative impact than an FMD-infected exporter with a slaughter policy; no matter which fixed effects are controlled. This implies that a slaughter policy can result in smaller negative impacts than a vaccination policy for exporting countries.

Pork importers with FMD may not necessarily import more pork depending which policy is adopted. Except for the result of the NB estimator with time and bilateral country pair fixed effects, the estimated parameters for FS_{jt} have the expected signs and are significant at the 1% level for all estimation techniques. FMD-infected importers increase pork imports when they adopt a slaughter policy, as reflected in figure 1.5a. Due to the supply shortage, FMD-infected importers with a slaughter policy would need to increase their imports. The estimated parameters for FV_{jt} are not significantly different than zero and have different expected signs, except for the result of the PPML estimator with time fixed effects. This implies that FMD-infected importers with a vaccination policy may not significantly increase pork imports. This result confirms the second hypothesis that FMD-infected importers will not specifically import more if they adopt a vaccination policy, as reflected in figure 1.5b.

As mentioned before, exporters with a vaccination policy have larger negative impacts on pork trade than those with a slaughter policy. A country could import and export pork (e.g., the U.S.). Thus, an FMD outbreak would impact exports and imports. If one compares the aggregated impacts (adding export and import effects) of a vaccination policy versus a slaughter policy in a country, the slaughter policy would have smaller negative impacts on international trade than with the vaccination policy. Hence, a slaughter policy not only strengthens the efficacy in controlling FMD outbreaks, but also eases the impacts of FMD outbreaks. FMD outbreaks can impair the global food chain and international pork trade. In order to retain a position as a top pork exporter, a slaughter policy seems a better choice than a vaccination policy.

The estimated parameters for the RTA_{ijt} variables also have the expected positive sign and are significant at the 1% level in Tables 3.2 and 3.3 for all estimation techniques. These empirical results contribute to the literature of RTA factors in agricultural trade (Grant and Lambert, 2008; Sun and Reed, 2010). When the RTA is included in the model, it is important to avoid endogeneity problems due to omitted variables. In table 3.2, we include country-and-time fixed effects under a panel setting to control time-varying multilateral price terms. These fixed effects will cover those related variables with bilateral and countries-by-time factors, so the estimated parameters for the RTA will be identical and only present in the table 3.2. Note that the estimated parameters of variable RTA_{ijt} are all very similar in magnitude among the PPML estimators, and have identical results with the NB estimator. This implies that the variable RTA_{ijt} may present less of an endogeneity problem for these PPML and NB estimators by controlling different fixed effects. The endogeneity concern seems less pronounced even when the primary results are only controlled with time and bilateral country pair fixed effects in table 3.2 and 3.3.

Over 96% of our sample data consist of zero-valued trade. This study uses a Heckman model as a final test to identify the effects of including zero observations in the sample. The indication of the Mills ratio in the Heckman model can confirm that the absence of control for zero observations may generate biased results (Disdier and Marette, 2010). The FMD_{jt} and FV_{jt} variables are excluded for the Heckman model to reduce collinearity concerns for the PPML regressions in Table 3.2 and 3.3, respectively (Puhani, 2000). The results of the inverse Mills ratios in Table 3.2 and 3.3 reveal that there is indeed a selection bias, and the empirical results are significantly different when zero observations are excluded. If we exclude these zero observations, our empirical results may be biased. In other words, these zero observations do possess important information for international pork trade, so they should be included in the model.

3.5 Conclusions

Our research findings confirm that FMD-infected exporters suffer from reduced pork exports, but FMD-infected importers may not increase their pork imports, depending on which policies importers adopt. FMD-infected countries can adopt either a slaughter or vaccination policy. Among pork exporters, countries with a slaughter or vaccination policy suffer reduced pork exports; countries with a slaughter policy have smaller reductions than those with a vaccination policy.

Among pork importers, countries with a slaughter policy tend to increase pork imports due to the shortage of domestic supply. However, importing countries with a vaccination policy do not significantly increase pork imports. The aggregate impacts for a country with a slaughter policy are smaller than those with a vaccination policy. This implies that a slaughter policy not only controls but also eases the impacts of FMD outbreaks. In order to retain a position as a top pork exporter, a slaughter policy seems a better choice than a vaccination policy. Better understanding of importer countries' reactions to FMD helps bilateral trade negotiation strategies that reduce the loss from FMD outbreaks, and also helps agribusinesses with their strategic response to the animal health scare.

The existence of an RTA also influences pork exports and imports. About 157 exporting countries had an RTA relation with other countries in the sample during 1996 to 2007. Our empirical findings on the RTA correspond and contribute findings on the FTA and RTA effects. The results indicate that some FMD-infected importers do not import more pork, but those following a slaughter policy and those with an RTA connection do.

The concerns of endogeneity and heteroskedasticity have often been raised with gravity models. The endogeneity problem is controlled here with bilateral country pair and country-and-time fixed effects, and the empirical results are consistent among the different ways for controlling fixed effects. The heteroskedasticity problem exists in our trade data whether zero observations are included or not. Over 96% of the observations in the pork trade data base consist of zero observations. Hence, it is important to examine whether sample selection bias exists. The results of the Heckman model indicate that zero observations should not be eliminated. Hence, this study contributes to the application of the PPML estimator using an extremely large number of zero observations. The PPML estimator shows its application successfully when including this extreme number of zeros.

Table 3.1: Descriptive Statistics of Variables (N = 172,050)

Variables	Description of variable	Mean	Std. Dev.	Min.	Max.
Exports (X_{ijt})	Annual total value of countries' pork exports (U.S. $ in thousands)	411	11,900	0	1,540,000
RGDP ($RGDP_{it}$)	Annual real GDP for exporting countries (2005 U.S. $ in billions)	224	960	0.052	13,050
RGDP ($RGDP_{jt}$)	Annual real GDP for importing countries (2005 U.S. $ in billions)	224	960	0.052	13,050
Distance ($Dist_{ij}$)	The shortest distance from the largest population regions to the U.S. (km)	7,936	4,492	35	19,780
Language ($Lang_{ij}$)	Binary variable=1 if importing countries use same official language with exporting countries	0.156	0.363	0	1
Col45 ($Col45_{ij}$)	Binary variable=1 if importing countries had colonial relations with exporting countries since 1945	0.007	0.082	0	1
Muslim ($Muslim_{j}$)	Binary variable=1 if over 50% of Muslim population in importing countries	0.237	0.425	0	1
RTA (RTA_{ijt})	Binary variable=1 if importing countries had RTA relations with exporting countries	0.062	0.241	0	1
eFMD (FMD_{it})	Binary variable=1 if exporting countries had FMD outbreaks in time *t*	0.113	0.316	0	1
iFMD (FMD_{jt})	Binary variable=1 if importing countries had FMD outbreaks in time *t*	0.113	0.316	0	1
eFMD*V (FV_{it})	Binary variable=1 if exporting countries had FMD outbreaks and applied a vaccination policy	0.073	0.260	0	1
eFMD*S (FS_{it})	Binary variable=1 if exporting countries had FMD outbreaks and applied a slaughter policy	0.073	0.260	0	1
iFMD*V (FV_{jt})	Binary variable=1 if importing countries had FMD outbreaks and applied a vaccination policy	0.040	0.195	0	1
iFMD*S (FS_{jt})	Binary variable=1 if importing countries had FMD outbreaks and applied a slaughter policy	0.040	0.195	0	1

Table 3.2: The Impacts of FMD in the Comparisons of Different Estimators and Fixed Effects

Dep. Variable:	PPML	Neg. Binomial	PPML	Neg. Binomial	PPML	Neg. Binomial
X_{ijt}	(α_t^θ)	(α_t^θ)	$(\alpha_t^\theta, \alpha_{ij}^\theta)$	$(\alpha_t^\theta, \alpha_{ij}^\theta)$	$(\alpha_{ij}^\theta, \alpha_{it}^\theta, \alpha_{jt}^\theta)$	$(\alpha_{ij}^\theta, \alpha_{it}^\theta, \alpha_{jt}^\theta)$
$RGDP_{it}$	0.625 ***	0.809 ***	0.713 ***	0.676 ***	1.000	1.000
	(0.005)	(0.009)	(0.015)	(0.010)	–	–
$RGDP_{jt}$	0.204 ***	0.224 ***	0.215 ***	0.256 ***	1.000	1.000
	(0.005)	(0.008)	(0.013)	(0.008)	–	–
$Dist_{ij}$	–0.733 ***	–1.046 ***	.	.	.	.
	(0.015)	(0.024)				
$Lang_{ij}$	0.129 ***	0.259 ***	.	.	.	.
	(0.036)	(0.056)				
$Col45_{ij}$	0.683 ***	1.236 ***	.	.	.	.
	(0.079)	(0.187)				
$Muslim_j$	–0.782 ***	–0.740 ***	.	.	.	.
	(0.037)	(0.047)				
FMD_{it}	–0.582 ***	–0.676 ***	–0.133 ***	–0.659 ***	.	.
	(0.043)	(0.059)	(0.019)	(0.050)		
FMD_{jt}	0.139 ***	0.100 *	0.026	0.009	.	.
	(0.036)	(0.058)	(0.018)	(0.042)		
RTA_{ijt}	0.293 ***	0.847 ***	0.330 ***	1.510 ***	0.293 ***	1.852 ***
	(0.035)	(0.075)	(0.016)	(0.039)	(0.025)	(0.039)
N	172,050	172,050	172,050	172,050	172,050	172,050
Log–likelihood	–135940	–47242	–56990	–40746	–50417	–37885
AIC	271908	94514	114003	81518	102871	77811
BIC	272049	94665	114114	81638	113118	88067
Mills Ratio			0.089 **			

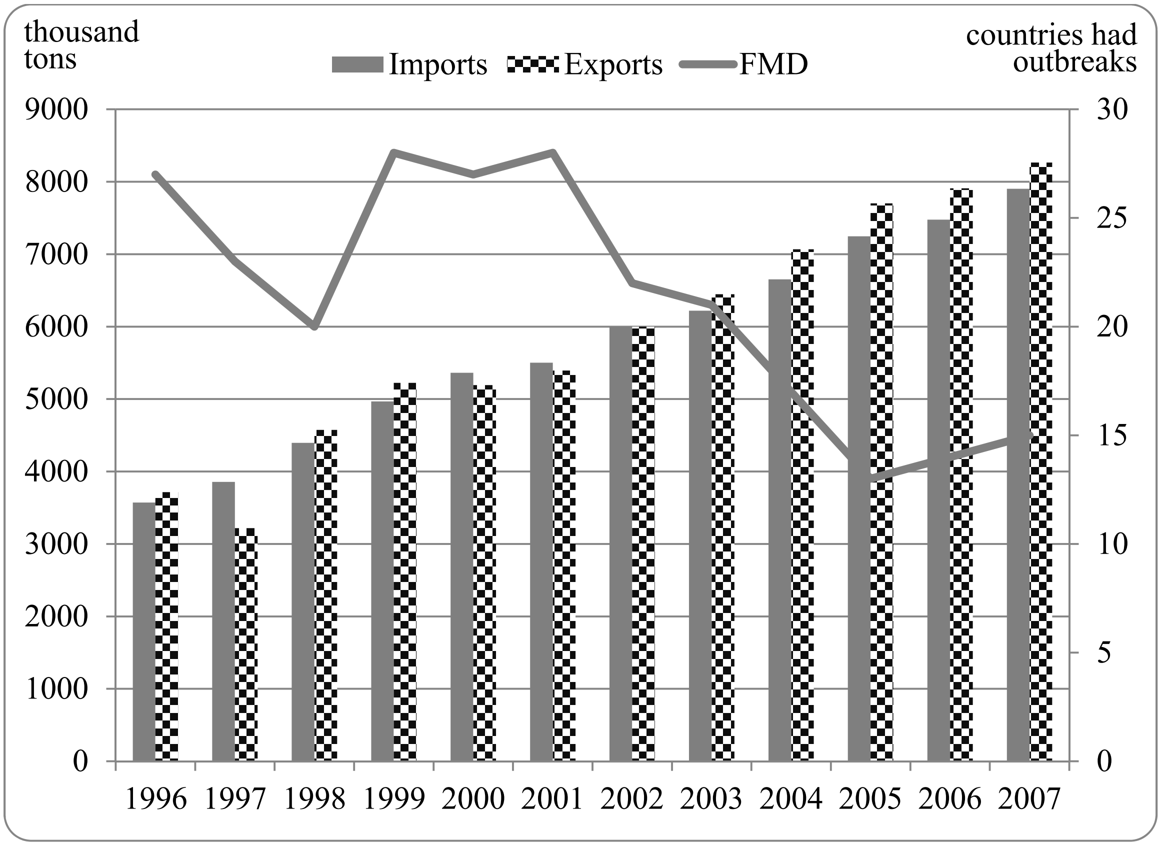
Note: *10% significance, ** 5% significance, and *** 1% significance; parentheses represent standard error.

Table 3.3: The Impacts of FMD in Different Policies (Slaughter versus Vaccination)

Dep. Variable: X_{ijt}	PPML (α_t^θ)	Neg. Binomial (α_t^θ)	PPML $(\alpha_t^\theta, \alpha_{ij}^\theta)$	Neg. Binomial $(\alpha_t^\theta, \alpha_{ij}^\theta)$
$RGDP_{it}$	0.622 ***	0.813 ***	0.722 ***	0.680 ***
	(0.002)	(0.009)	(0.015)	(0.010)
$RGDP_{jt}$	0.204 ***	0.230 ***	0.217 ***	0.260 ***
	(0.002)	(0.008)	(0.013)	(0.008)
$Dist_{ij}$	–0.732 ***	–1.038 ***	.	.
	(0.004)	(0.024)		
$Lang_{ij}$	0.130 ***	0.276 ***	.	.
	(0.010)	(0.056)		
$Col45_{ij}$	0.665 ***	1.194 ***	.	.
	(0.019)	(0.186)		
$Muslim_j$	–0.779 ***	–0.722 ***	.	.
	(0.012)	(0.047)		
FV_{it}	–1.056 ***	–1.274 ***	–0.368 ***	–1.274 ***
	(0.021)	(0.072)	(0.034)	(0.080)
FV_{jt}	0.200 ***	0.087	–0.011	–0.041
	(0.013)	(0.069)	(0.023)	(0.053)
FS_{it}	–0.074 ***	0.119	–0.071 ***	–0.243 ***
	(0.017)	(0.095)	(0.020)	(0.054)
FS_{jt}	0.039 **	0.174 *	0.059 ***	0.078
	(0.019)	(0.094)	(0.021)	(0.057)
RTA_{ijt}	0.284 ***	0.861 ***	0.334 ***	1.516 ***
	(0.010)	(0.074)	(0.016)	(0.039)
N	172,050	172,050	172,050	172,050
Log–likelihood	–135225	–47165	–56951	–40681
AIC	270483	94365	113928	81390
BIC	270644	94536	114059	81530
Mills Ratio			0.088 **	

Note: *10% significance, ** 5% significance, and *** 1% significance; parentheses represent standard error.

Figure 3.1: Pork Imports/Exports and FMD Outbreaks



Sources: UN Commodity Trade Database and Office of International Epizootics.

Appendix II – Regional Trade Agreement Groups

AFTA – ASEAN Free Trade Area
CAN – Andean Community of Nations
APTA – Asia-Pacific Trade Agreement
CACM – the Central American Common Market
CAFTA-DR – the Dominican Republic-Central America-United States Free Trade Agreement
CARICOM – Caribbean Community and Common Market
CEFTA – Central European Free Trade Agreement
CEZ – Common Economic Zone
CIS – Commonwealth of Independent States
COMESA – the Common Market for Eastern and Southern Africa
EAC – the East African Community
EAEC – Eurasian Economic Community
EFTA – European Free Trade Association
EU^{27} – European Union of 27 member states
MERCOSUR – Southern Common Market
NAFTA – the North American Free Trade Agreement
PAFTA – Pan-Arab Free Trade Agreement
PICTA – Pacific Island Countries Trade Agreement
SAARC – the South Asian Association for Regional Cooperation
SACU – Southern African Custom Union)
SADC – Southern African Development Community
SAFTA – South Asian FTA
SAPTA – South Asian Preferential Trade Agreement
SPARTECA – South Pacific Regional Trade and Economic Co-operation Agreement
TPP – the Trans-Pacific Partnership

Appendix III – List of 186 Countries

Afghanistan
Albania
Algeria
Andorra
Angola
Antigua and Barbuda
Argentina
Armenia
Australia
Azerbaijan
Bahamas
Bahrain
Bangladesh
Barbados
Belarus
Belize
Benin
Bermuda
Bhutan
Bolivia
Bosnia and Herzegovina
Botswana
Brazil
Brunei Darussalam
Burkina Faso
Burma
Burundi
Cambodia
Cameroon
Canada
Cape Verde
Central African Rep.
Chad
Chile
China
Colombia
Comoros
Congo
Costa Rica
Côte d'Ivoire
Croatia
Cuba
Dem. Rep. of the Congo
Djibouti
Dominica
Dominican Rep.
Ecuador
Egypt
El Salvador
Equatorial Guinea
Eritrea
Ethiopia
EU-27
Fiji
Gabon
Gambia
Georgia
Ghana
Greenland
Grenada
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hong Kong
Iceland
India
Indonesia
Iran
Iraq
Israel
Jamaica
Japan
Jordan
Kazakhstan
Kenya
Kiribati
Korea
Kuwait
Kyrgyzstan
Laos
Lebanon
Lesotho
Liberia
Libya
Macedonia
Madagascar
Malawi
Malaysia
Mali
Marshall Islands
Mauritania
Mauritius
Mexico
Micronesia
Rep. of Moldova
Mongolia
Morocco
Mozambique
Namibia
Nepal
New Caledonia
New Zealand
Nicaragua
Niger
Nigeria
Norway
Oman
Pakistan
Palau
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Qatar
Russian Federation
Rwanda
Saint Kitts and Nevis
Saint Lucia
Saint Vincent and the Grenadines
Samoa
Serbia and Montenegro
Seychelles
Sierra Leone
Singapore
Solomon Islands
South Africa
Sri Lanka
Sudan
Suriname
Swaziland
Switzerland
Syrian Arab Rep.
Taiwan
Tajikistan
United Rep. of Tanzania
Thailand
Togo
Tonga
Trinidad and Tobago
Tunisia
Turkey
Turkmenistan
Uganda
Ukraine
United Arab Emirates
USA
Uruguay
Uzbekistan
Vanuatu
Venezuela
Viet Nam
Yemen
Zambia
Zimbabwe

Chapter Four

FMD Alters Market Share in Pork Exports

4.1 Introduction

The Sanitary and Phytosanitary (SPS) Agreement concerning FMD continues as a major barrier regarding trade for countries, especially those which are free of foot-and-mouth disease (FMD). International pork trade has been affected by FMD outbreaks which lead disease-free exporters to gain market share. Global production and consumption of pork during 1996 to 2007 rose substantially (Table 1.1 and 1.2). The demand for pork clearly offers opportunities for disease-free pork producers to expand international sales. The growth of global pork exports and imports is shown in tables 1.3 and 1.4. The ranking of the top 20 pork exporters and importers have shuffled noticeably because of import bans from FMD-free importers. Hence, global pork export patterns have been influenced by FMD events.

Following the findings in chapter three, pork exports fall when an exporting country develops FMD. Exporters with a vaccination policy have larger negative impacts than those with a slaughter policy. Further, pork importers that develop FMD and institute a slaughter policy will import more pork, but importers with a vaccination policy import the same level of pork. The findings in chapter two reveal that FMD impacts on importing countries lead to increase imports from the U.S. FMD-affected importing countries are potential pork markets for the U.S., yet only importing countries with a vaccination policy increase pork imports from the U.S. The difference in the findings between chapters two and three indicates that other pork exporters may have more advantages to cover the increased needs for FMD-affected importers with a slaughter policy.

This chapter investigates foreign FMD impacts on these major FMD-free exporters. The aggregate export share of the top 20 pork exporters has declined (table 1.3), and only ten exporters have a positive growth in export share from 1996 to 2007. Among these ten exporters, Canada, USA, Germany, and Spain are ones which have FMD-free status for many decades. The first objective of this article is to investigate foreign FMD impacts on pork exports of these four countries. According to our previous findings with the gravity modeling, the empirical model with no fixed effects and no zero-valued trade showed the most robust and consistent results. In order to compare the same results for the U.S. with the other three countries, the set-up of the empirical model will follow the same structure as in chapter two. In addition, Canada and USA are grouped as an FMD-free North American exporter, and Germany and Spain are grouped as an FMD-free European exporter. North American and European exporters are distinctively different from each other by location and surrounding countries. The second objective of this article is to evaluate foreign FMD impacts on North American and European exporters. Especially when these exporters face different surrounding countries and face different distances to their importers, foreign FMD may impact differently based on these factors.

Figure 1.1 exhibits that some countries adopted a slaughter policy and others adopted a vaccination. Vaccination was abandoned by the European Union (EU) in 1991 because FMD was successfully eradicated (Horst et al. 1999). Hence, the slaughter policy has only been adopted in European countries since 1991. Most countries with a vaccination policy are in South America and Asia. These different policies adopted by FMD-affected countries may alter market competition in pork exports. Therefore, these different policies, slaughter and vaccination, will be included in the empirical model which explains exports for the four exporters.

Besides the FMD factor, the existence of a regional trade agreement (RTA) is a key factor for competitive exporters. The RTA factor in this study covers: Free Trade Agreements (FTAs), Economic Integration Agreements (EIAs), Preferential Trade Agreements (PTAs), and Customs Union (CU). Canada has two RTAs: the European Free Trade Agreements (EFTAs) and the North American Free Trade Agreement (NAFTA). Canada also has several FTAs and EIAs with individual countries. The U.S. has two RTAs: the Dominican Republic-Central America-United States Free Trade Agreement (CAFTA-DR) and the NAFTA. The U.S. also has many agreements with individual countries, such as FTAs and EIAs. Germany and Spain are member countries of the European Union, and they have the EFTA, and several FTAs with many individual countries. Hence, an RTA variable is included for the analysis of market competition.

4.2 Literature Review

Gravity model has been widely used to investigate and examine bilateral trade (Anderson, 2008). Many scholars have applied and improved the measurement of gravity model for the impacts of regulations, policies, and standards on food trade (Swann, Temple, and Shurmer 1996; van Beers and van den Bergh 1997; Peridy, Guillotreau, and Bernard 2000; Wilson and Otsuki 2004; Anderson and van Wincoop 2004; Santos-Silva and Tenreyro 2006; Anders and Caswell 2009; Kim and Koo 2011). Their research with gravity models has recognized possible endogeneity problems and the presence of heteroskedasticity, and their findings with the gravity model reveal a robust and consistent result. Hence, this study also uses a gravity model.

A highly contagious disease, such as FMD, can result in tremendous impacts on a domestic economy and animal health risk. Rushton (2009, p.199) mentioned that “FMD is probably the most important disease in the world in terms of economic impact.” Countries gain from trade because exporters can concentrate to effectively produce their products and import the products that they do not effectively produce (Reed 2001). When countries are more dependent on each other, the economic impacts can be highly interrelated. Hence, the economic impacts are not only from domestic FMD outbreaks but also from foreign FMD outbreaks via international trade.

Few studies have focused on the FMD impacts from foreign markets. Yang and Saghaian (2010) investigated the economic impacts of foreign FMD outbreaks on U.S. pork exports to seventeen FMD-affected countries. Their findings show that U.S. pork exports have increased by 241% in volume because of FMD outbreaks in those seventeen countries. Furthermore, Yang, Reed, and Saghaian (2010) found that different treatment policies, slaughter and vaccination, lead to different economic outcomes. The question here is whether other major pork exporters face the same market opportunity as the U.S. from FMD events? Indeed, FMD-free exporters would not necessarily have the same market opportunity as the U.S. due to several factors, such as distance, trade barriers, and FMD treatment policies.

Many countries have suffered from FMD impacts on their domestic economy. On March 14, 1997, the first case of FMD in Taiwan was reported. Taiwan had been one of the major players in pork exports since the mid-1980s. Before the FMD outbreaks in 1997, Taiwanese pork exports accounted for 15 percent of world pork exports, and about 99.4 percent of those pork exports went to Japan (Fuller, Fabiosa, and Premakumar 1997). An import ban was applied to Taiwanese pork exports after the FMD outbreaks, so the international market lost 15 percent of its pork supplies from Taiwan in 1997. Taiwan accounted for 41 percent of total Japan pork imports before the outbreak. Huang (2000) estimates that this 41 percent shortage was made up by the U.S. (23 percent), Denmark (18 percent), and Canada (5 percent). As one exporter loses its market share from the disease, other exporters gain market share.

Another example of FMD impacts on pork exports is Brazil. Brazil's pork and beef industries are affected by FMD outbreaks, but the pork sector has been more disadvantaged than the beef sector (UN/FAO 2006). Brazilian pork exports are heavily dependent on the market of the Russian Federation (about 65% of total Brazilian pork exports (UN/FAO 2006)). Though FMD impacts on Brazilian pork exports have been influenced (about 60 importers imposed restrictions on Brazilian pork), a resumption of pork exports to the Russian Federation within a year of the FMD outbreak implies a fast recovery. Certainly, Santa Catarina (the only state in Brazil under FMD-free status and without a vaccination policy) may help Brazil to maintain pork exports.

The Office International des Epizooties (OIE) sets rules on schedules for moving countries from FMD-affected to FMD-free status (UN/FAO 2006). Not all FMD-affected countries return to FMD-free status at the same period. There are two types of FMD-free conditions: FMD-free with vaccination and FMD-free without vaccination. The difference between these two conditions is that FMD-free countries without vaccination are able to export, while FMD-free countries with vaccination are not. When an FMD outbreak occurs in an FMD-free zone where vaccination is not practiced, the OIE requires a waiting period as following:

- 3 months after the last case of stamping out
- 3 months after the slaughter of all vaccinated animals where a stamping out policy is imposed
- 6 months after the last case or the last vaccination where a stamping out policy was not applied.

When an FMD outbreak occurs in an FMD free zone where vaccination is practiced, the OIE requires the waiting period as one of following:

- 6 months after last case where stamping out is applied; or
- 18 month after the last case where a stamping out policy is not applied.

Products from countries that are FMD-free without vaccination usually command higher prices. Both live animals and meat products from such countries can export to other FMD-free or FMD-affected countries. In contrast, products from countries which are

FMD-free through vaccination are restricted because a vaccinated animal cannot be distinguished from an infected animal. If one country adopts a slaughter policy for an FMD outbreak, it takes at least 6 months to become FMD-free without vaccinations. As a result, the competitive environment for pork exports can be isolated when one country is FMD-affected or FMD-free through vaccination.

4.3 Data Description and Empirical Models

4.3.1 Data Description

The model is estimated for Canada, the U.S., Germany and Spain with data for their 181 importing countries from 1996 through 2007. Bilateral trade flows (X_{jt}) in U.S. dollars for Harmonized System (HS) coding 0203, which is meat of swine, fresh, chilled, and frozen, are obtained from the United Nations Commodity Trade Statistics Database (http://comtrade.un.org). Real GDP (*RGDP*) is derived from the FAS/ USDA (http://www.ers.usda.gov/Data/Macroeconomics) in U.S. dollars. The *FMD* records for each policy, slaughter and vaccination, are collected from the OIE (http://www.oie.int/hs2/report.asp?lang=en). The indicators of distance, contiguity, colonial relations, and common language are from the Centre d'Etudes Prospectives et d'Informations Internationales (http://www.cepii.fr/anglaisgraph/bdd/ distances.htm). The *RTA* variable for Canada, USA, Germany, and Spain came from the WTO website.

The definition of variables is shown in table 4.1 and the sample statistical summary of each variable for each country is shown in table 4.2. Annual averaged total values of pork exports among 181 importing countries for Canada, USA, Germany, and

Spain are $19, $18, $18, and $17 million in U.S. dollars, respectively. The importers' average RGDP for Canada, USA, Germany, and Spain is $507, $322, $404, and $457 billion (U.S. dollars) annually, respectively. The average distance between the largest urban areas for Canada, USA, Germany, and Spain is 7613, 9369, 3852, and 3929 kilometers, respectively. Eighty-four of the importing countries include English as an official language (about 36% and 31% of the observations for Canada and USA, respectively). Three importing countries (5% of the observations) use German as their official language. Twenty-one countries (almost 12% of the observations) use Spanish as their official language. The U.S. has a colonial linkage with Philippines, and Spain has a colonial linkage with Equatorial Guinea. From 1996 to 2007 over 58 countries had FMD outbreaks (about 15%, 15%, 10%, and 10% of the observations for Canada, USA, Germany, and Spain, respectively). Over 6% of the observations have an RTA connection with Canada and USA, and over 37% and 44% of the observations have an RTA linkage with Germany and Spain (through the E.U.), respectively.

4.3.2 Empirical Models

Our first objective is to investigate foreign FMD impacts on pork exports for Canada, the U.S., Germany, and Spain. In order to compare the same results of the U.S. with the other three countries, the set-up of the empirical model in this study is identical to chapter two. The estimation of the gravity equation for U.S. pork exports provided robust and consistent results when fixed effects and zero observations were not included. Hence, the gravity equation used in this section will not include fixed effects and zero observations for easier comparison among these four countries. Further, the gravity equation is applied using the PPML estimator.

For the distinguishing convenience of each empirical model on each country, the gravity model for each country is as following:

(A) Canada

(4.1) $\ln X_{jt}^{C} = \alpha_0 + \alpha_1 \ln(RGDP_{jt}) + \alpha_2 \ln(Dist_j^{C}) + \alpha_3(Lang_j) + \alpha_4(Col45_j) + \alpha_5(Contig_j) +$

$\alpha_6(RTA_{jt}) + \alpha_7(FV_{jt}) + \alpha_8(FS_{jt}) + \varepsilon_{jt}$

(B) USA

(4.2) $\ln X_{jt}^{U} = \beta_0 + \beta_1 \ln(RGDP_{jt}) + \beta_2 \ln(Dist_j^{U}) + \beta_3(Lang_j) + \beta_4(Col45_j) + \beta_5(Contig_j) +$

$\beta_6(RTA_{jt}) + \beta_7(FV_{jt}) + \beta_8(FS_{jt}) + \varepsilon_{jt}$

(C) Germany

(4.3) $\ln X_{jt}^{D} = \gamma_0 + \gamma_1 \ln(RGDP_{jt}) + \gamma_2 \ln(Dist_j^{D}) + \gamma_3(Lang_j) + \gamma_4(Col45_j) + \gamma_5(Contig_j) +$

$\gamma_6(RTA_{jt}) + \gamma_7(FV_{jt}) + \gamma_8(FS_{jt}) + \varepsilon_{jt}$

(D) Spain

(4.4) $\ln X_{jt}^{E} = \delta_0 + \delta_1 \ln(RGDP_{jt}) + \delta_2 \ln(Dist_j^{E}) + \delta_3(Lang_j) + \delta_4(Col45_j) + \delta_5(Contig_j) +$

$\delta_6(RTA_{jt}) + \delta_7(FV_{jt}) + \delta_8(FS_{jt}) + \varepsilon_{jt}$

In equations (4.1) to (4.4), *t* denotes time and *j* denotes importing country; $\ln X_{jt}$ is the log of pork export value from Canada, U.S., Germany, or Spain to importing country *j* in time *t*; the superscript *C*, *U*, *D*, and *E* in $\ln X_{jt}$ and $Dist_j$ denotes Canada, USA, Germany, or Spain, respectively. $RGDP_{jt}$ is the real gross domestic product of the importing country as a proxy for economic size. $Dist_j$ is the distance between each of these four countries and importing country *j* used as a proxy for transportation costs for each country. Other geographic and preference similarities, such as sharing a common language $(Lang_j)$, having colonial linkages since 1945 $(Col45_j)$, and two countries that are contiguous $(Contig_j)$, are commonly used in gravity equations. RTA_{jt} is a dummy variable indicating the existence of a regional trade agreement between the exporting country and importing country *j* in time *t*. The variable $FV_{jt}(FS_{jt})$ denotes a dummy variable indicating whether the importing country *j* in time *t* under FMD status adopted a vaccination (or a slaughter) policy. The ε_{jt} is assumed to be a log-normally distributed error term.

After our analysis on the impacts of foreign FMD for each of these four countries, we further examine and compare these four countries as North America versus European pork exporters. Canada and the U.S. are grouped as the North American FMD-free exporter; Germany and Spain are grouped as the European FMD-free exporter. The sample data of Canada and the U.S. are merged into a North America data set, and the sample data of Germany and Spain are merged as a European data set. The empirical model for North American and European pork exports is individually applied using the same gravity equation. Hence, the empirical results of these two estimations for North American and European pork exports can be compared to investigate competition between these two continents.

4.4 Empirical Results

The value of pork exports was the dependent variable for each exporter, i.e., Canada, USA, Germany, and Spain. The empirical results for the first objective are shown in table 4.3. The empirical results for the U.S. are the same as finalized results in chapter two which indicate that only importing countries with a vaccination policy are more likely to increase pork imports from the U.S. Overall, the empirical results for these four countries are significantly different from zero and have the expected sign in this gravity equation.

For Canada, the coefficients for $RGDP_{jt}$, $Lang_j$, $Contig_j$, and RTA_{jt} in equation (4.1) have the expected signs and are significantly different from zero. The empirical results of real GDP for Canada reveal that pork importers are likely to import more from Canada when the importing country has a higher standard of living. Importing countries with English as the official language are also likely to import more from Canada. The only adjacent country, the U.S., imports more pork from Canada than the average country. A regional trade agreement with an importing country stimulates pork imports from Canada. The coefficients for $Dist_j$, $Col45_j$, and FV_{jt} are not significantly different from zero, but the coefficient for FS_{jt} has a negative sign and is significant at the 10% level. This implies that pork importing countries decrease pork imports from Canada when they have an FMD outbreak and use a slaughter policy. This is an example where some pork exporters are negatively affected when an importing country has an FMD outbreak. Those importers adopting a vaccination policy maintain the same level of trade with Canada.

For the U.S., the coefficients for $RGDP_{jt}$, $Dist_j$, $Col45_j$, and RTA_{jt} in equation (4.2) have the expected sign and are significantly different from zero. When the importing country has a higher standard of living, importing counties increase pork imports from the U.S. The larger distance between countries means higher transportation costs, so the negative sign is expected. Apparently, Philippines has higher pork imports from the U.S. because the dummy variable for colonial ties is positive and significant. Regional trade agreements with importing countries spur U.S. pork exports too. Note that the U.S. shares the same official language with Canada, but language plays no role in U.S. pork exports (in contrast to Canada). The coefficient for FV_{jt} has the expected sign and is significant at the 5% level. The aggregate impacts of foreign FMD are positive to U.S. pork exports because pork importers with a vaccination policy increase purchases. The coefficient for FS_{jt} is not significantly different from zero; pork importers that have FMD and adopt a slaughter policy don't change their imports from the U.S.

For Germany, the coefficient for $Lang_j$ is not significantly different from zero, the coefficients for $RGDP_{jt}$ and $Dist_j$ in equation (4.3) have the expected sign and are significantly different from zero. Importers with a higher standard of living import more pork from Germany. Longer distances (and higher transportation costs) limit imports from Germany. The coefficient for $Contig_j$ is significantly different from zero but has a negative sign. Germany is surrounded by Denmark, Netherlands, Belgium, France, Austria, and Poland. These countries are also among the top 20 major pork producers and exporters, so it is reasonable that Germany has a negative sign in $Contig_j$. Regional trade agreements don't seem to affect German pork exports, but the coefficients for FV_{jt} and FS_{jt} are significantly different from zero. With positive signs for the coefficients on FV_{jt}

and FS_{jt}, German pork exports are positively impacted with an FMD outbreak no matter which policy they adopted. Germany seems to be the exporter that is most positively affected by FMD outbreaks. Among these four countries, only the U.S. and Germany are able to capture pork import markets that adopt a vaccination policy. Further, only Germany is able to increase pork exports to markets that adopt a slaughter policy.

For Spain, the coefficients for $RGDP_{jt}$, $Dist_j$, $Col45_j$, $Contig_j$, and RTA_{jt} in equation (4.4) have the expected signs and are significantly different from zero. Countries with higher income import more pork from Spain and Spanish pork exports are hindered by long distances. Former Spanish colonies and adjacent countries also have higher import levels from Spain. Regional trade agreements enhance Spanish pork exports. The coefficient for $Lang_j$ is significantly different from zero and has a negative sign. This implies that importers with Spanish as their official language imports less pork from Spain. Countries with Spanish as their official language are either a long distance from Spain or are major pork producers; so there is a negative relationship between imports from these countries and Spain. The coefficients for FV_{jt} and FS_{jt} are not significantly different from zero, so FMD-affected importers maintain their pork import levels from Spain.

The four countries can be ranked for the degree that their exports increase from an FMD outbreak. Germany ranks first, the U.S. ranks second, Spain is third, and Canada is fourth. This ranking is dependent on the specific FMD outbreaks that occurred during the observation period; for instance an FMD outbreak in Western Europe that benefits German pork exports. An analysis that combines data for North American (Canada and the U.S.) and European (Germany and Spain) pork exporters might also be instructive. The empirical results for North America and European exporters are provided in table 4.4.

In the North America case, the coefficients for $RGDP_{jt}$, $Dist_j$, $Lang_j$, $Col45_j$, $Contig_j$, RTA_{jt}, and FV_{jt} have the expected signs and are significantly different from zero, except for the coefficient for FS_{jt}. Overall, North American exporters ship more pork when importing countries have a higher standard of living, relatively lower transportation costs, English as their official language, a colonized relations with Canada or the U.S., adjacent to Canada or the U.S., in a regional trade agreement with Canada or the U.S., and FMD events with countries using a vaccination policy. The FMD-affected markets that adopted a slaughter policy kept their imports from North America unchanged.

In the European exporter case, the coefficients for $RGDP_{jt}$, $Dist_j$, $Col45_j$, RTA_{jt}, FV_{jt}, and FS_{jt} have expected sign and are significantly different from zero except for the coefficient for $Contig_j$. In general, European countries export more pork when importing countries have higher income, relatively lower transportation cost, colonized relations with Germany or Spain, a regional trade agreement with Germany or Spain, and are FMD-infected using either a slaughter or vaccination policy. The coefficient for $Contig_j$ is not significantly different from zero because the effects for Germany and Spain cancel each other; they have the opposite outcome for the adjacent countries in table 4.3. The coefficient for $Lang_j$ is significantly different from zero and has a negative sign, similar to the results with Spain. Since the coefficient for $Lang_j$ consists of two languages for European exporters, German and Spanish, we know that Spanish dominated the coefficient for $Lang_j$ in the empirical findings between German and Spanish. Many importers with Spanish as the official language are also major pork producers and exporters in the world, so they import less pork from Germany and Spain.

Importing countries that suffer from FMD and employ a slaughter or vaccination policy increased their pork imports from European countries. Moreover, the markets of pork importers with a slaughter policy are primary provided by European exporters rather than North American exporters. This finding likely stems from the abandonment of vaccination policies by the European Union in 1991. Most countries with a slaughter policy are in Europe, as reflected in figure 1.1, so this proximity to countries with a slaughter police naturally benefits European pork exporters because they have an advantageous location and lower transportation costs than North American exporters. Furthermore, though North American and European exporters benefit when importers adopt a vaccination policy, the coefficient for FV_{jt} shows Europeans receiving larger positive impacts than North American exporters.

4.5 Conclusions

FMD outbreaks have altered international pork trade among exporters and importers. Past research findings have shown: first, pork exports decline when an exporting country develops FMD, and exporters with a vaccination policy have larger negative impacts than those with a slaughter policy; second, overall pork imports increase when an importing country institutes a slaughter policy, but importers with a vaccination policy import the same level of pork. However, the competition among pork exporters is different for each exporting country. For U.S. pork exports, importers with a vaccination policy tend to increase pork imports from the U.S., but importers with a slaughter policy do not change their trade with the U.S.

The FMD events during 1996 to 2007 greatly impacted global pork trade. Among the top 10 pork exporters, only Canada, U.S., Germany, and Spain showed strong growth in exports during that time. These four countries are FMD-free and have not had an outbreak, so they have not had bans imposed through the SPS agreements on FMD. Markets for FMD-affected pork imports have been captured by Germany no matter which policy is adopted by importing countries; the FTA that many countries have with Germany through the European Union is also helpful. The U.S. only seems able to capture increased exports when the importing country adopts a vaccination policy. FMD outbreaks don't seem to affect Spain pork exports, but they negatively impact Canadian pork exports when the importers adopt a slaughter policy. Hence, the empirical results reveal that Germany gains the most among these four countries when there is an FMD outbreak; the U.S. is next; followed by Spain and Canada.

When the market competition between North American and European exporters is analyzed, importing countries with either slaughter or vaccination policies increase their pork imports from European countries when they have an FMD outbreak. However, North American pork exporters still hold markets where FMD-affected pork importers adopt a vaccination policy. Moreover, the pork import markets with a slaughter policy are primarily provided by European exporters rather than North American exporters. Hence, the analysis of pork exports between North America and European exporters shows that European countries have a better competition position than North American exporters when importing countries have FMD outbreaks.

The different competitive environment between North American and European pork exporters during FMD events may link to several factors. First, vaccination policies were abandoned by the European Union after 1991 due to the successful eradication of FMD. Thus, most countries with a slaughter policy are European and other European pork exporting countries which are FMD-free are the largest beneficiaries. European countries are simply closer to countries that use a slaughter policy, so their exports are positively affected when an outbreak occurs and a slaughter policy is used. This situation benefits European pork exporters because they have locational advantages and lower transportation costs than North American exporters. Second, though North American and European exporters increase sales when importers adopt a vaccination policy, European exporters still receive larger positive impacts than North American exporters. Consequently, the analysis reveals that European exporters are relatively advantaged when there is an FMD outbreak.

Table 4.1: Definitions of Variables for Canada, USA, Germany, and Spain

Variables	Description of variables
Exports^{CAN} (X_{jt}^{C})	Annual average total value of pork exports from Canada (U.S. millions)
Exports^{USA} (X_{jt}^{U})	Annual average total value of pork exports from the U.S. (U.S. millions)
Exports^{DEU} (X_{jt}^{D})	Annual average total value of pork exports from Germany (U.S. millions)
Exports^{ESP} (X_{jt}^{E})	Annual average total value of pork exports from Spain (U.S. millions)
RGDP ($RGDP_{jt}$)	Annual real GDP for each importing countries (U.S. dollar 2005 base – billions)
Distance^{CAN} ($Dist_{j}^{C}$)	The shortest distance from the largest population regions to Canada (Kilometers)
Distance^{USA} ($Dist_{j}^{U}$)	The shortest distance from the largest population regions to the U.S. (Kilometers)
Distance^{DEU} ($Dist_{j}^{D}$)	The shortest distance from the largest population regions to Germany (Kilometers)
Distance^{ESP} ($Dist_{j}^{E}$)	The shortest distance from the largest population regions to Spain (Kilometers)
Com-Lang ($Lang_{j}$)	Binary variable=1 if importing countries use same official language with Canada, USA, Germany, or Spain
Col45 ($Col45_{j}$)	Binary variable=1 if importing countries had colonial linkage with Canada, USA, Germany, or Spain since 1945
Contiguity ($Contig_{j}$)	Binary variable=1 if importing countries have land connected with Canada, USA, Germany, or Spain
RTA (RTA_{jt})	Binary variable=1 if importing countries had RTA relations with Canada, USA, Germany, or Spain
FMD*V (FV_{jt})	Binary variable=1 if importing countries had FMD outbreaks and applied a vaccination policy
FMD*S (FS_{jt})	Binary variable=1 if importing countries had FMD outbreaks and applied a slaughter policy

Table 4.2: Sample Statistics of Variables

Variables	Canada (n = 713)				USA (n = 941)				Germany (n = 730)				Spain (n = 584)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Exports (X_{jt})	19	94	0	783	18	99	0	1,100	18	65	0	741	17	59	0	578
RGDP ($RGDP_{jt}$)	507	1,592	0.276	13,050	322	681	0.199	4,467	404	1,196	0.244	13,050	457	1,097	0.215	13,050
Distance ($Dist_j$)	7,613	3,560	1,154	15,445	9,369	3,470	1,154	16,357	3,852	3,760	281	18,216	3,929	3,227	346	17,016
Com-Lang ($Lang_j$)	0.356	0.479	0	1	0.313	0.464	0	1	0.049	0.216	0	1	0.116	0.321	0	1
Col45 ($Col45_j$)	0	0	0	1	0.012	0.112	0	1	0	0	0	1	0.018	0.136	0	1
Contiguity ($Contig_j$)	0.016	0.128	0	1	0.025	0.157	0	1	0.128	0.335	0	1	0.041	0.198	0	1
RTA (RTA_{jt})	0.058	0.235	0	1	0.061	0.240	0	1	0.371	0.483	0	1	0.446	0.497	0	1
FMD*V (FV_{jt})	0.106	0.308	0	1	0.095	0.294	0	1	0.064	0.245	0	1	0.071	0.258	0	1
FMD*S (FS_{jt})	0.050	0.219	0	1	0.051	0.220	0	1	0.042	0.073	0	1	0.037	0.190	0	1

Note: the unit for X_{jt} is U.S. millions; $RGDP_{jt}$ is U.S. billions; $Dist_j$ is kilometers.

Table 4.3: The Comparison of Pork Exports in Major FMD-Free Exporters

Dependent variable: X_{jt}	Canada	USA	Germany	Spain
$RGDP_{jt}$	0.038 ***	0.048 ***	0.047 ***	0.039 ***
	(0.004)	(0.003)	(0.004)	(0.004)
$Dist_j$	0.003	–0.110 ***	–0.156 ***	–0.116 ***
	(0.016)	(0.010)	(0.009)	(0.015)
$Lang_j$	0.052 ***	0.015	–0.016	–0.117 ***
	(0.017)	(0.012)	(0.025)	(0.027)
$Col45_j$	.	0.119 ***	.	0.199 ***
		(0.029)		(0.039)
$Contig_j$	0.114 **	0.014	–0.057 ***	0.122 ***
	(0.049)	(0.038)	(0.022)	(0.021)
RTA_{jt}	0.135 ***	0.073 **	0.022	0.083 ***
	(0.028)	(0.030)	(0.019)	(0.022)
FV_{jt}	0.037	0.047 **	0.081 ***	0.046
	(0.023)	(0.024)	(0.037)	(0.040)
FS_{jt}	–0.046 *	–0.004	0.070 ***	0.046
	(0.028)	(0.030)	(0.035)	(0.028)
N. of sample	708	941	730	584
AIC	3420.250	4443.856	3532.419	2818.822
BIC	3456.749	4487.479	3569.164	2858.151
Log Likelihood	–1702.125	–2212.928	–1758.210	–1400.411

Note: * 10% significance, ** 5% significance, and *** 1% significance;
Parentheses represent standard errors.

Table 4.4: The Comparison of Market Competition (North America v.s. European)

Dependent variable: X_{jt}	North America		European	
$RGDP_{jt}$	0.043	***	0.044	***
	(0.002)		(0.003)	
$Dist_j$	–0.065	***	–0.139	***
	(0.009)		(0.008)	
$Lang_j$	0.031	***	–0.086	***
	(0.010)		(0.017)	
$Col45_j$	0.085	***	0.193	***
	(0.024)		(0.034)	
$Contig_j$	0.066	**	0.007	
	(0.028)		(0.017)	
RTA_{jt}	0.082	***	0.054	***
	(0.020)		(0.014)	
FV_{jt}	0.045	***	0.064	**
	(0.016)		(0.027)	
FS_{jt}	–0.022		0.062	***
	(0.021)		(0.024)	
N. of sample	1649		1314	
AIC	7864.183		6347.113	
BIC	7912.855		6393.740	
Log Likelihood	–3923.092		–3164.556	

Note: * 10% significance, ** 5% significance, and *** 1% significance;
Parentheses represent standard errors.

Chapter Five

Summary and Conclusion

5.1 Summary

Chapter one gives a brief introduction to SPS Agreements, the impacts of FMD outbreaks, world pork markets (pork production, pork consumption, pork exports, and pork imports), slaughter and vaccination policies, and the illustration of FMD impacts on FMD-free and -affected exports and imports. The rank order of pork exporters and importers is highly correlated with FMD events in the world. Hence, the contribution of this dissertation is to investigate the impacts of FMD on international pork trade and further study market competition among the major FMD-free exporters that do not use vaccination, i.e., Canada, the U.S., Germany, and Spain.

Chapter two provides an analysis of foreign FMD impacts on U.S. pork exports. The analytic approach used is a gravity model which is compared with a spatial econometric model. The investigation of foreign FMD events on U.S. pork exports shows that FMD impacts on importing countries lead to increased imports from the U.S. The empirical results for spatial econometric and gravity models are similar and consistent when fixed effects and zero observations are excluded. The results of Cragg's model also reveal that FMD-affected importing countries are potential pork traders with the U.S., but only importing countries with a vaccination policy are more likely to increase pork imports from the U.S. This empirical result reveals a special finding for U.S. pork exports. Our analysis of FMD-affected pork importers illustrates that pork importers will import more when they adopt a slaughter policy and will not specifically import more if they adopt a vaccination policy.

Chapter three focuses on pork trade among 186 countries from 1996 to 2007. International pork trade has not only been influenced by trade agreements but also altered by consumer perceptions on FMD-infected animals. This chapter uses a gravity model with fixed-effects to investigate how pork trade is affected by FMD among 186 countries. Results confirm that pork exports fall when an exporting country develops FMD. Exporters with a vaccination policy have larger negative impacts than those with a slaughter policy. Further, pork importers that develop FMD and institute a slaughter policy will import more pork, but importers with a vaccination policy import the same level of pork. This reflects the differentiation of export markets among pork exporting countries, so this implies that some countries have gained more pork sales while foreign countries had FMD outbreaks during 1996 to 2007. Based on the growth of the top 10 pork exporters in table 3, four FMD-free pork exporters, i.e., Canada, the U.S., Germany, and Spain, have gained larger share of export markets from 1996 to 2007, so the market competition among these four countries is evaluated in chapter four.

Chapter four extends the study of foreign FMD impacts to four major pork exporters, Canada, the U.S., Germany, and Spain. For comparison convenience, the research methodology in this investigation also applies a gravity model that is identical to the final model for U.S. pork exports in chapter two. Results confirm that the impacts of foreign FMD have altered pork exporters differently. Germany has gained the most exports during foreign FMD outbreaks in importers no matter which policy is applied; the U.S. has the second most positive effect on pork exports; Spain's exports remain at the same level with both slaughter and vaccination policies; and Canada's exports are negatively affected when the FMD-infected importer adopts a slaughter policy. European exporters have advantages over North American exporters because the E.U. prohibited a vaccination policy after 1991, which lead to many FMD-affected European countries slaughtering animals. Hence, European pork exporters have locational advantages and lower transportation costs to those markets than North American exporters.

5.2 Policy Implication

FMD-infected countries can adopt either a slaughter or vaccination policy. The economic impacts of these two policies are different for exporting and importing countries. Countries adopting different policies lead to different impacts on the market share of pork exports too, such as Canada, U.S., Germany, and Spain.

In the short-run, the slaughter policy creates increased potential demand for pork imports, especially from surrounding exporting countries rather than from far away countries. For instance, Canadian pork exports are negatively affected when an FMD-infected country adopts a slaughter policy. Particularly, Canada has more trade agreements with European countries than the U.S. Many European countries adopt a slaughter policy if they have an FMD outbreak, and it creates a market opportunity for the major pork exporters in European countries. Therefore, the market share for Canadian pork exports can be affected when their importing countries adopted a slaughter policy.

The impacts of a vaccination policy do not respond the same way as a slaughter policy. Countries with a vaccination policy tend to have longer period of disease impacts. The potential for increased pork imports is lower because production impacts are smaller. FMD-free exporting countries, like the U.S. and Germany, may be able to increase their market share if importing countries have further impacts from an FMD outbreak. However, not all FMD-free exporting countries benefit from these market opportunities when FMD-infected importing countries adopt a vaccination policy. On the other hand, U.S. and Germany pork exports exhibit an advanced competition and increased market share when FMD outbreaks have taken place around the world.

5.3 Conclusions

Food safety scares affect consumption behavior, and further increasingly impact international pork trade. The SPS Agreement among WTO member countries has not only prevented the spread of disease to further ensure safe food, but also significantly changed pork trading patterns. A total of over 255 FMD outbreaks greatly impacted international pork trade during 1996 to 2007. Approximately 58 countries were infected by FMD outbreaks during this period, so pork markets have segmented into FMD-free and FMD-affected areas for pork trade. The attention of this dissertation on this differentiation focuses on the international trade of FMD-free exporters and FMD-affected importers.

The U.S., one of the FMD-free pork exporters, has been FMD-free for many decades. Foreign FMD outbreaks enhanced U.S. pork exports during 1996 to 2007, and further boosted U.S. pork market share in global market. U.S. pork exporters have gained sales to FMD-affected pork importers when a vaccination policy is adopted. Although U.S. pork exports remain constant when a slaughter policy is adopted, the market share of U.S. pork exports in global pork trade has grown by 100% from 1996 to 2007. FMD has been an important factor that has allowed U.S. pork exporters to export more pork to other markets.

The global market share of pork exports for Canada, the U.S., Germany, and Spain have grown 40%, 100%, 226%, and 114% during 1996 to 2007, respectively. Each country has different advantages in pork exports. If these four countries seem as the market share of pork exports for North America and European, then it ranges from 140% to 340%, respectively. The global market shares of pork exports for North America and European also confirm our empirical findings that European exporters have relatively advantageous than North America exporters in market competition. Among European exporters, Germany represents most competitive in pork export markets during the impacts of FMD outbreaks. Though the market competition of North America exporters are not able to compete with European exporters, the U.S. still represents the second competitive in pork export market than Spain and Canada. The advantage of Germany in pork exports reveals that location related with cost benefits contributes a big factor to Germany pork exports.

The trade agreements between exporters and importers remove most- or partial-barriers in agricultural trade which has not only benefit domestic producers' but also foreign consumers' welfare. Though the impacts of FMD outbreaks affect international pork trade during 1996 to 2007, the RTA participate an important element when trading partners had FMD outbreaks. The empirical findings of the RTA show that most countries have traded for pork because of the trade agreements. This implies that FMD-affected countries would have pork trade with their member countries when importing countries had FMD outbreaks.

The comparison between spatial econometric and gravity models has revealed that the gravity PPML model exhibits a consistent result when fixed effects and zero observations are not included. The empirical results between the gravity and spatial econometric models are very comparable. Although gravity models have often been raised with the concerns of endogeneity and heteroskedasticity, the application of gravity model in our study has paid a special attention on these issues and coped with different estimators and fixed effects in contrast with AIC, BIC, and log likelihood for goodness of fit. The issue of zero trade flows is the most relative to the issues of endogeneity and heteroskedasticity. Additionally, the estimator used in this dissertation also contributes to an extremely large number of zero observations (over 96% of zeros in the dependent variable) to the PPML estimator. Given the results of Cragg’s and Heckman models, zero observations are properly decided whether zeros should be included or excluded. The PPML estimator shows its application successfully when including this extreme number of zeros.

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