SIMULATING THE IMPACTS OF AGROTERRORISM ON U.S. FINANCIAL MARKETS AND REGIONAL ECONOMIC PERFORMANCE

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ABSTRACT

The threat of terrorism against the United States has been a primary concern of public policy makers, particularly after the attacks of September 11, 2001. Economic theory and statistical analysis provide valuable insights into the challenge of estimating the regional and national economic impacts of future attacks. Terrorist events represent exogenous shocks on the economy which can cause significant emotional and psychological damage. The initial chapters describe a simulation model that captures the impacts of agricultural terrorism (agroterrorism) on the economic performance of various sectors within a regional economy, while the final chapters examine the impacts of agroterrorism on U.S. financial markets.

I begin the analysis by examining the probable direct and indirect economic impacts of bioterrorism originating in St. Lawrence County, New York. The specific biological weapon examined is a foot-and-mouth disease (FMD) attack that disrupts the local agricultural food supply. A county-level simulation is valuable because it focuses on the immediate impact of FMD, providing useful estimates of the short-to-medium term impacts. The regional model contains in depth analysis of the livestock industry with specific links to regional tourism, and the results section includes impact estimates using a Social Accounting Matrix (SAM) framework.

St. Lawrence County serves as an interesting case study to explore supply-chain linkages, since the region depends heavily on its livestock and tourism industries which would suffer following an FMD attack. I perform simulations assuming that the attack has no direct impact on dairy farm products, before relaxing this assumption to account for economic impacts associated with parallel shocks to the livestock and dairy industries. The methodology focuses on estimating the economic implications of production and trade disruptions in the international market. The costs of

agroterrorism are estimated in terms of disruptions to regional output, employment, and value added for key sectors within the economy. I provide impact assessments for livestock, tourism, dairy, and all sectors within the region.

The direct costs of the attack within the region would reflect the initial output reductions, and the indirect costs would reflect changes in inter-industry transactions as supplying industries react to falling demand from the directly affected industries. Indirect effects significantly increase the magnitude of losses suffered by the economy as the damage flows beyond the industries directly impacted. These indirect effects would include losses suffered by related industries, such as firms engaged in food supply, transportation, distribution, and retail. The firm-level impacts are outside the scope of this research project.

The latter chapters explore the broader impacts on financial asset classes in equities, fixed income, and foreign exchange to produce real GDP growth rate forecasts using the Global Insight macroeconomic model of the U.S. economy. By linking to the macro model following the regional analysis, we can examine the economy-wide repercussions of a terrorist attack on U.S. agriculture. I will show that a state of financial uncertainty brought forth by terrorism can decrease consumer confidence, increase interest rates, increase credit spreads, dampen the stock market, and impact the value of the U.S. dollar relative to the currencies of trading partners.

I will demonstrate that extreme terrorist events tend to disrupt the normal relationships among financial asset classes. The results section for the macro impact model includes real GDP growth rate forecasts and projected real output losses. For both the regional and national models I draw on the literature to examine the attack under various assumptions regarding the severity of output reductions. I conclude with policy recommendations based on my findings, as well as directions for future research.

BIOGRAPHICAL SKETCH

Chris graduated from the University of Minnesota in May 2004 with a B.S. in applied economics and a minor in political science. That year Chris was awarded an assistantship to pursue graduate study in the Department of Applied Economics and Management at Cornell University. While at Cornell he worked as a teaching assistant in business management and international economics courses, and pursued his own coursework and research interests in economic theory and finance. After the first year of his graduate studies program, he worked as a research analyst on a project for the National Center for Food Protection and Defense. The project examined the potential macroeconomic impacts of a terrorist attack on the U.S. food supply. This research effort would later provide the foundation for his M.S. thesis topic. Chris graduated from Cornell in August 2006 with an M.S. in applied economics and a concentration in finance. He then started his new job covering food companies as an equity research analyst for Piper Jaffray in Minneapolis, Minnesota.

DEDICATED TO MY FAMILY

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CHAPTER ONE

BACKGROUND

1.1 Region of Study

The initial chapters focus on simulating the regional economic impacts of a foot-and-mouth disease (hereafter FMD) attack on local agricultural food supplies within St. Lawrence County, New York. A county-level simulation offers a valuable starting point because it focuses on the immediate consequences of FMD, providing conservative estimates of the short-to-medium term impacts. The time frame under consideration is short enough that the outbreak does not impose economic losses to neighboring regions, but long enough that the outbreak delivers measurable countywide repercussions. St. Lawrence Country contains primary livestock and tourism industries which would suffer following an FMD attack.

Agriculture and tourism, which are two sectors most vulnerable to agroterrorism, contribute significantly to the local economy. This county thus serves as a representative case to explore regional supply-chain linkages. Data collected in 2005 from the National Agricultural Statistics Service show that St. Lawrence County was in that year the largest producer of beef cows in New York, and was the second largest cattle-producing county with 73,000 head of cattle (Table 1). Table 2 provides summary data for the St. Lawrence County economy, compiled from the Impact Analysis for Planning (IMPLAN) database.

Table 1   New York County-Level Rankings of Cattle Production

New York County	All Cattle (# head)	Beef Cows (# head)	Dairy Cows (# head)
Wyoming	87,500	1,500	47,600

Table 1 (Continued)

St. Lawrence	73,000	3,900	36,900
Jefferson	67,100	3,300	32,000
Washington	59,000	1,500	23,500
Cayuga	58,900	1,900	30,100
State Total	1,410,000	80,000	650,000

Table 2 Key Economic Statistics for St. Lawrence County (2000 data)

Population	111,931
Area (square miles)	2,686
Employment	49,915
Households	40,527
Number of Industries	170
Income per Household	$54,512
Total Personal Income	$2,209,188,000

St. Lawrence County comprises 32 towns, 1 city, and 13 villages. In addition to a vital agricultural sector, the southeastern third of the county is a major tourist attraction. Within the Adirondack region, a patchwork of private and public lands encompasses several hamlets, scenic vistas, and wilderness areas that are open to the public for recreational use. There is significant tourism demand in St. Lawrence County for fishing, hunting, canoeing, cycling, bird watching, horseback riding, skiing, and water sports. The region has many hotels, motels, bed and breakfasts, campgrounds, parks, museums, restaurants, theater performances, and art centers. As will be explained shortly, an FMD attack would impact not only agricultural industries, but also industries engaged in tourism activity. Figure 1 shows the geographical location of St. Lawrence County.[1]

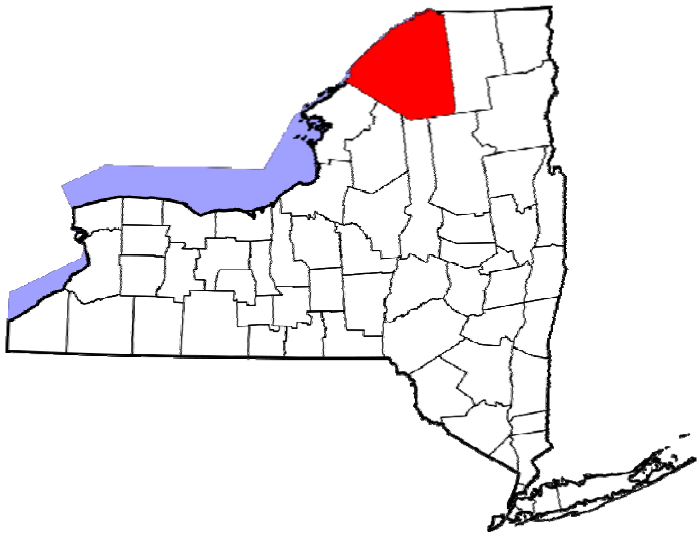

Figure 1   Geographical location of St. Lawrence County, New York

1.2 The Threat of Agroterrorism

An attack on agricultural crops would be more difficult to execute than an attack on livestock because the former requires favorable weather conditions and greater technical capabilities. Additionally, government officials and farmers have more experience coping with plant diseases than with livestock epidemics. In general livestock farming is more vulnerable to terrorist attacks than crop farming, because livestock are housed in very close proximity to one another. St. Lawrence County is particularly vulnerable to agroterrorism precisely because of its dependency on cattle production.

My research emphasizes the regional impacts of FMD, and assumes that the outbreak is contained within St. Lawrence County in the short-to-medium term.[2] The

[1] For more information about the St. Lawrence economy, refer to iloveny.com, the official New York State tourism website, or the New York Visitors Network at visitnewyorkstate.net/stlawrence. Map reproduced from www.answers.com/topic/st-lawrence-county-new-york.

regional model contains in depth analysis of the livestock industry with specific links to regional tourism. I examine a number of scenarios corresponding to different extents of the economic damage following such an outbreak. The size and distribution of the impacts over sectors and time would depend on a range of factors, including the nature of the attacks, the multiplier effects, the type of policies adopted in response to the attacks, and the resilience of the markets (Bruck and Wickstrom, 2004).

The results section first presents simulation output for 5 scenarios assuming direct impacts to livestock and tourism only, and no direct impacts to dairy farm products. I will then relax this assumption to account for the economic impacts of FMD with parallel shocks to the livestock and dairy industries. The direct impact of terrorist attacks depends on timing and place, and is highly unpredictable (Richardson et al., 2005). A quantitative framework is therefore needed to evaluate various alternatives, which in turn can contribute to the preparation of effective protection against bioterrorist threats.

Agricultural security in general is regarded as a high priority for the U.S. Department of Homeland Security.[3] FMD in particular is considered one of the three most serious foreign animal diseases, in addition to avian influenza and New Castle disease (Wilson et al. 2000). Of all animal diseases, FMD has the potential for greatest economic damage, due to its rapid spread and the expected loss of international customers. Pate and Cameron (2001) describe FMD as the agricultural equivalent to the use of small pox on humans, except that FMD is more readily available than

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[2] This assumption would not likely hold under longer time horizons; however, the analysis provides useful insights into the countywide repercussions immediately following an FMD attack. Should the disease become endemic, the costs to surrounding regions and the national economy would greatly exceed the estimates to be presented here. Due to the necessary assumptions built into the regional model, the impact estimates to follow should therefore be considered lower-bound estimates of the true value.

[3] The importance of agro-security, specifically foot-and-mouth disease, is described in “Homeland Security Selects Texas A&M University and University of Minnesota to Lead New Centers of Excellence on Agro-Security,” Department of Homeland Security Press Release, April 27, 2004.

smallpox. The OIE of the World Organization for Animal Health maintains a list of transmissible diseases, and FMD is the first disease on the OIE List A due to its economic importance and ease of transmission. List A diseases such as FMD are attractive agents for bioterrorism, because of the potential for rapid spread.

Attacks on agriculture are not necessarily intended to target humans, but are mostly a means of extortion, intimidation, or economic punishment (Pate and Cameron 2001). Chalk (2001) defines agroterrorism as the deliberate introduction of a disease agent, either against livestock or into the food chain, for purposes of undermining stability and/or generating fear.[4] The vulnerability of the U.S. food supply system was highlighted in a recent General Accounting Office report which casts doubt on the system's ability to detect and quickly respond to an agroterrorist attack. There are several lags built into the damage-control procedure, from the time it takes investigators to determine if the illness or disease was deliberately introduced, to the time it takes for procedures to be enacted and followed.

The agricultural sector is one of the easiest sectors of the economy to disrupt, and the likelihood of inflicting maximum damage from the interruption of agricultural food supplies is high (Cupp et al., 2004). An attack on agriculture should be regarded as a high-consequence, high-probability event that deserves greater attention than it is currently receiving. A terrorist group could obtain an anti-agricultural biological weapon by isolating it from the environment, obtaining it from microbe laboratories, or obtaining it from state sponsors.

[4] The case study examined in this paper qualifies as agroterrorism based on this definition. Enders and Sandler (2004) define terrorism as the premeditated use, or threat of use, of extra-normal violence by an individual or subnational group to obtain a political objective through intimidation or fear directed at a large audience usually beyond the immediate victims. Nestle (2003) defines food bioterrorism as "the deliberate poisoning or contamination of the food supply to achieve some political goal". See also Hoffman (1988), Mickolus (1982), and Schmid and Jongman (1988).

There exists a common misconception that agricultural pathogens are difficult to obtain and disseminate, when in fact an attack could be carried out by a series of infections generated by pathogens delivered to various public locations (Casagrande 2000). For example, the U.S. food supply could be attacked on the farm, in processing plants, in grocery stores, or at food service locations. Due to these multiple potential entry points typically associated with an open society, farms and agricultural systems have become increasingly susceptible to terrorist attacks aimed at destroying consumer confidence in the stability of food supplies.

1.3 Characteristics of the U.S. Food Supply System

The other source of vulnerability is the centralized nature of cattle production. The food system of St. Lawrence County and the greater United States is predicated on centralized production within a widespread distribution network. Improved agricultural efficiency through centralization has, in part, allowed American consumers to benefit by allocating a lower share of their personal disposable income on food expenditures than ever before. The remarkable efficiency of the food marketing and distribution system has been very successful at transporting large quantities of food over great distances and has contributed to these declining food costs. Agricultural producers adopt centralization to take advantage of scale economies, while at the same time maintain an extensive distribution network to expand market shares. As a result, increasingly more commodities are produced from batch processing, then distributed and consumed across regional boundaries. This allows a wide variety of food items to travel more quickly and cheaply to consumers, but also makes the supply chain more vulnerable to sabotage.

Figure 1 depicts the food supply chain for animals, reproduced from Cupp et al. (2004). The integrated supply chain, resulting from globalization and consolidation of agriculture, has increased the number of points along which the terrorist could attack the food supply. Because of centralized production, animals are concentrated in a few production facilities, increasing the likelihood that the deliberate introduction of a single pathogen could result in widespread infection (Breeze 2004). For instance, three packers control roughly 72% of the live beef market, and four packers control roughly 57% of the pork market. This vertical integration and concentration of agribusiness firms has contributed to the vulnerability of terrorist attack. A major FMD attack would cause catastrophic economic damage, due to the size of the international export market, the interdependence of regional markets, and the intensification of production technologies.

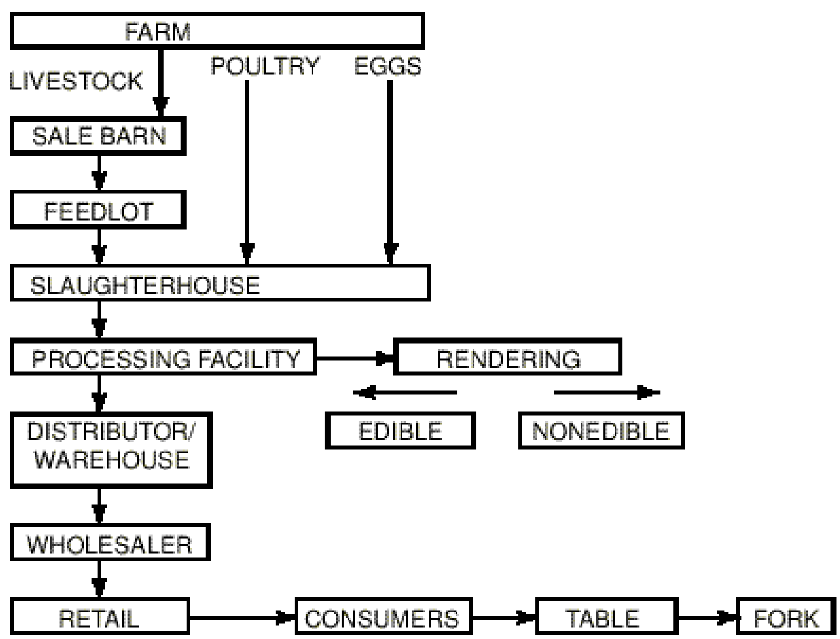

Figure 2 U.S. Food Supply Chain (Animals)

1.4 History of Foot-and-Mouth Disease

FMD is a potential instrument of terrorism aimed at attacking the livestock supply chain, and if introduced in the U.S. could have similar consequences to the outbreak in Great Britain that resulted in serious economic and emotional damage to farmers, communities, and the overall economy. Not including economic losses resulting from trade restrictions, the U.K outbreak caused over $6.5 billion in economic damage and imposed a $5 billion cost to the British tourism industry (Kohnen, 2000). FMD is widely considered to be the most economically devastating livestock disease. FMD is a highly infectious viral disease that does not affect humans, but can infect cattle, swine, sheep, goats, elk, deer, bison, and other cloven-hoofed animals. In young animals under conditions of dense stocking, a mortality rate approaching 90% is likely. FMD has been inadvertently introduced into the U.S. on eight previous occasions since the first case was reported in 1870. Although the U.S. has not had an outbreak of FMD since 1929, different types of the FMD virus have been identified in Africa, South America, Asia, and part of Europe. There have been outbreaks of FMD in 75 countries between 1996 and 1999, with the most recent outbreaks occurring in Great Britain, Northern Ireland, Argentina, and France.

These previous natural outbreaks of FMD shed light onto the potential economic devastation brought about by deliberate introduction of the disease into the livestock population. It is important to note that natural outbreaks do not bring forth levels of psychological damage generally associated with terrorism, but they do offer a baseline for impact assessments at the regional and national levels (Pate and Cameron 2001). In particular, an examination of natural outbreaks of FMD allows us to estimate the impact of an agroterrorist attack designed to spread the disease. A deliberate introduction of FMD into U.S. livestock would result not only in serious economic losses in the form of lost products and trade, but also psychological impacts affecting the hospitality industries. This would cause severe economic damage to the local economy and a loss of consumer confidence in the food supply chain.

FMD is not recognized as a zoonotic disease, meaning there is no personal risk to the terrorist in terms of accidental transmission from animal to human. Once the disease is introduced, however, preventing the spread to susceptible animal species becomes a very difficult task, primarily because FMD can spread by way of airborne aerosols. The virus can be carried on clothing, uncooked meat from infected animals, dairy products from infected animals, and on the wind to other locations within a 100-kilometer radius. Although humans are not directly affected, tourists can still inadvertently spread the disease from one area to another by means of their automobiles, clothing, shoes, and respiratory tracts.

Nearly all exposed animals would become infected, and unless the disease was detected early, a regional outbreak could spread quickly to other regions by ordinary movements of livestock across state borders. For example, within a week after the FMD outbreak in Taiwan was confirmed in 1997, nearly 150,000 cases were discovered. Testing for the virus showed that the same strain was present in China, leading officials to conclude that it was carried into the country via pork brought into Taiwan from China. After this incident, fears regarding the disease dampened consumer confidence in meat products from Taiwan, and this fact, combined with the loss of export markets, caused a crash in domestic pork prices that lasted several weeks following the outbreak.[5]

[5] This historical account comes from the report released by FAS (Foreign Agricultural Service) October 1997. "Foot-and-Mouth Disease Spreads Chaos in Pork Markets," United States Department of Agriculture, FAS, Livestock and Poultry, World Markets and Trade. Cameron et al. (2001) describes other cases involving the use of pathogenic agents to contaminate food, in which the objective appeared to be economic disruption.

1.5 The Potential Consequences of U.S. Agroterrorism

A single reported case of an FMD attack within the U.S. would impact all segments of the U.S. export markets for animal and animal-products. U.S. producers would be prohibited from selling animals and animal products on the international market until the disease was eradicated. Moreover, deer and other wildlife populations could become infected and could cause serious livestock re-infection after the initial terrorist attack. FMD could be transmitted to a large number of animals over a wide geographic area, as the animals themselves become the vehicle for further transmission of the disease (Manning and Baines, 2005).

The direct economic impacts alone of an FMD attack would be devastating. Nationally, agriculture is responsible for one-sixth of U.S. gross domestic product, and one in eight Americans are employed in agriculture, making the industry one of the largest employers in the U.S. (Parker, 2003). The agricultural sector exports over $50 billion worth of national output annually, and makes the largest positive contribution to the U.S. trade balance. The tables provided below offer data from the National Agricultural Statistics Service that are specific to St. Lawrence County. In 2002 the agricultural sector in this region consisted of 1,451 farms holding a market value of agricultural products sold approaching $100 million, with over 90 percent of this total market value attributed to livestock, poultry, and their products.

Table 3 Agricultural summary statistics for St. Lawrence County (2002 data)

Item	**Value ($)**
Estimated market value of land and buildings, average per farm	198,182
Estimated market value of all machinery and equipment, average per farm	91,853
Market value of agricultural products sold	99,715,000
Market value of agricultural products sold, average per farm	68,722

Table 3 (Continued)

Market value of agricultural products sold for livestock, poultry, and their products	90,817,000
Total income from farm-related sources, gross before taxes and expenses	2,652,000
Net cash farm income of operation	14,339,000

Table 4 Livestock and poultry inventory and sales for St. Lawrence County (2002)

Item	**Value (#)**
Cattle and calves inventory (total)	76,182
Cattle and calves inventory (beef cows)	3,827
Cattle and calves inventory (milk cows)	38,018
Cattle and calves sold	26,546
Hogs and pigs inventory	1,405
Hogs and pigs sold	2,379
Sheep and lambs inventory	3,373

Estimates of the direct impacts alone are likely to underestimate the true extent of the economy-wide damage. Equally important are the indirect impacts that are transmitted throughout the economy via the inter-industry linkages. In the following, I propose the use of a Social Accounting Matrix (SAM) model as a general equilibrium framework that takes into consideration both the direct and indirect impacts of the attack on the entire regional economy.

CHAPTER TWO

THE SAM MODEL

2.1 Model Introduction

This chapter presents the Social Accounting Matrix (SAM) model, which I employ in this study to simulate the impacts of agroterrorism on the regional economy. A SAM is a data system that records the monetary transactions among various economic actors to capture the salient interdependence among activities, production factors, and household groups. These transactions are contained in a framework that is both consistent and complete; consistency implies that for every income (of actor i) there must be a corresponding expenditure (of another actor j), while completeness is ensured when both the recipient and the provider of every transaction are identified. Table 5 shows a typical organization of SAM transactions into those belonging to the endogenous accounts, which affect and can be affected by the transactions of other accounts, and a group of exogenous accounts that affect the former but whose behavior is determined outside of the system. By convention, the SAM matrix is square because every actor has a ‘spending account’ (a column) and a corresponding ‘income account’ (a row), hence identical number of columns and rows.

Table 5 Endogenous and exogenous transactions in a SAM

	Endogenous Accounts			**Exogenous**	
	Production Factors (1)	Household Groups (2)	Production Activities (3)	Other Accounts (4)	Totals
Production Factors (1)	0	0	Z_{13}	Y_1	X_1
Household Groups (2)	Z_{21}	Z_{22}	0	Y_2	X_2

Table 5 (Continued)

Production Activities (3)	0	Z_{32}	Z_{33}	Y_3	X_3
Other Accounts (4)	Z_{41}	Z_{42}	Z_{43}	Y_4	Y
Totals	X_1	X_2	X_3	Y	

A further disaggregation creates submatrices within the block of endogenous accounts, which contain the transactions between production factors, household groups, and activities. For example, submatrix Z_{13} distributes compensation payments by production activities to their workers and shareholders. These payments constitute the 'value added' that these activities generate. In contrast, Z_{33} encapsulates the structure of inter-industry linkages (i.e., the input-output transaction matrix), while Z_{21} describes the mapping of factors' income into households' income. Naturally, it is the explicit treatment of income distribution – among both factors of production and household groups – that defines the key distinction between a SAM and its predecessor, the Leontieff input-output system. Finally, Z_{22} captures inter-household transfers, and Z_{32} details households' consumption pattern into various expenditures on goods and services. Note that $Y_i = Z_{i4}$ denotes the exogenous expenditures on account i.

2.2 Model Equations

To transform the SAM database into a model suitable for analyzing the impact of agroterrorist attacks, a matrix of average expenditures A needs to be constructed. Each element a_{ij} of the A matrix is computed as follows:

$$a_{ij} = z_{ij} / X_j \, , \qquad (1)$$

where z_{ij} denotes the flow of money from one endogenous account j to another endogenous account i, and X_j the total expenditures of the former. For example,

$z_{workers,manufacturing}$ represents workers compensation from their employment in the manufacturing industry. Thus in an economy with n endogenous accounts, their income identities can be written as follows:

$$
\begin{aligned}
X_1 &= a_{11} \cdot X_1 + a_{12} \cdot X_2 + \ldots + a_{1n} \cdot X_n + Y_1 \\
X_2 &= a_{21} \cdot X_1 + a_{22} \cdot X_2 + \ldots + a_{2n} \cdot X_n + Y_2 \\
&\vdots \\
X_n &= a_{n1} \cdot X_1 + a_{n2} \cdot X_2 + \ldots + a_{nn} \cdot X_n + Y_n
\end{aligned} \tag{2}
$$

which, after suitable rearrangements, can be presented more compactly in matrix format:

$$(I - A)X = Y\ , \tag{3}$$

where A = $\begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix}$, and where A_{ij} are submatrices corresponding to the endogenous partitions in Table 1, X = $\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}$, and Y = $\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}$.

Solving Eq. 3 for the endogenous accounts X, one obtains:

$$X = (I - A)^{-1} Y \tag{4}$$

The inverse matrix $(I - A)^{-1}$ is the well-known matrix of SAM multipliers, which measures the magnitude of economic impacts driven by exogenous changes in final demand. Note that for a given industry, the multiplier can vary with the size of the region. A larger economy typically tends to diversify more, import less, and hence purchase more from local producers, resulting in higher multipliers other things equal (Sirkin, 1959).

The SAM multipliers can be decomposed in order to identify the different paths by which an impact is transmitted throughout the economy. In particular, a SAM multiplier can be broken down into its direct, indirect, and induced components. The "direct effects" in this study correspond to the initial shock of the FMD attack, which include losses in the local farms' output, employment, and income. Specifically, a successful terrorist attack will significantly reduce the livestock industry output produced within St. Lawrence County, which in turn will lower the revenues of agricultural farms, resulting in lower incomes for farm proprietors and workers.

This initial, direct effect will have further repercussions due to the fall in agricultural demand for intermediate inputs produced in non-farm industries. The "indirect effects" thus capture the extent of these inter-industry repercussions. For example, a contraction in the agriculture sector will lead to falling demand for animal feeds, barn supplies and other industry inputs necessary to maintain farm operations. The combined direct and indirect effects are known as the input-output (Type I) multipliers, which can be computed by setting inter-industry transactions to be the only endogenous variables in the model.[6] Thus, using the notations of Eq. 3, Type I multipliers are contained in the inverse matrix $\left[I_{22} - A_{22}\right]^{-1}$, where I_{22} is an identity matrix with the same dimensions as A_{22}.

The induced effects, by contrast, are generated when household consumption and income are also considered endogenously. To illustrate these feedbacks, consider again an agriculture contraction leading to lower sales of livestock. The result is a decline in income for farm workers and producers, who as a result will reduce their expenditures on goods and services, in turn adversely affecting other industries in the region. The cumulative impact of the direct, indirect, and induced effects is known as the Type II multipliers, which are identical to the SAM multipliers $\left[I - A\right]^{-1}$.

[6] To the best of my knowledge, Miernyck (1965) was the first to coin the terms 'Type I' and 'Type II' multipliers to distinguish between Leontief input-output multipliers and those incorporating the feedback effects of household consumption and income.

2.3 SAM Output Multipliers

The output multipliers presented in the tables below relate the changes in sales to final demand by the livestock industry to total changes in output by all industries within St. Lawrence County.[7] Likewise, the income and employment multipliers relate the changes in direct income by the livestock industry to changes in total income, and the value added multipliers relate the changes in value added in the livestock industry to changes in total value added.

Table 6 Output Multipliers for Disaggregated Livestock Industries

Industry	Direct Effects	Indirect Effects	Induced Effects	Total Effects	Type I Multiplier	Type II Multiplier
Ranch Fed Cattle	1.000	0.331	0.136	1.467	1.331	1.467
Range Fed Cattle	1.000	0.337	0.137	1.475	1.337	1.475
Cattle Feedlots	1.000	0.174	0.119	1.293	1.174	1.293
Sheep, Lamb and Goats	1.000	0.307	0.141	1.448	1.307	1.448
Hogs, Pigs and Swine	1.000	0.179	0.098	1.277	1.179	1.277
Other Meat Animal Products	1.000	0.219	0.094	1.312	1.219	1.312
Miscellaneous Livestock	1.000	0.190	0.161	1.350	1.190	1.350

Table 7 Employment Multipliers for Disaggregated Livestock Industries

Industry	Direct Effects	Indirect Effects	Induced Effects	Total Effects	Type I Multiplier	Type II Multiplier
Ranch Fed Cattle	12.745	5.161	2.110	20.015	1.405	1.571
Range Fed Cattle	13.900	5.250	2.135	21.285	1.378	1.531
Cattle Feedlots	5.185	2.961	1.851	9.997	1.571	1.928
Sheep, Lamb and Goats	57.409	10.347	2.197	69.953	1.180	1.219

[7] Source: Impact Analysis for Planning (IMPLAN), 2000 data.

Table 7 (Continued)

Hogs, Pigs and Swine	10.905	3.116	1.528	15.550	1.286	1.426
Other Meat Animal Products	17.286	3.866	1.456	22.608	1.224	1.308
Miscellaneous Livestock	27.617	3.438	2.500	33.552	1.124	1.215

Table 8 Value Added Multipliers for Disaggregated Livestock Industries

Industry	**Direct Effects**	**Indirect Effects**	**Induced Effects**	**Total Effects**	**Type I Multiplier**	**Type II Multiplier**
Ranch Fed Cattle	0.216	0.125	0.085	0.426	1.581	1.976
Range Fed Cattle	0.218	0.115	0.086	0.419	1.527	1.923
Cattle Feedlots	0.216	0.084	0.075	0.375	1.390	1.736
Sheep, Lamb and Goats	0.229	0.120	0.089	0.438	1.525	1.913
Hogs, Pigs and Swine	0.178	0.087	0.062	0.327	1.488	1.834
Other Meat Animal Products	0.152	0.102	0.059	0.313	1.672	2.060
Miscellaneous Livestock	0.302	0.084	0.101	0.486	1.277	1.611

Table 9 Output Multipliers for Aggregated Industries

Industry	**Direct Effects**	**Indirect Effects**	**Induced Effects**	**Total**	**Type I Multiplier**	**Type II Multiplier**
Dairy Farm Products	1.000000	0.243564	0.228463	1.472027	1.243564	1.472027
Other Agriculture	1.000000	0.239304	0.225903	1.465206	1.239304	1.465206
All Livestock	1.000000	0.378418	0.227258	1.605677	1.378418	1.605677
Mining	1.000000	0.383508	0.286523	1.670031	1.383508	1.670031
Construction	1.000000	0.287353	0.352007	1.639359	1.287353	1.639359
Manufacturing	1.000000	0.278128	0.251501	1.529629	1.278128	1.529629
Wholesale Trade	1.000000	0.167718	0.365494	1.533212	1.167718	1.533212
Tourism	1.000000	0.243821	0.360298	1.604119	1.243821	1.604119
Transportation, Communications, & Other Utilities	1.000000	0.357303	0.272612	1.629915	1.357303	1.629915
Retail Trade	1.000000	0.160159	0.424229	1.584388	1.160159	1.584388
Finance and Insurance	1.000000	0.245945	0.168926	1.414871	1.245945	1.414871
Services	1.000000	0.287178	0.515127	1.802305	1.287178	1.802305
Public Admin.	1.000000	0.079677	0.631937	1.711614	1.079677	1.711614

Table 10 Employment Multipliers for Aggregated Industries

Industry	Direct Effects	Indirect Effects	Induced Effects	Total	Type I Multiplier	Type II Multiplier
Dairy Farm Products	4.656270	4.684462	3.493834	12.834565	2.006055	2.756405
Other Agriculture	29.457531	3.846130	3.454679	36.758340	1.130565	1.247842
All Livestock	19.610823	7.167755	3.475413	30.253991	1.365500	1.542719
Mining	4.700518	4.434018	4.381733	13.516269	1.943304	2.875485
Construction	9.412547	4.473122	5.383161	19.268830	1.475230	2.047143
Manufacturing	4.180536	3.445725	3.846150	11.472412	1.824230	2.744244
Wholesale Trade	12.355647	2.551374	5.589421	20.496442	1.206495	1.658872
Tourism	24.835144	3.883194	5.509954	34.228292	1.156359	1.378220
Transportation, Communications, and Other Utilities	5.191341	4.442556	4.168989	13.802886	1.855763	2.658828
Retail Trade	24.323322	2.620007	6.487642	33.430971	1.107716	1.374441
Finance and Insurance	3.798898	2.677210	2.583348	9.059456	1.704733	2.384759
Services	20.229237	4.821697	7.877719	32.928653	1.238353	1.627775
Public Administration	20.075714	1.062073	9.664076	30.801863	1.052903	1.534285

Table 11 Total Value Added Multipliers for Aggregated Industries

Industry	Direct Effects	Indirect Effects	Induced Effects	Total	Type I Multiplier	Type II Multiplier
Dairy Farm Products	0.269925	0.122848	0.146550	0.539323	1.455119	1.998047
Other Agriculture	0.396916	0.132571	0.144907	0.674394	1.334001	1.699085
All Livestock	0.252822	0.162517	0.145777	0.561116	1.642810	2.219410
Mining	0.466045	0.207556	0.183793	0.857394	1.445357	1.839725
Construction	0.400318	0.159196	0.225798	0.785312	1.397674	1.961722
Manufacturing	0.315169	0.154363	0.161328	0.630860	1.489779	2.001657
Wholesale Trade	0.680665	0.102021	0.234450	1.017136	1.149885	1.494327
Tourism	0.663185	0.147704	0.231117	1.042005	1.222719	1.571214
Transportation, Communications, and Other Utilitie	0.521405	0.208798	0.174869	0.905072	1.400452	1.735833
Retail Trade	0.800225	0.098219	0.272126	1.170570	1.122739	1.462801
Finance and Insurance	0.710090	0.160734	0.108359	0.979184	1.226358	1.378957
Services	0.597518	0.176540	0.330433	1.104491	1.295455	1.848465
Public Administration	0.895647	0.044615	0.405363	1.345625	1.049814	1.502405

Once the output multipliers have been computed, the employment impact can be determined using the following equation:

$$W = w \cdot (I - A)^{-1} \cdot Y \,, \tag{5}$$

where w denotes the vector of worker coefficients, each of which is computed as the ratio of total number of workers employed in that sector divided by that sector's output. One interpretation of the worker coefficients is that they measure the labor intensity of the production technology. The employment multipliers are utilized in this study in order to measure the impact of agroterrorism on the labor market. I note that underlying Eq. 5 is the assumption that output Y and employment W correlate perfectly, which corresponds to perfectly elastic labor supply.

The impact on labor income (an important component of value added) can be measured using a similar equation:

$$L = l \cdot (I - A)^{-1} \cdot Y \,, \tag{6}$$

where l denotes the vector of labor income coefficients, each of which is computed as the ratio of total wage bill in that sector divided by the corresponding output in that sector.

SAM models have a few well-known limitations. SAM models are strictly linear in the formulation of economic inter-relationships, and do not allow for the possibility of input substitution or conservation following the agroterrorism event. Other criticisms include its short-term focus implied by constant prices and excess capacity, the non-spatial nature (unless an inter-regional SAM is built), and the fact that the data is often only available for administrative units (counties) which might be poorly defined as economic regions. Despite these limitations, the SAM model remains one of the most powerful economic tools used to quantify the impacts of regional economic shocks.

CHAPTER THREE

IMPLAN DATA

The regional impact model utilizes the 2000 Impact Analysis for Planning (IMPLAN) data for St. Lawrence County. The Minnesota IMPLAN Group (MIG)[8] collected the original data primarily from U.S. Government sources, and then developed the social accounting matrix suitable for regional impact analysis. The sources include:

- Bureau of Economic Analysis (BEA) Benchmark Input-Output Accounts of the U.S., Output Estimates, and Regional Economic Information System
- Bureau of Labor Statistics (BLS) Consumer Expenditure Survey and ES-202 (Covered Employment and Wagers Program), which details sectoral employment and sources of income
- Census Bureau (CB) County Business Patterns, Decennial Census, Population Surveys, Economic Censuses and other surveys
- Department of Agriculture Crop and Livestock Statistics
- Geological Surveys

IMPLAN data contain highly detailed breakdown of the production economy, value added, household consumption patterns, and income distribution. In the original database, production is disaggregated into 528 production sectors corresponding to the North American Industry Classification System (NAICS).[9] Value added on the other hand includes employee compensation, proprietary income, other property income, and indirect business taxes. They represent factor payments from production activities

[8] http://www.implan.com
[9] See http://www.census.gov/epcd/www/naics.html.

in the form of wages to workers, profits to shareholders, rent to property owners, and taxes to the government.

There are three main types of institutions in the IMPLAN data; namely households, enterprises (i.e., corporations), and the government. Households are broken down further into 9 income groups, ranging from the poorest group earning less than $10,000 to the highest-income group earning more than $150,000. The sources of household income consist of factor payments (wages, profits, and rents) as well as transfers from other households and incomes earned outside of the region. Households spend their after-tax income on consumption of both locally produced and imported goods, and save the remainder in their capital accounts.

The exogenous accounts in this study are the government accounts (Federal, State, and Local), domestic and foreign trade. The government at various levels receives both indirect and direct (income) tax revenues, allocates its expenditures on goods and services, provides transfers and services, and saves the residuals in the capital account. Finally, domestic trade records transactions between local residents and other U.S. residents, while foreign trade records transactions between local residents and residents of other countries.

The principal focus of this study is on estimating the economy-wide impact of an agroterrorist attack on output, employment, and value added. These are key regional economic indicators that are selected for different reasons; output levels suggest the relative importance of an industry in that region, sectoral employment indicates which industries are the primary job generators, and value added represents the breakdown of factor income between workers and owners.[10] The IMPLAN model is used to develop the SAM model for St. Lawrence County and to structure the various impact scenarios. The estimated model can then be used to project economic

[10] For more information regarding this section, see Rickman, D. and Schwer R.K. (1993).

losses resulting from various attack scenarios, based on the interactions between sectors within the region. All values are expressed in year 2000 dollars.

CHAPTER FOUR

REGIONAL MODEL SIMULATIONS

4.1 Aggregating the Data

Performing the multiplier analysis first requires aggregation of the 528 IMPLAN production sectors into 20 divisions using the 2002 two-digit NAICS classification system of the U.S. Census Bureau (http://www.census.gov/epcd/naics02/naicod02.htm) with the exception of animal production activities. To facilitate the impact analysis under various FMD attack scenarios, I have decomposed agriculture activities into (i) an "all livestock" classification and (ii) "other" agriculture activities using IMPLAN data from year 2000. Table 12 describes the animal production sectors included in this "all livestock" group, as well as their corresponding values for output, value added, and employment (2000 data). This method is consistent with Ekboir (1999), which assumes that all susceptible species within the region of interest are affected by the outbreak. It is impossible to know if any particular strain of FMD would affect all or some livestock species following a hypothetical attack, but given the existence of high-density animal production, all vulnerable species are at risk and have been aggregated into a single sector.

Table 12 "All Livestock" Sectors and Demand Values

Industry	**Output**	**Employment**	**Employee Comp.**	**Proprietor Income**	**Other Property Income**	**Indirect Business Taxes**	**Total Value Added**
Ranch Fed Cattle	5.532	70	0.554	0.368	0.153	0.117	1.192
Range Fed Cattle	0.532	7	0.053	0.039	0.014	0.010	0.116

Table 12 (Continued)

Cattle Feedlots	0.194	1	0.019	0.013	0.006	0.004	0.042
Sheep, Lambs and Goats	0.130	7	0.013	0.010	0.004	0.003	0.030
Hogs, Pigs and Swine	0.092	1	0.009	0.003	0.003	0.002	0.016
Other Meat Animal Products	0.002	0	0.000	0.000	0.000	0.000	0.000
Miscellaneous Livestock	4.957	137	0.226	0.226	0.263	0.048	1.495
"All Livestock"	11.438	224	1.606	0.660	0.442	0.184	2.892

(Note: all values except for employment are in millions of dollars)

Table 13 Aggregated Industry Demand Values

Industry	**Industry Output**	**Employment**	**Employee Comp.**	**Proprietor Income**	**Other Property Income**	**Indiret Business Taxes**	**Total Value Added**
Dairy Farm Products	78.047	363	10.465	7.603	2.767	0.233	21.067
Other Agriculture	72.141	2,125	8.781	6.898	10.417	2.538	28.634
All Livestock	11.438	224	1.606	0.660	0.442	0.184	2.892
Mining	70.981	334	19.113	-1.385	11.276	4.077	33.080
Construction	329.688	3,103	99.344	18.261	12.547	1.829	131.980
Manufacturing	1,115.532	4,664	243.726	12.133	83.908	11.814	351.581
Wholesale Trade	84.553	1,045	32.784	2.095	10.794	11.879	57.552
Tourism	336.020	8,345	111.273	15.370	59.723	36.478	222.843
Transportation, Communications, and Other Utilities	208.250	1,081	36.533	10.496	48.524	13.029	108.583
Retail Trade	99.012	2,408	42.928	6.032	14.914	15.357	79.232
Finance and Insurance	440.575	1,674	51.200	14.017	216.680	30.950	312.848
Services	642.965	13,007	292.782	62.356	23.001	6.044	384.183
Public Administration	574.958	11,543	463.686	1.204	49.947	0.122	514.959
All Sectors	4,064.161	49,915	1,414.221	155.739	544.942	134.533	2,249.435

(Note: all values except for employment are in millions of dollars)

Table 14 Household Commodity Demand for Disaggregated Income Groups

Commodity	**<$5k**	**$5-10k**	**$10-20k**	**$20-25k**	**$25-30k**	**$30-40k**	**$40-50k**	**$50-70k**	**$70k+**
Dairy Farm Products	0.005	0.004	0.008	0.007	0.008	0.008	0.003	0.002	0.001

Table 14 (Continued)

Other Agriculture	0.868	0.771	2.083	1.977	2.708	2.725	1.220	0.694	0.286
All Livestock	0.030	0.027	0.090	0.106	0.144	0.167	0.106	0.060	0.025
Mining	0.005	0.004	0.008	0.008	0.010	0.011	0.005	0.003	0.001
Construction	0.981	0.866	2.301	2.154	2.950	2.897	1.252	0.713	0.293
Manufacturing	19.885	18.371	47.909	47.087	65.688	70.811	33.901	19.295	7.937
Wholesale Trade	6.477	6.133	17.932	18.882	27.615	29.754	15.259	8.685	3.572
Tourism	28.097	25.258	65.172	68.329	91.924	92.213	45.422	25.853	10.634
Transportation, Communications, and Other Utilities	9.556	8.506	19.863	20.196	25.237	27.299	12.407	7.062	2.905
Retail Trade	3.877	4.683	10.384	11.060	16.027	17.813	8.474	4.823	1.984
Finance and Insurance	15.731	14.957	44.207	53.143	76.100	91.705	50.428	28.702	11.806
Services	29.883	32.818	73.760	76.668	85.704	106.709	61.488	34.997	14.395
Public Administration	2.288	2.712	6.674	6.822	10.397	12.003	6.260	3.563	1.466
All Commodities	117.683	115.110	290.389	306.440	404.512	454.114	236.226	134.453	55.304

(Note: all values are in millions of dollars. Demands are commodity based and include imports)

4.2 Regional Model Assumptions

Following aggregation, the next step is to divide the regional economy into endogenous and exogenous accounts. In contrast to an input-output model that assumes production activities to be the only endogenous variables, a SAM model is ‘closed with respect to households,’ which means that household consumption patterns and income generation are deemed endogenous, which in turn requires that factor accounts (labor and capital) be rendered endogenous as well. On the other hand, it is reasonable to assume that government accounts are exogenous because they are determined in the previous year by political forces. I also assume that St. Lawrence County is a ‘small open economy’ and therefore has no market power to alter its export demand. I assume that initially the attack is contained within the county’s borders, the disease does not become endemic, and the attack is a single-period event that is fully eradicated at the end of one year. As a corollary, I assume that in the short- and medium-run exporters in other countries are unable to permanently capture share of the foreign meat market vacated by U.S. producers following the FMD attack.

4.3 Impact on the International Export Market

Following a major FMD attack, it is likely that direct impacts on livestock production would generate foreign export restrictions on U.S. producers. The thesis contributes to an emerging literature that studies the impacts of FMD on international livestock exports. Jensen et al. (2001) argue that any outbreak of FMD would result in a national halt of livestock exports for a period of one year, and Rich (2004) argues that the discovery of FMD in the U.S. would lead to the closure of export markets and impose significant costs on other sectors of the economy. These export restrictions would be imposed even if the outbreak were limited and only a few animals were infected. Other studies conclude that U.S. exports of animal products would halt abruptly and would not continue again for a period of six months, probably longer.[11]

Blake et al. (2001) employs a model for the UK economy that imposes export bans for the first year following the outbreak, but assumes that by the second year the bans are lifted. With reference to the growing literature, my analysis assumes output losses for the entirety of one year following the attack, but assumes that by the beginning of the second year the export bans are lifted and output recovers. Admittedly, this is an optimistic assumption, and the simulation results should therefore be regarded as lower-bound estimates of the total economic impacts arising from production and export losses.

Ekboir (1999) constructs an economic model in which an FMD outbreak reduces U.S. livestock prices by 50%, but assumes that the volume exported remains constant. This scenario is unlikely, since exports would presumably decline due to restrictions imposed by trading partners. As an alternative, I have simulated the impact

[11] This latter estimate of the impact of FMD on U.S. exports of animal products appeared in The Voice of Agriculture, "Foot-and-mouth surveillance may prevent attacks," Farm Bureau News (2001) vol. 80 No. 19.

of FMD through the decline in quantity of exports, and not through the price mechanism. Whereas the earlier model accounts for trade losses arising entirely from lower export prices, my approach reflects the opposite perspective. That is, the model assumes that trade losses arise entirely from lower export quantity. I argue that this is a more plausible assumption, since trade restrictions would unambiguously curb agricultural export volume, while the net effect on prices appears ambiguous.

The three agricultural cost components resulting from an outbreak of FMD include disposal costs, production losses, and export bans on affected animals and animal products. The cost estimates to be presented do not include any disposal costs. However, it is important to note that the cost of slaughtering and disposing of infected and exposed animals would represent a small percentage of the total eradication costs, with the greater fraction of economic losses coming from shocks to production and trade (Jayarao 2001). These production and trade components are the focus of my analysis. Production losses would result from a case of FMD due to lost production in depopulated areas and industries linked to the "all livestock" industry.

Countries that have eradicated FMD impose strict sanitary restrictions on meat imports, resulting in a segmented market in which meat from FMD-free countries sells at a premium over meat from non-FMD-free countries. The international beef market is further segmented into FMD-free with vaccination and FMD-free without vaccination. WTO sanitary and phytosanitary measures permit nations coping with an FMD outbreak to export to nations holding FMD-free status if the products originate from FMD-free areas, provided the disease has been contained by way of quarantine. However, the likelihood of major trading partners embracing this regionalization principle is still unknown, and the best assumption is that the total foreign beef market would be closed to U.S. producers for a "substantial length of time" (Ekboir, 1999).

4.4 Alternative Attack Scenarios

The economic impacts of an FMD outbreak in St. Lawrence County are explored under alternative attack scenarios of 10%, 20%, 30%, 40%, and 50% of total livestock industry output. The methodology closely parallels that of the Agri-Industry Modeling & Analysis Group, which produced a study on the projected economic impacts of an FMD outbreak in Tennessee.[12] The Tennessee study, which examines depopulation rate scenarios at the 10%, 25%, and 50% levels, also assumes a 10% decline in the tourism industry. The authors cite a British Tourist Authority study that estimated 10% annual losses in tourism due to FMD. Using this figure as a benchmark, my regional model adopts a 10% decline in tourism demand in the local economy.

FMD would adversely impact not only agricultural industries within St. Lawrence County but also tourism and related industries due to mass slaughtering, burning, and burying of FMD-infected animals. In addition, government response policies could contribute to the negative impact on the regional tourism industry. Government-imposed restricted access areas that include tourist attractions, historic sites, walking paths, waterways, and public events would exacerbate the decline in tourism activity. After the UK outbreak, for instance, the government closed country paths, zoos, parks, country houses, and roughly 70% of the inland waterway network. Initial estimates show that within several weeks tourism bookings declined up to 80% in the county of Cumbria, 60% in the county of Dumfries and Galloway, and roughly 10% nation-wide (Blake et al. 2001).

There have been only a few cases in which an FMD outbreak was controlled through vaccination alone, most notably Argentina (2003), Uruguay (2001), and

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[12] Preliminary analysis begins by assuming production losses in accordance with those assumed by Jensen, K. et al. "Projected Economic Impacts of a Foot and Mouth Disease (FMD) Outbreak in Tennessee," *Industry Brief,* AIM-AG

Zimbabwe (1991). All meat exports were suspended in each of these cases. There are several types and dozens of subtypes of the FMD virus, and vaccines must correspond to the exact type and subtype present in the affected region. The only proven method of eliminating the outbreak is total stamping-out, which would involve the use of vaccination to limit the spread of the outbreak, followed by depopulation of all infected and vaccinated livestock. It is policy of the U.S. government to destroy all infected and exposed animals, and a quarantine area would be enforced around the stamping-out area. This policy is justified primarily on economic grounds, as recovered animals show a decline in meat and milk productivity.

4.5 U.S. Response Policy to FMD Attack

To defend against FMD, the U.S. government has established a two-tier system: the first entails controlling imports and travelers at the borders, the second entails swift intervention and the activation of a stamping-out program following an FMD attack.[13] Following such an event, and in accordance with APHIS guidelines, the U.S. would enact a stamping-out policy that would involve mass slaughter, burning, and burial of all infected and exposed animals, followed by extensive cleaning and disinfection of all exposed locations.

The policy would also restrict the movement of animals and people and put controls in place to limit human access to certain area. These response measures, coupled with consumer fears over food safety and disease recurrence, would adversely impact tourism demand within St. Lawrence County. The initial attack creates direct effects on agriculture and also indirect effects through inter-industry linkages within

[13] The U.S. strategy for responding to an FMD outbreak is detailed in the "Foot-and-mouth Disease Emergency Disease Guidelines," published by the Animal and Plant Health Inspection Service (APHIS)

the region, but the direct effects on tourism are perpetuated not by the terrorist but by the government acting in response to the attack.

Tourists might be prevented or discouraged from traveling as a result of quarantine enforcement measures or amid overriding fears of spreading the disease. The attack could diminish consumer confidence in the government's capacity to regulate and maintain the food supply. Moreover, the inaccessibility of businesses within the restricted areas would have a major impact on rural tourism and on other rural businesses, as was the case of the UK outbreak in 2001. Following this outbreak, the cost of vaccinating all vulnerable animals was considered exorbitant, and the slaughter of all exposed animals was concluded to be the only viable option. Blake et al. (2003) performed an analysis on the impact of FMD on tourism in the UK and concluded that FMD had much larger adverse effects on tourism than on agriculture, suggesting that policy provisions take into account the roles of other sectors, such as tourism, when setting domestic agricultural policy. Their paper also contends that recent outbreaks of FMD in other countries, such as Greece in 1999, did not negatively impact their respective tourism industries precisely because governments did not close tourist amenities.

The 10% decline in tourism assumed in all model simulations is consistent with historical responses in tourism data. However, this decline could be considered a statistically conservative estimate of the true value, since county-level impacts might be higher than the national average. Although intra-regional tourism might recover relatively quickly after the outbreak is eradicated and movement restrictions are removed, inter-regional travelers and foreign visitors might be hesitant to return to pre-shock levels of tourism demand because the outbreak will have tarnished the regional and national reputation. The region would become a less appealing destination for tourists to visit and spend money on lodging, retail stores, and entertainment due to ongoing concerns regarding food safety and the possibility of spreading the disease.

This tourism simulation is intended to be an example of how FMD might impact nonagricultural industries and does not mean to preclude the possibility that other industries could also be directly impacted. However, it is important to note that the impact on tourism is rather unique in the case of an FMD attack. For instance, it is not clear that analogous reductions in tourism demand would follow from other forms of agroterrorism, such as a biological attack on the milk supply[14], because government response to such an event conceivably would not restrict the movement of people to the degree suggested under the FMD scenario.

The decline in the tourism industry results not only in direct and indirect effects, but also induced effects on other economic activities caused by inter-industry linkages. The induced effects of changes in demand for tourism are generally quantified through SAM modeling techniques. Following the FMD attack, a mass slaughter in St. Lawrence County and elsewhere in the U.S. might be justified on purely economic grounds, as FMD causes permanent losses in meat productivity. The traditional international sentiment is that the disease should be swiftly eradicated, bringing about bans on imports of potentially FMD-infected livestock and dairy products.

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[14] This example comes from Wein and Liu (2005), which explores the possibility of terrorists spreading botulinum toxin through the milk supply chain. The authors construct a model that takes into account the various stages of the supply chain, while limiting the event to a single milk-processing plant. They then examine the effects of a deliberate release of botulinum toxin at key points along the supply chain, such as delivery trucks and raw milk silos. This type of biological attack would result in economic disruption, although its direct effects on tourism are less transparent than in the case of a foot-and-mouth disease attack.

4.6 Tourism Classification System

The tourism division was created through model intervention to determine which sectors to extract from the other divisions. Industries that depend heavily on sales to tourists can be expected to incur the greatest losses in output and value-added (Blake et al. 2001). The lower demand for tourism in the region will directly affect spending on hotels and lodging places, merchandise and food stores, and entertainment. There is scarce literature on the performance of tourism over time, which makes it difficult to identify with reasonable certainty the costs and benefits of greater resilience on the industry (Wilkerson, 2003).

Tourism is not an industry in the traditional sense, because tourism belongs to a variety of sectors and no individual sector can be considered exclusively tourism. Because tourism generally is not given a separate industry category in economic data sources, the task of establishing the economic importance of tourism and measuring the activity of this sector can be difficult, particularly at the regional level. This thesis work, therefore, makes a contribution not only to the economics of terrorism literature, but also to the methodologies of modeling the performance of tourism following extreme economic events. To determine which sectors to include in the broader tourism classification, I will refer to the literature on the subject.

The Bureau of Economic Analysis (BEA) defines tourism in its national travel and tourism satellite accounts as: "the economic activity generated inside the United States by visitors of all types – for business and pleasure, by residents and nonresidents alike – and outside the United States by U.S. residents" (Okubo and Planting, 1998). The BEA Satellite Industry Accounts are statistical frameworks based on input-output accounts that allow researchers to examine a narrow focus of economic activity. The BEA partitions tourism goods and services into a separate account, which includes: traveler accommodations, transportation (both air and other), food services and drinking places, recreation, entertainment, and shopping.

A study conducted by Global Insight (2003) aggregates sectors into a Core Tourism Industry, composed of the following sectors: eating and drinking, hotels and lodging places, real estate, racing and track operation, amusement and recreation services, railroads and related services, air transportation, transportation services, automobile rental and leasing, local interurban passenger transit, automotive dealers and service stations, apparel and accessory stores, food stores, furniture and home furnishing stores, general merchandise stores, and all other.

I have adopted the Global Insight tourism classification system for this analysis, which parallels the BEA tourism account and provides greater specification within each subcategory. I apply specific entertainment sectors to comprise the "all other" category. These entertainment sectors include: motion pictures, theatrical productions, bowling alleys and pool halls, and commercial sports. The remaining agricultural sectors, including dairy farm products, were aggregated into "other agriculture," and the non-agricultural sectors were aggregated into divisions consistent with the NAICS classification system. These divisions, their corresponding IMPLAN sector codes, the value of industry output, and the value of industry employment are listed in Table 15 below. The aggregated output, employment, and value added statistics for the newly constructed livestock and tourism sectors are given in Table 16.

Table 15 Divisions and IMPLAN Sector Codes

Industry Name	**IMPLAN Sector Codes**	**Industry Output***	**Industry Employment**
All Livestock	3-9	11.438	224
Other Agriculture	1, 2, 10-27	150.188	2,489
Construction	48-58	329.688	3,103
Finance and Insurance	456-461	440.575	1,674
Manufacturing	59-383, 389-432	1,115.532	4,664
Mining	28-47	70.981	334

Table 15 (Continued)

Transportation, Communications, and Other Utilities	435, 436, 438, 439, 441-446	208.250	1,081
Wholesale Trade	384-388, 447	84.553	1,045
Public Administration	509-528	574.958	11,543
Retail Trade	448, 455	99.012	2,408
Services	464-476, 478-482, 489-508	642.965	13,007
Tourism	433, 434, 437, 440, 449-454, 462, 463, 477, 483-488	336.020	8,345

* Millions of dollars

Table 16 Economic Statistics for Aggregated Livestock and Tourism Sectors

Industry Name	**All Livestock**	**Tourism**
Total Output	$11,438,000	$336,020,000
Employment	224	8,345
Labor Income	$2,266,000	$126,643,000

CHAPTER FIVE
RESULTS OF REGIONAL ANALYSIS

5.1 Impacts of FMD on St. Lawrence County (No Direct Impact to Dairy Industry)

The simulation was performed under various assumptions regarding the severity of the FMD attack, while assuming a 10-percent tourism reduction in each scenario. I aggregate the dairy farm products sector into "other agriculture" to perform the initial simulations assuming no direct impacts to the dairy industry. I then impose shocks to livestock output at increasing intervals of 10 percent. These impacts represent alternative scenarios regarding the direct impacts and the time horizon under consideration. The 10% and 20% output reduction scenarios are representative of the immediate-term regional impacts.

We can interpret the 50% reduction scenario as the medium-term scenario in which the international market has reacted to the outbreak and reduces trade volume. Once the international market has adjusted by banning U.S. exports, we would observe a larger fall in industry output. We can expect a gradual adjustment process in the international market, such that the response path exhibits a smoother transition among the various intervals instead of shifting immediately from the 10% short-term scenario to the 50% medium-term scenario. No attempt was made to generate long-term projections of the impact. The SAM model is a static economic model that assumes constant prices. In the long-run, however, this assumption is violated as prices change. With respect to this fixed price assumption I have provided only immediate and medium-term projections, precisely because the SAM model is invalidated under fluid pricing conditions.

Note that the numbers presented are in 2000 dollars (except for employment), and should be interpreted as negative impacts. Labor income is equal to the sum of total employee compensation and proprietary income, excluding the value added components of other property type income and indirect business taxes.

Table 17 Scenario 1: 10-percent Reduction in Livestock Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	1,143,800	169,886	13,071	1,326,703
Employment	22.4	3.3	0.3	26.0
Labor Income	226,549	33,649	2,578	262,776
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	1,619,004	2,177,395	37,398,400
Employment	834.5	40.2	54.1	928.8
Labor Income	12,664,330	610,190	820,643	14,095,160
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	34,745,800	8,543,666	12,299,125	55,588,593
Employment	856.9	135.6	187.6	1,180.1
Labor Income	12,890,876	3,556,169	4,867,446	21,314,492

Table 18 Scenario 2: 20-percent Reduction in Livestock Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	2,287,600	320,589	13,284	2,621,472
Employment	44.9	6.3	0.3	51.4
Labor Income	453,097	63,498	2,631	519,226
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	1,661,268	2,221,958	37,485,220
Employment	834.5	41.3	55.2	931.0
Labor Income	12,664,330	626,119	837,438	14,127,880
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	35,889,600	8,935,405	12,550,843	57,375,847
Employment	879.4	142.0	191.4	1,212.8
Labor Income	13,117,424	3,666,230	4,967,065	21,750,720

Table 19 Scenario 3: 30-percent Reduction in Livestock Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	3,431,400	471,292	13,550	3,916,242
Employment	67.3	9.2	0.3	76.8
Labor Income	679,646	93,347	2,684	775,677
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	1,703,536	2,266,521	37,572,060
Employment	834.5	42.3	56.3	933.1
Labor Income	12,664,330	642,049	854,234	14,160,610
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	37,033,400	9,327,148	12,802,561	59,163,108
Employment	901.8	148.4	195.2	1,245.5
Labor Income	13,343,973	3,776,293	5,066,684	22,186,950

Table 20 Scenario 4: 40-percent Reduction in Livestock Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	4,575,200	621,995	13,816	5,211,012
Employment	89.7	12.2	0.3	102.2
Labor Income	906,194	123,196	2,737	1,032,127
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	1,745,800	2,311,084	37,658,880
Employment	834.5	43.4	57.4	935.3
Labor Income	12,664,330	657,978	871,029	14,193,330
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	38,177,200	9,718,887	13,054,279	60,950,365
Employment	924.2	154.8	199.1	1,278.1
Labor Income	13,570,521	3,886,355	5,166,303	22,623,178

Table 21 Scenario 5: 50-percent Reduction in Livestock Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	5,719,000	772,698	14,083	6,505,781
Employment	112.2	15.2	0.3	127.6
Labor Income	1,132,743	153,046	2,789	1,288,578
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	1,788,064	2,355,648	37,745,710
Employment	834.5	44.4	58.5	937.4
Labor Income	12,664,330	673,907	887,825	14,226,060

Table 21 (Continued)

All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	39,321,000	10,110,625	13,305,997	67,737,623
Employment	946.7	161.2	202.9	1,310.8
Labor Income	13,797,070	3,996,416	5,265,921	23,059,407

The direct costs of the attack within the region reflect the initial output reductions, and the indirect costs reflect changes in inter-industry transactions as supplying industries react to falling demand from the directly affected industries. These indirect effects would include losses suffered by related industries, such as firms engaged in food supply, transportation, distribution, and retail. The induced effects capture the overall impact to household income and consumption. The total effects exceed the direct effects when we account for indirect and induced impacts, as the damage extends beyond the industries directly impacted due to the inter-industry supply-chain linkages within the region. The firm-level impacts of agroterrorism are outside the scope of this research project.

Under the low-impact scenario presented in Table 17, the estimated total impact for all sectors totals over $55.5 million loss in output, 1,180 loss in local jobs, and $21.3 million loss in labor income. Under the high-impact scenario presented in Table 21, the estimated total impact for all sectors totals over $67.7 million loss in output, 1,310 loss in local jobs, and $23 million loss in labor income. The intermediate-impact scenarios are presented in tables 18 – 20. The size of the economic impact increases with the severity of the FMD attack. As losses in livestock industry output increase from 10 percent (Scenario 1) to 20 percent (Scenario 2), the direct effects, indirect effects, and induced effects corresponding to output, employment, and labor income increase accordingly.

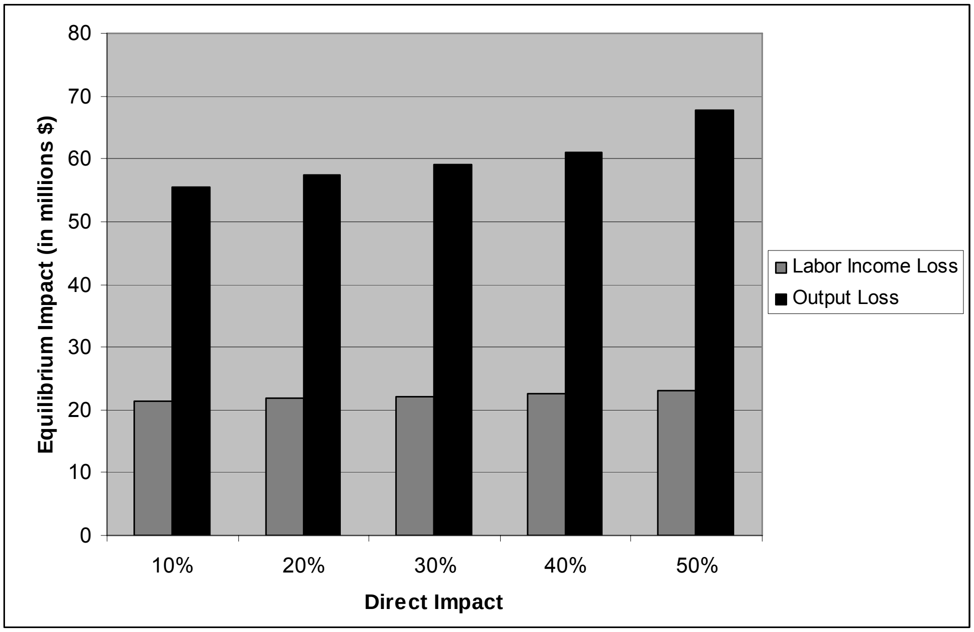

Figure 3 Total Effects on Output and Labor Income in All Sectors

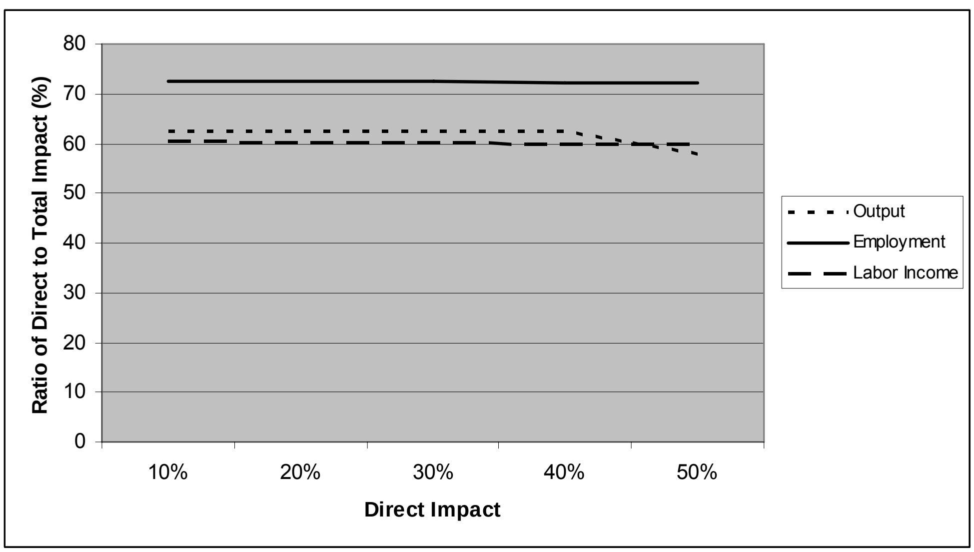

Figure 4 Ratio of Direct to Total Impact in All Sectors

As losses in livestock industry output increase from 20 percent (Scenario 2) to 30 percent (Scenario 3) the impacts of this change become more severe. Figure 2 illustrates this trend. Looking at the results of the FMD impacts for all sectors in Scenario 1, the direct effects component for output constitutes 62.5% of the total effect. This ratio remains relatively fixed across Scenarios 1, 2, 3, and 4, but falls to 58% in the medium-term outlook in Scenario 5, which is lower than the corresponding value for labor income. The ratio of direct to total effects for employment in all sectors is greater than that for output, and appears stable across all scenarios at approximately 72%. When calculated for labor income, this ratio is lower than the same measures for output and employment, hovering at or below 60% in all simulations (See Figure 3). This result illustrates the SAM multipliers at work. Variables with greater corresponding multiplier values generate greater indirect and induced effects, and therefore the direct impact will constitute a smaller fraction of the total economy-wide damage.

5.2 Testing for Non-Linearity

I will now examine whether the various impacts are linearly or non-linearly related to the scale of the initial shock. Comparing a range of impacts between 10% and 50% intervals allows for statistical evaluation of the relationship between the initial direct impact on output and the equilibrium final impact. I test for non-linearity and examine whether the sectoral composition of the total impact changes as the output losses grow. Analysis of the impact results reveals that the various impact scenarios are linearly related to the scale of the initial shock for the livestock and tourism sectors. However, it appears that the impact on output of agroterrorism for all sectors is scale dependent across the highest impact scenarios.

Although there appears to be a positive linear relationship between the direct and equilibrium impacts for the livestock and tourism sectors taken independently, we observe a non-linear relationship between the two variables for all sectors taken collectively, as measured on the 10-percent interval scale. The two variables move together linearly across the lower impact scenarios, but move together non-linearly across the higher impact scenarios. In other words, the direct and equilibrium impacts taken for all sectors move linearly, but only in the short run. In the medium-term scenario of 40% to 50% loss in output, after the international market responds to the outbreak by imposing export bans, the equilibrium impact increases disproportionately faster than the direct impact. The impact on employment and labor income for all sectors appears strictly linear.

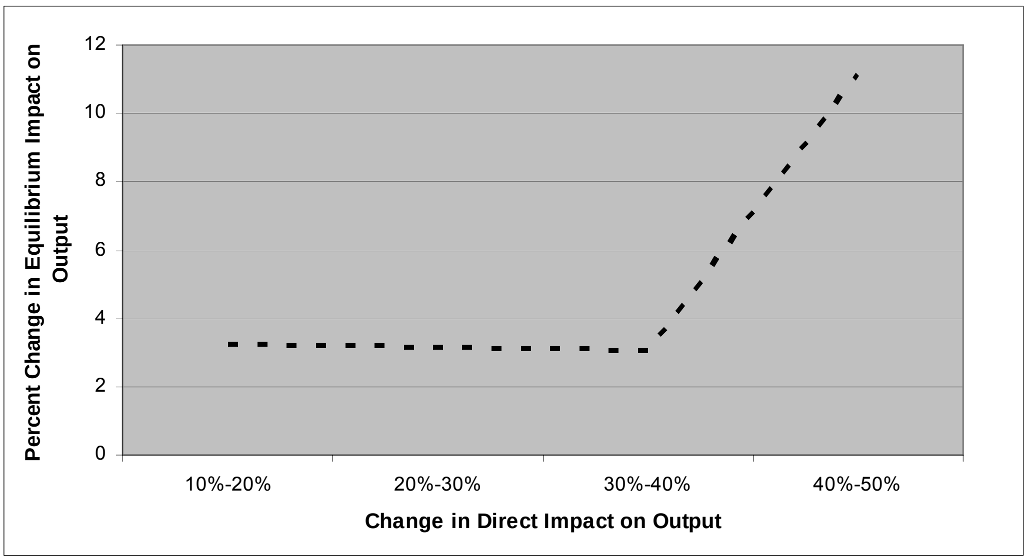

Figure 5 Test of Scale Dependence Based on Percent Change in Output for All Sectors in Regional Economy

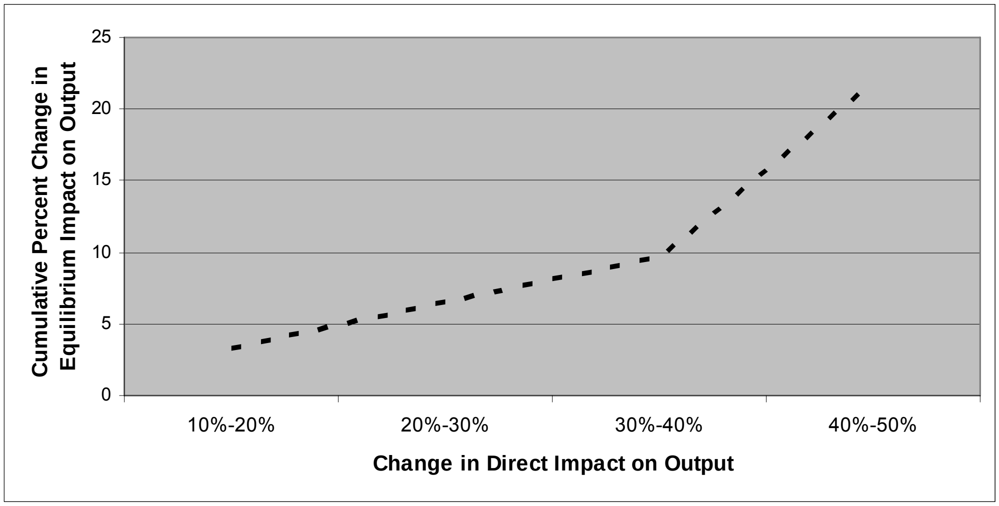

Figure 6 Test of Scale Dependence Based on Cumulative Percent Change in Output for All Sectors in Regional Economy

5.3 Impacts of FMD on St. Lawrence County (With Direct Impact to Dairy Industry)

The analysis is now extended to account for impacts to the dairy industry following the attack, and I relax the previous assumption that dairy farm products remain sheltered from any direct impacts. I do so because dairy cattle are susceptible to infection, and the particular strain of the virus is an unknown variable in the simulation analysis. Therefore I assume in this section that these animals are at risk and render them in isolation of the “other agriculture” sector before delivering shocks to livestock, dairy, and tourism. I deliver equivalent shocks to livestock and dairy at the same 10% increment, while maintaining the 10% reduction in tourism across all simulations. The key economic statistics for these aggregated sectors are provided in Table 22, the results of the various impact scenarios under my revised assumption are provided in Tables 23-28, and the results across all impact scenarios are represented graphically in Figure 6. I decompose the output impacts at the 20-percent reduction level to illustrate the effects of the attack on each major sector within the regional economy.

Table 22 Economic Statistics for Aggregated Livestock, Tourism, and Dairy Sectors

Industry Name	**All Livestock**	**Tourism**	**Dairy**
Total Output	$11,438,000	$336,020,000	$78,047,000
Employment	224	8,345	363
Labor Income	$2,266,000	$126,643,000	$18,068,000

Table 23 Scenario 6: 10-percent Reduction in Livestock and Dairy Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	1,143,800	176,289	15142	1,335,231
Employment	22.4	3.5	0.3	26.2
Labor Income	226,549	34,917	2,999	264,465
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	1,822,124	2,512,684	37,936,810
Employment	834.5	45.3	62.4	942.2
Labor Income	12,644,330	686,744	947,010	14,298,080
Dairy Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	7,804,700	11,206	8,006	7,823,912
Employment	36.3	0.1	0.0	36.4
Labor Income	1,806,718	2,594	1,853	1,811,166
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	42,550,500	10,526,653	14,149,748	67,226,902
Employment	893.3	175.2	216.4	1,284.9
Labor Income	14,697,594	4,145,555	5,595,826	24,438,974

Table 24 Scenario 7: 20-percent Reduction in Livestock and Dairy Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	2,287,600	333,120	17,328	2,638,049
Employment	44.9	6.5	0.3	51.7
Labor Income	453,097	65,980	3,432	522,509
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	2,056,952	2,875,480	38,534,430
Employment	834.5	51.1	71.4	957.0
Labor Income	12,664,330	775,249	1,083,745	14,523,320
Dairy Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	15,609,400	17,449	9,162	15,636,010
Employment	72.7	0.1	0.0	72.8
Labor Income	3,613,437	4,039	2,121	3,619,597

Table 24 (Continued)

All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	51,499,000	12,860,430	16,192,770	80,552,201
Employment	952.1	220	247.6	1,419.7
Labor Income	16,730,861	4,832,971	6,403,784	27,967,615

Table 25 Industry Output Impacts for 20-percent Reduction in Livestock and Dairy Output, 10-percent Reduction in Tourism

Industry	**Direct Effects**	**Indirect Effects**	**Induced Effects**	**Total Effects**
Dairy Farm Products	15,609,400	17,449	9,162	15,636,011
Other Agriculture	0	1,765,367	50,437	1,815,804
All Livestock	2,287,600	333,120	17,328	2,638,049
Mining	0	82,636	66,453	149,089
Construction	0	867,425	325,446	1,192,871
Manufacturing	0	675,551	699,499	1,375,050
Wholesale Trade	0	576,298	446,937	1,023,234
Tourism	33,602,000	2,056,952	2,875,480	38,534,432
Transportation, Communications, and	0	1,547,914	1,245,991	2,793,905
Retail Trade	0	24,505	817,626	842,131
Finance and Insurance	0	979,860	3,569,529	4,549,390
Services	0	3,144,934	5,054,764	8,199,698
Public Administration	0	788,420	1,014,120	1,802,539
Foreign Trade	0	0	0	0
Domestic Trade	0	0	0	0
All Sectors	51,499,000	12,860,430	16,192,770	80,552,201

Table 26 Scenario 8: 30-percent Reduction in Livestock and Dairy Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	3,431,400	489,951	19,515	3,940,866
Employment	67.3	9.6	0.4	77.3
Labor Income	679,646	97,043	3,865	780,554
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	2,291,780	3,238,276	39,132,060
Employment	834.5	56.9	80.4	971.9
Labor Income	12,664,330	863,754	1,220,480	14,748,560
Dairy Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	23,414,100	23,692	10,318	23,448,110

Table 26 (Continued)

Employment	109.0	0.1	0.0	109.2
Labor Income	5,420,155	5,484	2,388	5,428,028
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	60,447,500	15,194,206	18,235,793	93,877,500
Employment	1,010.8	264.8	278.9	1,554.5
Labor Income	18,764,128	5,520,387	7,211,742	31,496,256

Table 27 Scenario 9: 40-percent Reduction in Livestock and Dairy Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	4,575,200	646,782	21,701	5,243,683
Employment	89.7	12.7	0.4	102.8
Labor Income	906,194	128,106	4,298	1,038,598
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	2,526,608	3,601,072	39,729,680
Employment	834.5	62.7	89.4	986.7
Labor Income	12,664,330	952,259	1,357,215	14,973,800
Dairy Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	31,218,800	29,936	11,473	31,260,210
Employment	145.4	0.1	0.1	145.6
Labor Income	7,226,873	6,930	2,656	7,236,459
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	69,396,000	17,527,984	20,278,815	107,202,800
Employment	1,069.6	309.5	310.1	1,689.2
Labor Income	20,797,394	6,207,804	8,019,699	35,024,898

Table 28 Scenario 10: 50-percent Reduction in Livestock and Dairy Output, 10-percent Reduction in Tourism

Livestock Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	5,719,000	803,613	23,887	6,546,501
Employment	112.2	15.8	0.5	128.4
Labor Income	1,132,743	159,169	4,731	1,296,643
Tourism Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	33,602,000	2,761,436	3,963,868	40,327,300
Employment	834.5	68.6	98.4	1,001.5
Labor Income	12,664,330	1,040,763	1,493,950	15,199,040
Dairy Sector	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	39,023,500	36,180	12,629	39,072,310
Employment	181.7	0.2	0.1	181.9
Labor Income	9,033,591	8,375	2,923	9,044,889
All Sectors	*Direct Effect*	*Indirect Effect*	*Induced Effect*	*Total Effect*
Output	78,344,500	19,861,761	22,321,838	120,528,098

Table 28 (Continued)

Employment	1,128.4	354.3	341.4	1,824.0
Labor Income	22,830,661	6,895,220	8,827,657	38,553,537

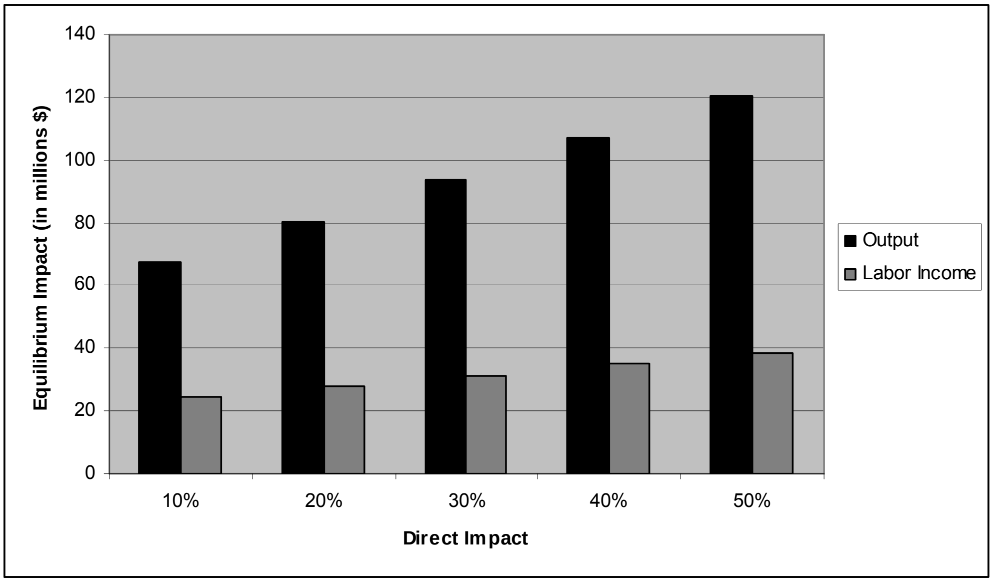

Figure 7 Total Effects on Output and Labor Income in All Sectors, Including Direct Impacts to Dairy

Under the low-impact scenario presented in Table 23, the estimated total impact for all sectors – including direct impacts to dairy – grows to over $67.2 million loss in output, 1,285 loss in local jobs, and $24.4 million loss in labor income. Under the high-impact scenario presented in Table 28, the estimated total impact for all sectors grows to over $120.5 million loss in output, 1,824 loss in local jobs, and $38.5 million loss in labor income. The intermediate-impact scenarios are presented in tables 24 – 27. As before, the size of the economic impact increases with the severity of the FMD attack.

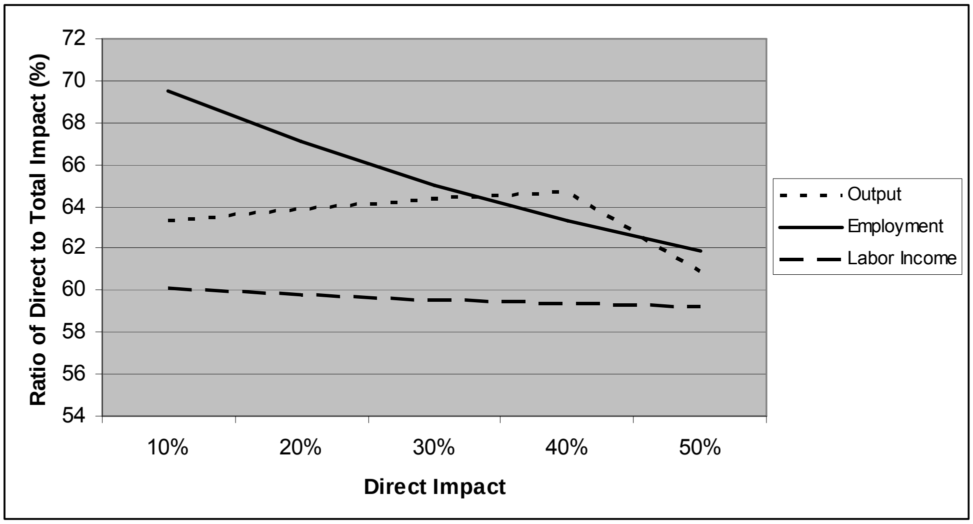

Figure 8 Ratio of Direct to Total Impact in All Sectors, Including Direct Impacts to Dairy

In the 10% output reduction scenario, the direct effect on output for all sectors constitutes 63.3% of the equilibrium impact. This ratio remains relatively constant through Scenario 9, before falling slightly to 60.8% in Scenario 10. The ratio of direct to total effects for labor income is slightly lower, hovering around 60% in all scenarios, and this ratio for employment is slightly higher across the lower impact scenarios, falling steadily from 69.5% in Scenario 6 to 61.9% in Scenario 10 (See Figure 7).

CHAPTER SIX

IMPACTS ON U.S. FINANCIAL MARKETS

6.1 Introduction to Macroeconomic Research

The regional component presented in the initial five chapters places a valuable benchmark for the near-term, localized effects of the attack. However, a catastrophic agroterrorist attack would have major implications for U.S. financial markets. Considering the magnitude and importance of these markets, the losses on a national scale would overshadow the regional losses. By linking to the macro model following the regional analysis, we can examine the economy-wide impacts associated with a future terrorist attack on U.S. agriculture.

Any future agroterrorist attack would involve two distinct measures of impact: direct costs and indirect costs. Direct costs of terrorism include the value of lost income and productive lives, the value of buildings and infrastructure damaged or destroyed, and the value of disrupted commercial activity in the targeted industries. Much more costly, however, are the broader indirect impacts to U.S. financial markets estimated over several consecutive periods. The indirect impacts of terrorism can be significant and have the potential to affect the economy in the medium term by undermining consumer and investor confidence.

This deterioration of confidence can reduce the incentive to spend as opposed to save, a process that can reverberate through the economy by way of normal business cycle and trade channels. Falling confidence may also lower asset prices and trigger a flight to quality that increases the borrowing costs for riskier borrowers (Johnston and Nedelescu, 2005). The remaining thesis chapters will focus particularly on the impact of terrorism on broad financial asset classes, although the procedural methodology could be applied in future research to other categories of catastrophic shocks that are capable of generating investor unrest and uncertainty.

Terrorist events involve unique emotional and psychological impacts that have shown to be significant in the short run. Communications technology allows information – especially negative information – to spread quickly with the potential to impose significant financial impacts and contagion effects in a short period of time. Critics argue that U.S. financial markets have shown resilience in the face of terrorist activity and the uncertainty surrounding corporate scandals, perpetually high crude oil prices, nuclear ambitions of rogue nations, and other forms of shocks to the international financial system. I would argue, however, that it would be shortsighted to overlook the negative impacts of terrorism on equity and debt capital markets simply because the economy has shown resilience in the past.

I put forth the idea that financial uncertainty in the aftermath of agricultural terrorism has the potential to decrease consumer confidence in the future state of the economy, increase interest rates, increase credit spreads, dampen the stock market, and impact the value of the U.S. dollar relative to the currencies of trading partners. Indirect effects are often referred to in the literature as multiplier effects, which significantly increase the magnitude of losses suffered by the economy as the damage flows beyond the industries directly impacted. Terrorist attacks, military invasions, and other unexpected shocks have serious implications for financial market activity.

A terrorist attack on U.S. agriculture via the deliberate introduction of FMD would adversely impact the finances of the agricultural, food processing, and food distribution sectors. Indirect multiplier effects would include losses suffered by related industries, such as firms engaged in food supply, transportation, distribution, and retail. These losses would be significant and potentially crippling at the micro level, but would be small in relation to the losses suffered to the financial markets.

Following a food terrorism event, we could expect to witness flight to quality and liquidity in the bond markets, and an increase in the value of the dollar and other major currencies as emerging market currencies become incrementally riskier relative to their risk levels in the baseline scenario.

The loss of confidence in the safety of the food supply chain would lower demand for food products, in turn causing producers to curb production and employment, which would spill over into related sectors of the economy and reduce consumer demand even further. The losses are compounded due to natural lags and the fact that the gestation period for agricultural production is fixed. Following an FMD attack we would likely witness a weakening consumer and increased corporate bankruptcies. When information of the attack became available, investors would likely disengage from market commitments in search for safer financial instruments.

The economy could experience impacts to consumer sentiment without an actual agroterrorist attack occurring, as long as the public perceives that an attack has in fact occurred. The effects of this lost sense of security would reverberate throughout the economy, affecting household spending patterns and private sector investment behavior. Some purchases and investments would be withheld until future time periods, while still others would be forgone indefinitely. This event, like previous terrorist events, would likely pervade the public consciousness. The loss of consumer sentiment in the food sector would likely transfer into an overall reduction in consumer sentiment, which would lead to a reduction in consumer spending of all types, not just spending on food and food-related products. And unlike some natural disasters, there is no foreseeable built-in economic stimulus following a terrorist attack that might shorten the path to full economic recovery and mitigate the impacts on U.S. financial markets and regional economic performance.

The capabilities that the United States has accumulated for conventional, nation-on-nation conflict are rather ineffective at coping with terrorist threats and mitigating the impact of these threats on the financial system. Acts of terrorism are often intended to create financial uncertainty and distress. Manuel Trajtenberg (2004) highlights the asymmetries between terrorists and victims, and argues that the threat of terrorism is magnified by uncertainty. In the absence of uncertainty, an FMD attack, for instance, could be easily thwarted by the deployment of minor police or military power. This differs significantly from conventional warfare, in which accurate intelligence still necessitates significant military capabilities in order to overcome an attack. Unconventional terrorist attacks on the food supply chain constitute a relatively new and evolving threat that presents significant challenges. Terrorist attacks can be thought of as a type of disaster that occurs through the intentional actions of human beings. Unlike natural disasters, such as earthquakes, hurricanes, or floods, terrorist attacks can be targeted strategically to inflict maximum damage.[15]

6.2 Objectives of Macroeconomic Research

The macro analysis introduces the idea that following an agricultural terrorist attack the indirect costs of declining asset value, business investment, and household spending across the national economy would be of a much higher order of magnitude than the direct, micro level costs. The remaining chapters will focus on these indirect costs and the broader implications for U.S. financial markets. I have chosen to pursue

[15] Although terrorists tend to act strategically, they are faced with an endowment of scarce resources and must allocate them not only strategically but also efficiently to maximize their utility subject to a budget constraint. When governments increase the costs of terrorist activity making it more difficult to pursue agroterrorism, there exists a motive for terrorists to substitute into other, less costly methods that achieve similar utility. In the case of agroterrorism, this rational actor model is applicable assuming the terrorist, attempting to introduce FMD, efficiently utilized his limited resources in the face of constraints, and responded in an efficient manner to changes in these constraints, to achieve the objective of attacking agriculture.

the macro cost component in depth, and different micro cost estimating factors could be used to complement my analysis. Researchers still know relatively little of the economic consequences of terrorist events. This original research is a first attempt to measure the impacts on broad financial asset classes resulting from a large-scale U.S. agroterrorist attack.

A large amount of the investment theory detailed in the finance literature presupposes standard operation of the capital markets driven by normal investment behavior. Traditional theories of asset allocation, for instance, typically assume normal conditions and investment cycles in which risk profiles remain fundamentally stable. However, the thesis demonstrates that periods of general market uncertainty brought forth by extreme events such as agroterrorism will tend to disrupt the normal relationships among asset classes and alter investor risk preferences. The immediate consequences of terrorist attacks for financial markets are predictable in that they increase levels of investor risk aversion. Karolyi (2006) argues that the expected economic impact of terrorism in the intermediate and longer term is a reduction in confidence, an increase in the risk aversion of consumers and firms, a decrease in consumption and real investment activity, an economic slowdown or recession, and a spillover into other stock markets, fixed income market yields, and currency markets.

The results suggest that terrorism and other severe exogenous factors generate periods of investor unrest, and that this prevailing condition in turn generates significant impacts to asset classes in equities, fixed income, and foreign exchange. For instance, the spread between lower quality and higher quality corporate bond yields tends to widen during these times, because investors are less certain of future economic conditions and therefore place a higher premium on the safety, stability, and liquidity of investment products. High yield credit spreads tracked against the 10-year Treasury can indicate heightened credit concerns in the market and thus potential systemic disruptions. This flight to quality implies that investors transfer funds into safer bonds unless they can procure higher premiums on lower-grade securities. Investors shift away from high-return asset classes such as equities and high yield bonds to intermediate-grade bonds and government bonds. Likewise, there is flight to safety and quality in the currency market similar to the flight to safety and quality observed in the fixed income market, which in turn impacts foreign exchange values.

Although under the new conditions of financial uncertainty and economic distress this defensive investment strategy may be optimal, it would likely represent suboptimal portfolio allocation during normal times. The agricultural terrorist event assumed to occur in the future alters the investment landscape, leading to optimal investment strategies that are more conservative. Over the long run this defensive investment strategy offers lower returns on investment, lower aggregate incomes, and lower economic growth rates relative to baseline projections. This theory is supported by the simulation results to be presented in Chapter 10, which provide real estimates of lower economic growth rates relative to baseline projections in the macro model.

Originating from a large open economy model, I impose exogenous shocks on key sectors of the macro economy: consumer sentiment, the S&P 500 stock index, 10-year Treasury yields, Aaa – 10-year Treasury yield spreads, Baa – Aaa yield spreads, the value of the dollar against currencies of major trading partners, and the value of the dollar against currencies of other important trading partners. When adversely impacted, each of these parameters in the Global Insight macro model contributes to the overall projected decline in real GDP growth. The strategy focuses on adjustments in these markets based on a macro view of economic, political, and business factors. Instead of assessing the impacts on individual securities, this top-down approach captures shocks in key financial variables.

At the micro level, the success of the firm is generally tied to the health of the macro economy. Therefore, impact analysis must account for the general business environment in which the firm operates. For many firms in different industries, shocks to the broader economy have a greater effect on profits than the firm's relative performance within its industry. Furthermore, research has shown that the level of the broad market and aggregate earnings trend together. It makes sense, then, for a top-down analysis of the impacts of agricultural terrorism to consider macro factors and the impacts on financial markets. In previous chapters we operated within a regional framework in order to explore the costs of agroterrorism in terms of output, employment, and value added for key sectors within a regional economy of interest. Here we do the same, except that the region is defined as the national economy of the United States, and the cost of the attack is defined as the total loss in national output.

I note that the projected adjustments in these financial variables are slight, and none of the alternative attack simulations forecast an oncoming recession. However, in the context of a $12 trillion U.S. economy, slight changes in key financial variables can result in significant cumulative current value dollar losses. Furthermore, the losses in national economic output are never fully recovered, even though the results will show that the real GDP growth rate recovers by the third quarter of 2007 following a hypothetical terrorist attack assumed to occur at the beginning of the third quarter of 2005. The macro results section will demonstrate that a period of increased financial uncertainty brought forth by a future agroterrorist event can be expected to cause a negative deviation in real GDP growth rates from baseline growth rates, and this deviation, although slight, proves very costly in terms of lost output. The expected shift to lower-return investments offers lower aggregate income and output, which translates into lower real GDP growth rates.

The event is assumed to occur during the summer of 2005, with baseline and post-shock simulations performed through 2010. The difference between projected real GDP in the post-shock and baseline scenarios is the measure of the total national economic cost of the event. I present only short-term real GDP impacts. No attempt was made to model long run changes in productivity growth, such as rising costs of transactions through increased security measures or higher insurance premiums. The focus of this study is on the broader costs of an agroterrorism event that impacts U.S. financial markets, and is not industry or firm specific.

CHAPTER SEVEN

DESCRIPTION OF MACRO DATA

7.1 Global Insight Macroeconomic Model

The data for the model are taken from the detailed Global Insight U.S. Macroeconomic Model, which is a 1,200-equation model of the U.S. economy. The model is solved iteratively to generate the results of the post-shock scenario. The model depicts the economic behavioral processes and interactions of households, firms, and governments. Major aggregate demand components of the model include consumption, investment, and government purchases. Consumer purchases are divided into three separate categories: durable goods, nondurable goods, and services.

Expenditures on durable goods are sensitive to consumer sentiment, household net worth, and current finance costs. The exchange rate component of the model is sensitive to international differences in inflation, trade deficits, interest rates, and capital flows between the U.S. and its competitors. Short run and long run interest rates are represented in the model, and they constitute the main output of the financial sector. Aggregate supply is estimated by a Cobb-Douglas production function, combining increases in total factor productivity with growth in factor inputs. Trend technological change and R&D stock are the key factors that determine total factor productivity. Again, however, no attempt was made to model the impacts on total factor productivity, and the add-factors associated with this variable remain fixed in all simulations. Inflationary expectations impact consumption through the consumer sentiment parameter, while expectations of future economic growth rates impact business investment.

7.2 University of Michigan Consumer Sentiment Survey

The University of Michigan Consumer Sentiment Index is the item employed in the Global Insight model that measures public confidence in the U.S. economy. The index is based on a telephone survey with a sample size of 500, and survey results are indexed for the national economy as a whole, as well as for four separate regions: north central, north east, south, and west. A preliminary mid-month release is based on roughly two-thirds of the full sample of interviews. The survey consists of five questions. Two of the five questions ask respondents to assess present economic conditions, and the remaining three questions ask respondents to provide their expectations of future economic performance. The level of the present conditions component relates to the level of economic activity, whereas the expectations component relates to the rate of economic growth.

The expectations sub-index is a component of the composite index of leading economic indicators. The Michigan survey asks respondents about their intent to purchase big-ticket household items and asks about changes in the respondent's own financial situation. Unlike the Conference Board's consumer confidence survey, which closely tracks labor market conditions, the Michigan survey does not account for employment outlook. The apparent rule of thumb is that a one-point movement in the Michigan index is equivalent to a two-point movement in the Conference Board index.[16]

[16] For more information regarding the University of Michigan Consumer Sentiment Survey, refer to Ludvigson, Sydney C. (2004), "Consumer Confidence and Consumer Spending." Journal of Economic Perspectives

CHAPTER EIGHT

THE KEYNESIAN MODEL

The theoretical model underlying my analysis was first specified by Cho and Moreno (2003). The model examines the impact of exogenous shocks in the context of a New Keynesian macroeconomic model. The IS or demand equation is based on representative agent utility maximization with external habit persistence. The effects of structural shocks are recovered from the model solution and changes to the macro variables are then interpreted. Because of the time series restrictions implied by the model, a close relationship is established between the equation parameters and changes in the macro variables due to global uncertainty following financial shocks.

The IS or demand equation explains the demand side of the economy, derived from a representative agent model presented in the literature by Fuhrer (2000), who focuses on consumption expenditures for non-durable goods and services. He argues that if the sources of gradual responses to economic shocks are not captured in adjustment costs or in a fuller accounting of uncertainty, then what is needed is a reexamination of the specification of the utility function. The utility function is represented as

$$U_t = \frac{1}{(1-\sigma)}\left[\frac{C_t}{C_{t-1}^{\gamma}}\right]^{(1-\sigma)} \tag{1}$$

Current utility, U_t, depends on current consumption, C_t, relative to the habit reference level, or lagged consumption. The parameter γ indexes current consumption to lagged consumption. Because the utility function allows for consumers who form slowly adjusting habits, the implications are slower responses to major changes in macroeconomic conditions. Because of assumed consumption smoothing behavior, both the level and the change in consumption will adjust slowly in response to shocks to interest rates or income. We can rewrite the utility function from (1) into the following:

$$U(C_t) = \frac{(\frac{C_t}{H_t})^{1-\sigma} - 1}{1-\sigma} \qquad (2)$$

where C_t denotes the level of consumption, H_t denotes the external level of habit, and σ denotes the inverse of the elasticity of substitution. By saying the level of habit is external implies that it does not factor in as an argument for utility maximization. The budget constraint is represented as

$$C_t + B_t \leq \frac{P_{t-1}}{P_t} B_{t-1} R_t + W_t \qquad (3)$$

The budget constraint suggests that the representative agent has a level of consumption, C_t, plus a value of present asset holdings, B_t, that cannot exceed the endowment level. This endowment level is derived from labor income, W_t, and the real value of asset holding held at the start of the period, $\frac{P_{t-1}}{P_t} B_{t-1}$, multiplied by the nominal gross return on the assets, R_t. Maximizing the utility function from (2) subject to the budget constraint from (3), the Euler equation can be represented as

$$1 = E_t \left\{ \psi \frac{U'(C_{t+1})}{U'(C_t)} \frac{P_t}{P_{t+1}} R_t \right\} \qquad (4)$$

where ψ is the time discount factor and *P* is the price level. By assuming joint lognormality of consumption and price, we can derive the following:

$$c_t = \alpha_c + \mu E_t c_{t+1} + (1-\mu)c_{t-1} - \phi(r_t - E_t \pi_{t+1}) \tag{5}$$

where $\alpha_c = \frac{-\ln(\psi) - \frac{1}{2}V_t(\sigma c_{t+1} + \pi_{t+1})}{\sigma(1+h) - h}$, c_t is the log of consumption, V_t is the conditional variance operator, $\mu = \frac{\sigma}{\sigma(1+h)-h}$, and $\phi = \frac{1}{\sigma(1+h)-h}$.

The national income identity is represented as follows:

$$Y_t = C_t + G_t \tag{6}$$

where Y_t represents aggregate supply and G_t represents the remaining components of aggregate demand: investment, government expenditures, and net exports. Taking logs yields $c_t = y*_t + z_t$, where $y*_t$ is the log of gross domestic product and $z_t = \log(\frac{Y_t - G_t}{Y_t})$. Let $y*_t = y_t^T + y_t$, where y_t^T represents the potential output element of $y*_t$ and y_t is the output gap. Thus, equation (5) is transformed into the following expression:

$$y_t = \alpha c + \mu E_t y_{t+1} + (1-\mu)y_{t-1} - \phi(r_t - E_t \pi_{t+1}) + g_t \tag{7}$$

where $g_t = -(z_t + y_t^T) + \mu E_t(z_{t+1} + y_{t+1}^T) + (1-\mu)(z_{t-1} + y_{t-1}^T)$. As g_t increases, y_t increases, and as g_t decreases, y_t decreases. By defining $\alpha_g = Eg_t$, where *E* represents the unconditional expectation operator, the demand side of the economy is represented by the following IS equation:

$$y_t = \alpha_{IS} + \mu E_t y_{t+1} + (1-\mu) y_{t-1} - \phi(r_t - E_t \pi_{t+1}) + \varepsilon_{IS,t} \quad (8)$$

where $\alpha_{IS} = \alpha_c + \alpha_g$ and $\varepsilon_{IS,t} = g_t - \alpha_g$. Utilizing this theoretical representation, we can interpret $\varepsilon_{IS,t}$ as an exogenous shock to aggregate demand. Notice that a positive shock increases y_t, whereas an adverse shock decreases y_t. Although the last term in equation (8) captures impacts to aggregate demand, it does not specify or measure shocks to the individual demand components. We would expect the agroterrorist attack to impact various demand components in reduced form, including consumer sentiment, interest rates, and foreign exchange values. Returning to equation (6), we can improve model specification by expanding the market clearing condition into the individual demand components, such that

$$Y = C + I + G + (X - M) \quad (9)$$

Where

C = Consumption, I = Business Investment, G = Government expenditures, X = Exports, M = Imports, (X-M) = Net Exports, and NFI = Net Foreign Investment

$$C = a + b(Y - T)$$
$$I = i_0 - i_1(r)$$
$$(X - M) = NX = e_0 - e_1(FX)$$
$$NFI = n_0 - n_1(r)$$
$$NFI = NX$$
$$e_0 - e_1(FX) = n_0 - n_1(r)$$

Where

Y = National Income, T = Taxes, r = the real rate of interest, and FX = foreign exchange value of the dollar

The parameters $a, i_0, e_0,$ and n_0 represent shifters that influence consumption, domestic investment, international trade, and foreign investment, respectively. The consumption demand shifter can be shown as some combination of consumer sentiment and consumer wealth components. The *a* term in the aggregate consumption function can be decomposed into $a = a_0 + a_1 CS + \alpha_1 CS + a_2 W + \alpha_2 W + a_z Z$, allowing us to rewrite consumption as

$$C = a_0 + a_1 CS + \alpha_1 CS + a_2 W + \alpha_2 W + a_z Z + b(Y - T) \quad (10)$$

The CS term represents consumer sentiment, W represents consumer wealth, and Z represents a vector of other consumer demand shifters. The α_1 parameter is interpreted as the add factor specific to consumer sentiment, and the α_2 parameter is interpreted as the add factor specific to consumer wealth. Shocks were similarly imposed to interest rates, the stock market, and the value of the dollar by adjusting the add factors specific to these model parameters. Thus, we can interpret exogenous shocks on aggregate demand as negative adjustments to independent variable add-factors.

CHAPTER NINE

THE EMPIRICAL STRATEGY

9.1 Historical Events Database

The first step involved assembling enough data series to determine what a normal response to an agroterrorist attack would be. The data series could then be used to obtain an impulse response function that describes how the variables move over time. This approach offers a main contribution to modeling impacts of terrorism on key financial variables. Whereas other approaches focus on estimating micro-level costs of terrorism starting with individual firms and agents, the methodology employed here starts with larger aggregates and allows for the broader estimation of the macroeconomic impacts.

The methodology becomes extremely useful in imposing exogenous shocks on various parameters in the econometric model. The difficulty arises in attempting to quantify the magnitude and duration of such shocks. The magnitudes of the changes in the add factors, and in turn the independent variables, were determined by compiling an historical database of observed events. Within the event study methodology, I examine the capital market response to a set of historical terrorist and military attacks. This is essentially the standard event study test to determine whether the capital markets experienced significant abnormal returns in response to any of the historical events (Chen and Siems, 2004).

Although the United States has not previously experienced a catastrophic attack on its food supply system, the country has experienced previous destabilizing terrorist and geopolitical events that were of a similar nature to the hypothetical event studied in this analysis. These events were of a national scale, and brought forth periods of financial uncertainty that influenced the movement of large macro variables. The historical response of these variables can be leveraged to model the typical market response to a U.S. agroterrorism event, in terms of both depth of shock and response path. Determining which events to include requires a somewhat subjective decision-making process. The set is restricted to transnational events, or shocks, that generated financial impacts and exhibited traceable responses. Although the list is subjectively determined, I selected events from the Significant Terrorist Incidents list released by the U.S. Department of State (2001), and also included major military shocks that were unexpected and resulted in geopolitical instability.

Domestic acts of terrorism typically do not demonstrate measurable impacts in large financial data sets, and are therefore excluded from consideration. For example, right wing acts of domestic terrorism, such as anti-abortion bombings, and left wing acts of domestic terrorism, such as environmental terrorism, are relatively minor and typically do not generate measurable impacts on large investment variables. They also seem to produce different impacts on investor psychology and market behavior relative to major geopolitical shocks, and likely originate from a different distribution than the set of shocks appropriate for this analysis. The chosen set of events was further broken down into categories of major events and lesser events in order to allow calculations of mean impacts for the three major events and for all events taken in sum.

The major events include the terrorist attacks of September 11, 2001, the Iraqi invasion of Kuwait on August 2, 1990, and the Iranian Embassy hostage incident that began on November 4, 1979. The impacts of the 2001 anthrax attacks are captured in the 9/11 observation, having occurred shortly after 9/11 and having been perceived by the general public as extensions of 9/11. The anthrax attacks illustrate the point that even minor cases of biological attacks that result in only a few cases of illness or death can still cause psychological damage and increasing levels of financial uncertainty.

The three lesser events include the first bombing of the World Trade Center on February 26, 1993, the bombing of U.S. embassies in Kenya and Tanzania on August 7, 1998, and the attack on the U.S. Navy destroyer USS Cole on October 12, 2000.

The data values in the events database are drawn from different years, ranging from 1979 to 2001. Because the data values for the events originate from different base levels, the impact estimates are given as cumulative monthly percent changes in the financial variables. Presented in tables 29-34 are cumulative monthly mean changes and standard deviations associated with all six events post-shock, which were determined on a monthly basis for a period of 12 consecutive months. These average monthly percent changes were then converted into quarterly cumulative percent changes from the base month. The base month was considered to be the month in which the shock occurred, and was given a value of $t = 0$. The first month after the shock was labeled $t + 1$, the second $t + 2$, and so on.

Adjustments had to be made for events occurring early in the month. I hypothesize that the 9/11 attacks, for example, occurred sufficiently early in the month for the $t + 1$ impacts to be captured in September rather than October. This hypothesis is supported by the empirical data. Thus, a rule was imposed on the data such that any event occurring on or before the 15^{th} of the month would be shifted back one month to better align the $t + 1$ values. The September 11, 2001 event has associated with it a month $t + 1$ percent change, which according to the rule reflects the percent change in the data from August to September. The same adjustments were made to all of the six events, with the exception of the first World Trade Center bombing which occurred toward the end of the month.

Table 29 Consumer Sentiment: average monthly cumulative percent change from base month

Months After shock	Mean Impact (%)	Standard Deviation
1	-4.12	6.49
2	-5.07	7.12
3	-8.15	11.21
4	-6.36	10.42
5	-10.60	9.98
6	-11.36	9.39
7	-9.24	10.25
8	-3.57	6.86
9	-3.42	7.44
10	-1.95	8.80
11	0.83	12.29
12	-0.94	14.08

Table 30 S&P 500: average monthly cumulative percent change from base month

Months After shock	Mean Impact (%)	Standard Deviation
1	-5.12	4.90
2	-5.94	6.40
3	-5.33	7.79
4	-2.25	8.06
5	-3.10	5.67
6	-4.35	9.65
7	-0.93	9.43
8	1.63	9.42
9	2.72	12.46
10	1.99	14.90
11	0.76	18.20
12	-0.94	14.08

Table 31 Value of the dollar versus currencies of major trading partners: average monthly cumulative percent change from base month

Months After shock	Mean Impact (%)	Standard Deviation
1	0.08	1.72
2	-1.20	2.46
3	-2.53	3.42

Table 31 (Continued)

4	-2.38	3.47
5	-0.99	4.17
6	-0.74	4.86
7	-1.39	4.65
8	-0.59	3.27
9	-0.40	3.10
10	-0.39	3.10
11	-0.80	3.14
12	-0.76	2.52

Table 32 Value of the dollar versus currencies of other important trading partners: average monthly cumulative percent change from base month

Months After shock	Mean Impact (%)	Standard Deviation
1	1.26	0.35
2	2.36	1.22
3	2.90	1.27
4	3.71	2.29
5	4.57	3.02
6	5.66	3.29
7	6.37	3.77
8	6.89	4.45
9	7.42	5.28
10	8.14	5.79
11	9.74	9.11
12	10.82	9.81

Table 33 10-year treasury yield: average monthly cumulative percent change from base month

Months After shock	Mean Impact (%)	Standard Deviation
1	-0.97	3.63
2	-3.36	6.13
3	-4.81	8.13
4	-0.90	11.83
5	-2.25	13.97
6	-5.47	9.86

Table 33 (Continued)

7	-6.07	7.48
8	-5.10	6.31
9	-4.08	4.94
10	-2.30	6.45
11	-1.89	9.99
12	-3.27	12.18

Table 34 Average Aaa – Baa corporate credit spread (bps)

Months after shock	Mean Impact (bps)	Standard Deviation (bps)
1	89	27
2	95	26
3	105	24
4	112	32
5	125	52
6	122	52
7	117	52
8	104	36
9	102	32
10	107	38
11	106	46
12	102	38

9.2 Methodology for Imposing Shocks on the Model

Imposing shocks on the baseline forecast did not require adjustments to the model equations, but rather adjustments to the appropriate model add-factors. In estimating large-scale econometric models, the estimated value of a single variable for the most recent time period often differs from what is observed in that same period. To provide a better fit with the most recent observed data, an add factor is used, which is a type of exogenous variable that is specific to the relevant explanatory variable. The adjusted value of the add factor enters the value of the parameter which enters the model.

A terrorism scenario was created after intervening in the baseline forecast and adjusting the projected baseline add-factors for the appropriate variables in the Global Insight model. The add factor adjustments were based on the mean shock values presented in the previous section, and were delivered to four separate sectors of the national economy: consumer sentiment, the S&P 500 stock price index, interest rates, and the foreign exchange value of the dollar. Within the fixed income asset class, interest rate add-factor adjustments were made to the 10-year treasury yield, the Aaa corporate yield, and the Baa corporate yield. Foreign exchange add-factor adjustments were made to the value of the dollar versus major trading partners and to the value of the dollar versus other important trading partners.

Table 35 Baseline add-factors for key financial variables

	Consumer Sentiment	S&P 500	Aaa Corporate	Baa Corporate	10-year Treasury	For. Ex. MTP	For. Ex. OITP
2005Q2	-0.814997	258.8427	0.099006	0.139010	0.673820	0.102063	0.091112
2005Q3	0.000191	265.6267	0.268159	0.291509	0.329724	0.092432	0.099947
2005Q4	0.000128	245.9663	0.309741	0.330808	0.299710	0.114553	0.118804
2006Q1	-0.000460	219.5573	0.327544	0.309470	0.279788	0.125430	0.131509
2006Q2	0.000261	217.0730	0.295624	0.283563	0.242957	0.136720	0.134248
2006Q3	-0.000608	231.0709	0.258686	0.254552	0.245329	0.145725	0.135699
2006Q4	-0.000602	241.4864	0.266339	0.242877	0.230217	0.154464	0.134981
2007Q1	0.000179	253.3121	0.245010	0.244870	0.140537	0.155102	0.134528
2007Q2	0.000487	238.5255	0.306854	0.279747	0.171399	0.163405	0.134597

Table 36 Post-shock add-factors for key financial variables

	Consumer Sentiment	S&P 500	Aaa Corporate	Baa Corporate	10-year Treasury	For. Ex. MTP	For. Ex. OITP
2005Q2	-0.814997	258.8427	0.099006	0.139010	0.673820	0.102063	0.091112
2005Q3	-5.079917	354.0000	0.470000	0.301300	0.271660	0.100000	0.120000
2005Q4	-8.297408	305.0000	0.400000	0.376300	0.163460	0.120000	0.160000
2006Q1	-4.755153	279.0000	0.347500	0.354000	0.180000	0.130000	0.200000

Table 36 (Continued)

2006Q2	-0.824476	277.0000	0.371000	0.316200	0.207000	0.140000	0.240000
2006Q3	-0.000608	267.0000	0.365000	0.278900	0.220000	0.145725	0.220000
2006Q4	-0.000602	257.0000	0.360000	0.261100	0.230217	0.154464	0.200000
2007Q1	0.000179	247.0000	0.345000	0.256500	0.140573	0.155102	0.180000
2007Q2	0.000487	238.5255	0.356800	0.285400	0.171399	0.163405	0.160000

The add factors for each parameter were adjusted for four consecutive quarters, then tapered, as necessary, to gradually bring the model back in line with baseline add factor estimates within eight quarters of the terrorist attack. The tapering method was used in order to provide a smoother transition and to eliminate large, sequential adjustments to the subsequent baseline add-factor. The attack is assumed to occur at the beginning of the third quarter of 2005, and the simulation continues through 2010, at which point the model appears to settle into long-run equilibrium.

The total economic losses are the difference in projected real GDP in the baseline and attack scenarios, excluding specific impacts on the food industry. The top-down model used in this analysis represents an aggregate model of the entire national economy and predicts economic behavior from statistically estimated relationships among variables in the past. The model has been estimated from actual macroeconomic behavior, and reflects the short-term costs of increased financial uncertainty surrounding an unexpected terrorist attack. The post-shock simulation generates a predicted economic impact with reference to the baseline scenario, measured as the percent change in real GDP in future years.[17]

[17] This approach quantifies post-shock GDP against a counterfactual (baseline real GDP forecast) based on individual observations that do not themselves utilize counterfactual estimation techniques. Alternatively, future research could measure each individual historical event against an estimated counterfactual (i.e. time trend variable) prior to measuring the aggregate mean against the baseline counterfactual. Thus, two sets of counterfactuals could be employed rather than one.

CHAPTER TEN

RESULTS OF MACRO ANALYSIS

10.1 Specifying the Magnitude of the Shock

The figures that follow show the monthly percent changes in the independent variables over time. Notice that we typically observe a negative reaction to the shock, followed by a return to pre-shock levels within one year. Also notice that the mean curve for the major events tracks the mean curve for all events very closely. The depth of the shock varies somewhat from event to event, and the response path returns quickly in some cases while more slowly in others. But looking at the mean values, we can see that recovery generally takes approximately 12 months, at which point the variables have returned to pre-shock levels. Consumer sentiment, the S&P 500, the interest rate variables, and the value of the dollar against currencies of major trading partners are all consistent with this pattern. The value of the dollar against currencies of other important trading partners, however, continues to increase over the entire 12-month period.

The University of Michigan's Consumer Sentiment Index, depicted in Figure 10, fell steadily after the first six months of the attack, and then returned to pre-shock levels within 12 months. The events included in the "Big 3" sub-index showed different individual responses, but the mean curve is relatively smooth. Consumer sentiment was surprisingly resilient following 9/11, returning to pre-shock levels within 5 months. The curve representing the Kuwait invasion shows that consumer sentiment fell roughly 30 percentage points within only 3 months following the shock, and required 8 months to reach pre-shock levels. Moreover, the initial recovery to the Kuwait invasion was quite slow, averaging at most one-percentage point recovery per month between months 3 and 6. Indeed, most of the recovery in consumer sentiment post-shock occurs between months 7 and 8. Previous research found that the decline in consumer sentiment associated with the Kuwait invasion helped predict subsequent weakness in consumer spending.[18]

Consumer sentiment following the U.S.S. Cole attack did not fully recover to pre-shock levels within 12 months, and similarly, consumer sentiment following the Kuwait invasion remained below pre-shock levels for eight consecutive months. Consumer optimism or pessimism concerning the present and future state of the overall economy is an important factor behind the level of economic performance. For instance, if consumers have lower confidence in their future levels of income, they may be less inclined to purchase big-ticket household items. Sentiment over the future state of the economy influences how much consumption and production will be sought and impacts aggregate demand for economic goods and services.

The first two figures show the value of the national consumer sentiment index across all years relevant to the data set, and provide evidence that the response path is strongly driven by the event and not by overall economic conditions. By inspection, we notice sharp breaks in the data following the event; often the variable is trending upward prior to the event and trending downward immediately following the event. And in those cases when the variable may be trending downward prior to the event, we observe an increase in the rate of this trend, suggesting the event is a contributing factor, if not the primary factor, behind the observed decline in value. The same pattern is evident in the stock market values presented in Figure12, and in the credit spread values presented in Figures 16 and 17.

[18] For a more detailed analysis of the link between consumer sentiment and consumer spending, refer to Throop, Adrian W. (1992), "Consumer Sentiment: Its Causes and Effects." Federal Reserve Bank of San Francisco Economic Review

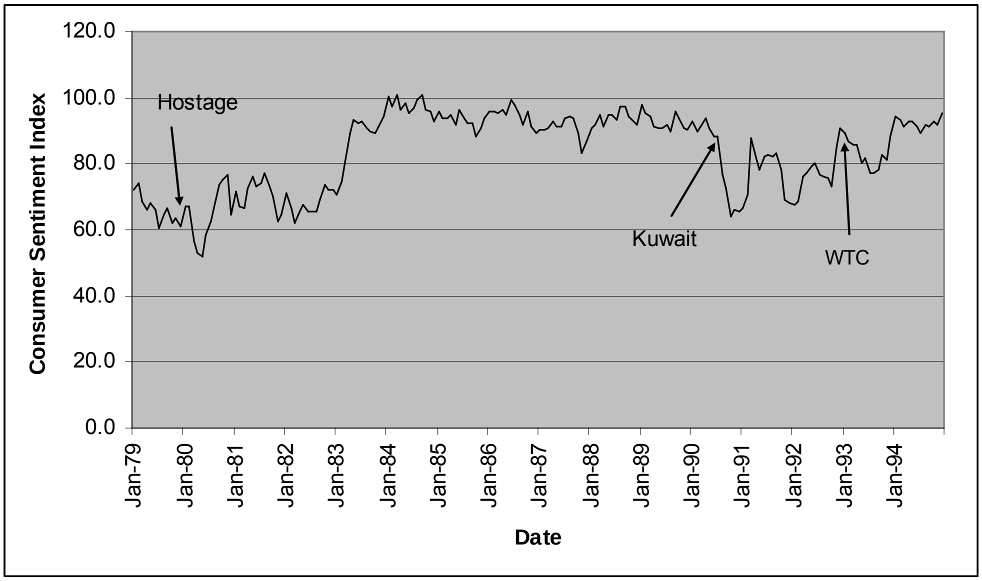

Figure 9 Historical Consumer Sentiment Index Values: 1979-1995

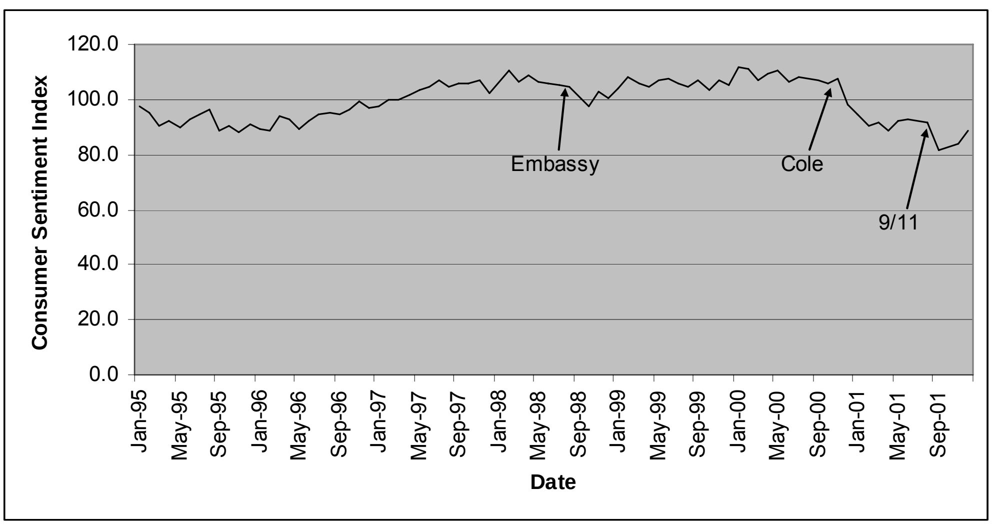

Figure 10 Historical Consumer Sentiment Index Values: 1995-2002

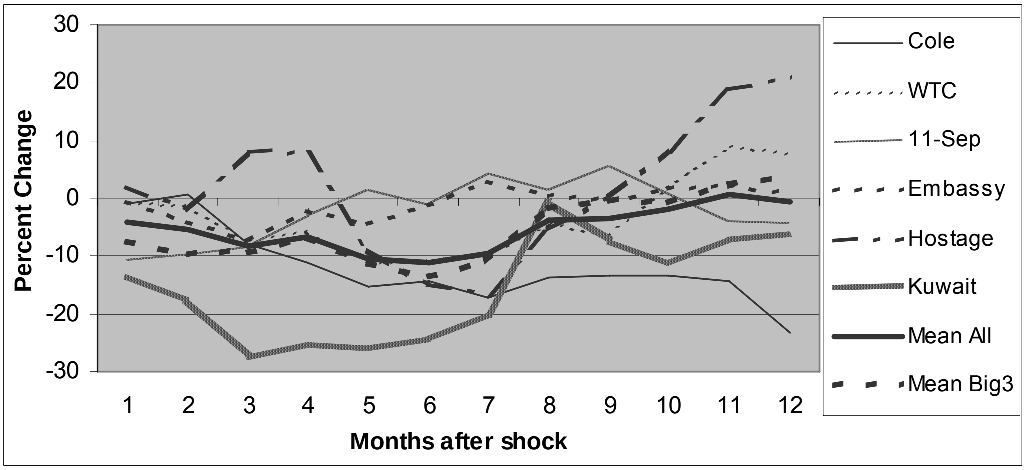

Figure 11   Monthly percent change in consumer sentiment index post-shock

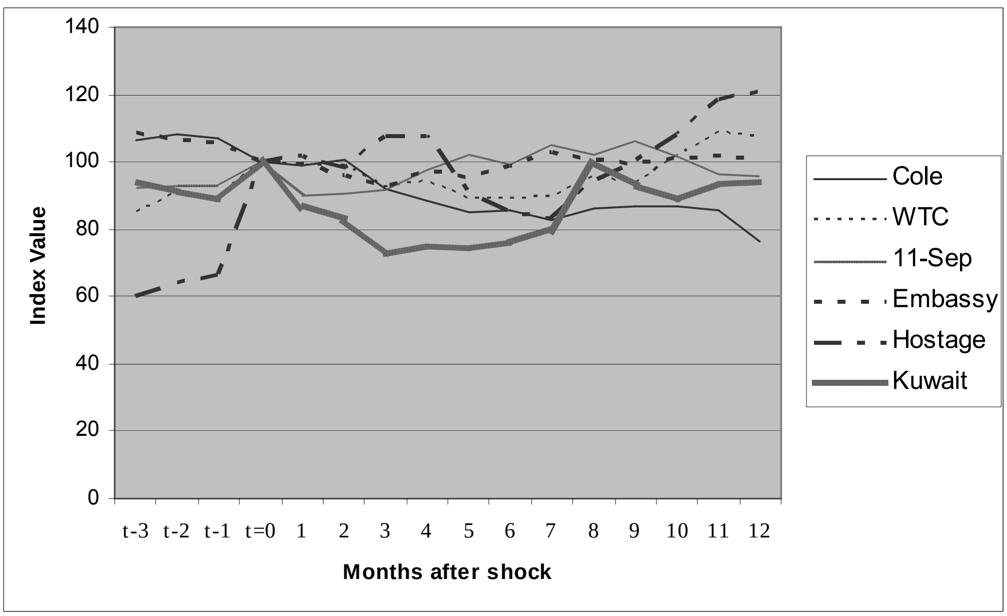

Figure 12   Monthly consumer sentiment values (indexed to 100)

Negative abnormal stock returns are analyzed using the S&P 500 composite stock index. In Figure 13, the S&P 500 appears to react negatively in the first six month following the shocks, which is similar to the results observed for consumer sentiment. Looking at the mean values for the “Big 3” major events, the stock market is down almost 7 percent during the first three months post-shock. The market recovers slightly after a six-month period, down more than 4 percent from pre-shock levels. After 12 months the market shows no lingering signs of negative reaction, and has returned to pre-shock levels. The mean line taken for all six events shows approximately the same reaction. The Kuwait invasion event follows the mean values most closely during months 7 through 12. The stock market following 9/11 was down almost 7 percentage points after 6 months.

This research project focuses on a hypothetical attack that is unanticipated by the market. The value of the stock market serves as an informative measure of the economic impact of agroterrorism. Stock prices reflect the expected future gains of a company, and also reflect expectations that those gains materialize (Frey and Luechinger, 2004). Both of these would be impacted by terrorism. First, expected profits would fall if anti-terrorism security measures increase production costs. Second, a future terrorist attack would increase uncertainty about future market prospects, which could potentially lead to a higher risk premium. As the economy recovers from the attack, the market would recognize large earning increases, in turn leading to higher stock prices.

In theory, bearish strategists might recommend industries with below-average sensitivity to the business cycle. Defensive investments likely would be pursued in lieu of higher growth opportunities in order to outperform the market during the economic slowdown. It is likely that we would observe a shift from small to large capitalization asset classes, as large-cap stocks typically outperform during periods of uncertainty. Although small and mid-cap stocks offer higher growth rates than large domestic stocks, the former would likely under perform if the U.S. economy slows following the agroterrorist attack. However, estimating shifts between individual stock classifications is not examined in this study, and the impact to the equity asset class is captured within the post-shock S&P 500 add-factor value. Figure 12 shows the historical value of the S&P 500 with logarithmic trend line from 1990 to 2001. The market declines immediately following each of the events depicted.

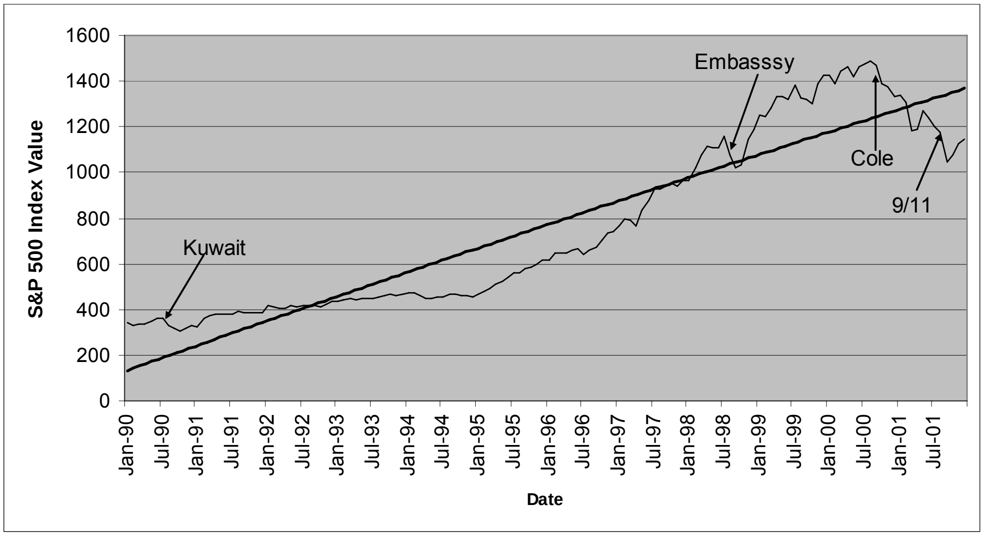

Figure 13   Historical S&P 500 Index Values: 1990 – 2001

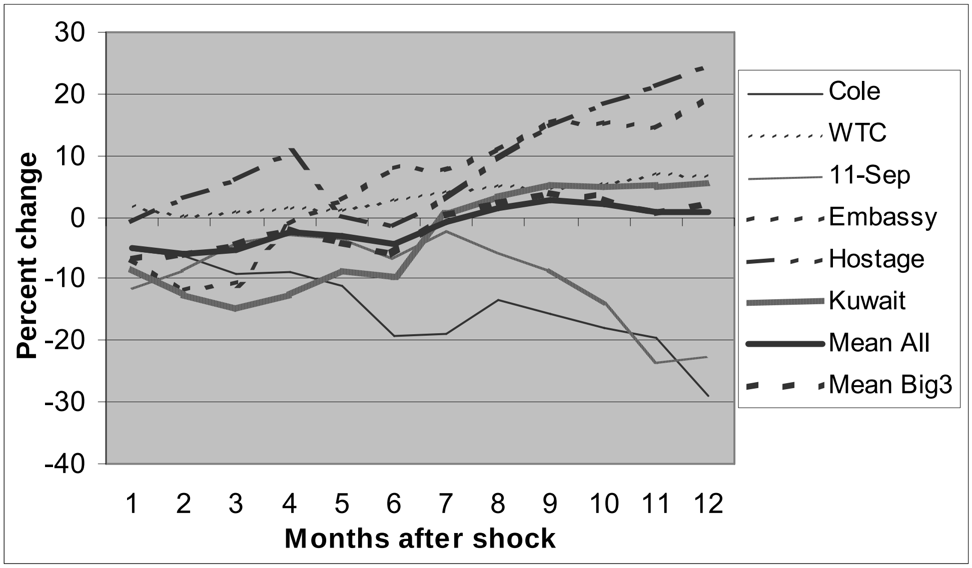

Figure 14 Monthly percent change in S&P 500 stock price index post-shock

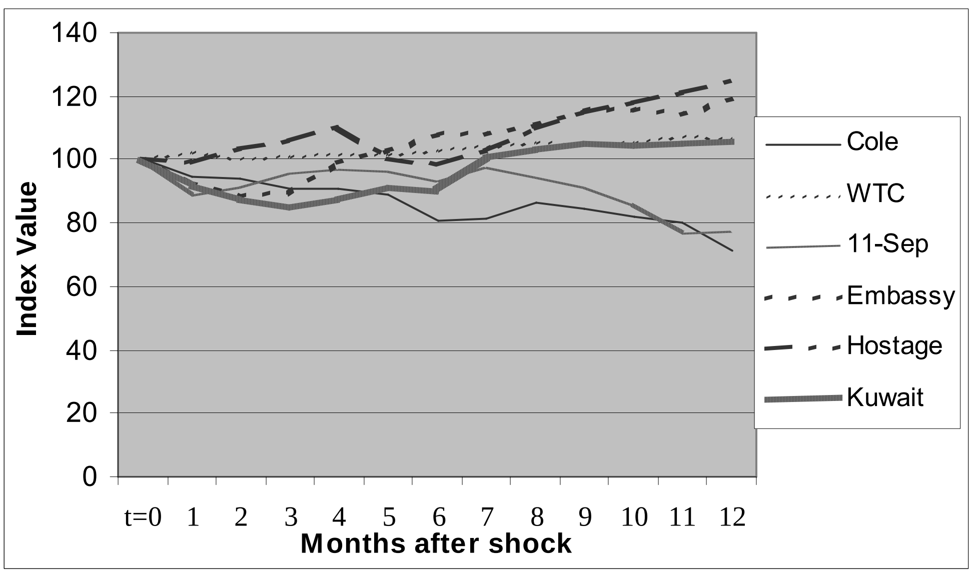

Figure 15 Monthly S&P 500 stock prices post-shock (values indexed to 100)

The Aaa corporate – 10-year Treasury spread did not noticeably change; however, Figures 16-19 show that the Baa-Aaa corporate spread did widen sharply, reflecting a movement from lower quality to higher quality credits during the post-shock period of uncertainty. As Figure 19 illustrates, credit spreads remained stable in the months immediately prior the attack, and then increased sharply for the first two quarters post shock. As the macro economy slows following the attack, yield spreads will tend to widen. Investors perceive a higher probability of corporate bankruptcy when economic growth declines, even assuming bond ratings remain fixed, because investors demand a commensurately higher default premium measured by the difference between the promised yield on a corporate bond and the yield on a risk-free asset.

This result is more pronounced in the curve representing mean values for the "Big 3" events, which suggests that a more serious attack would impact credit spreads more significantly. Bond managers would likely lower the term of bond portfolios in the presence of general market uncertainty and higher projected interest rates. With the economy weakened, corporate profits in aggregate would be expected to decline and bond managers would likely decrease portfolio exposure to lower-grade corporate bonds because such bonds would exhibit deteriorating credit worthiness during the post-shock period. The thesis relates to several studies in the literature, such as Krishnamurthy (2002) and Longstaff (2004) that demonstrate widening spreads between illiquid and liquid assets during episodes of flight to quality. Gatev and Strahan (2006) argue that during these periods investors shift from riskier assets such as commercial paper toward safe assets such as bank deposits. Other studies, including Stock and Watson (1989) and Friedman and Kuttner (1993) show that widening credit spreads are a leading economic indicator for business cycle downturns.

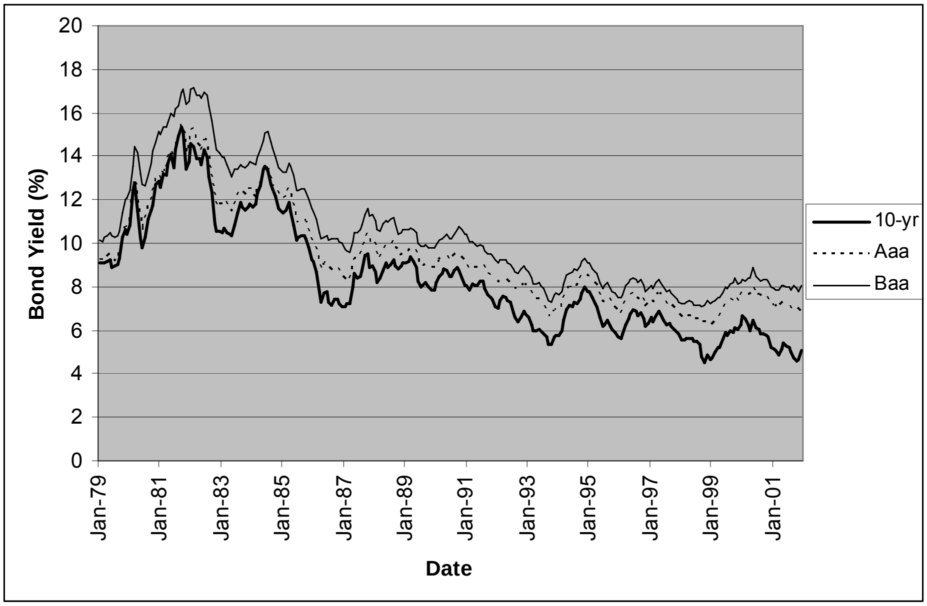

Figure 16 10-year treasury and corporate bond yields from 1979-2002

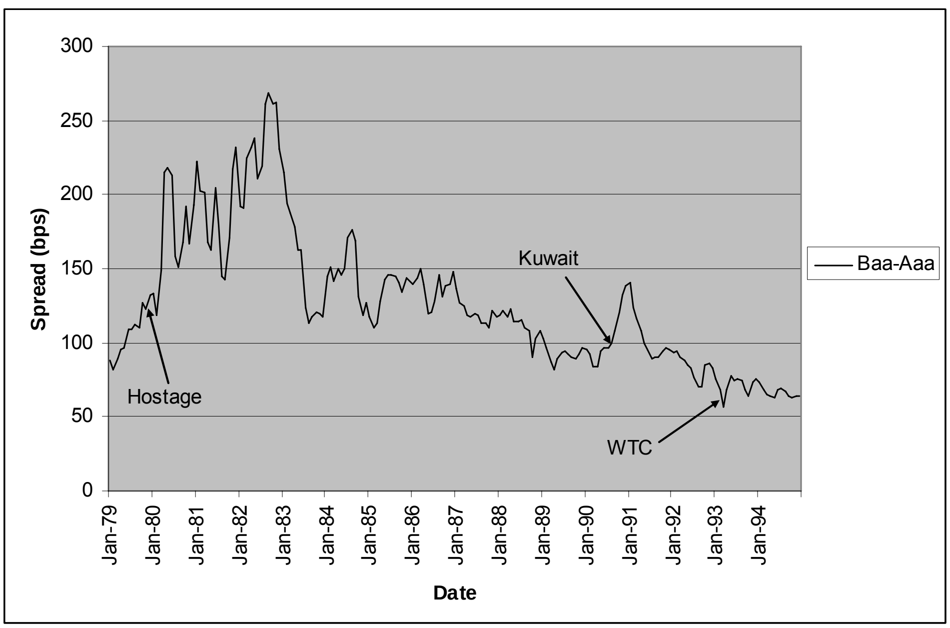

Figure 17 Baa-Aaa credit spread (bps) from 1979-1995

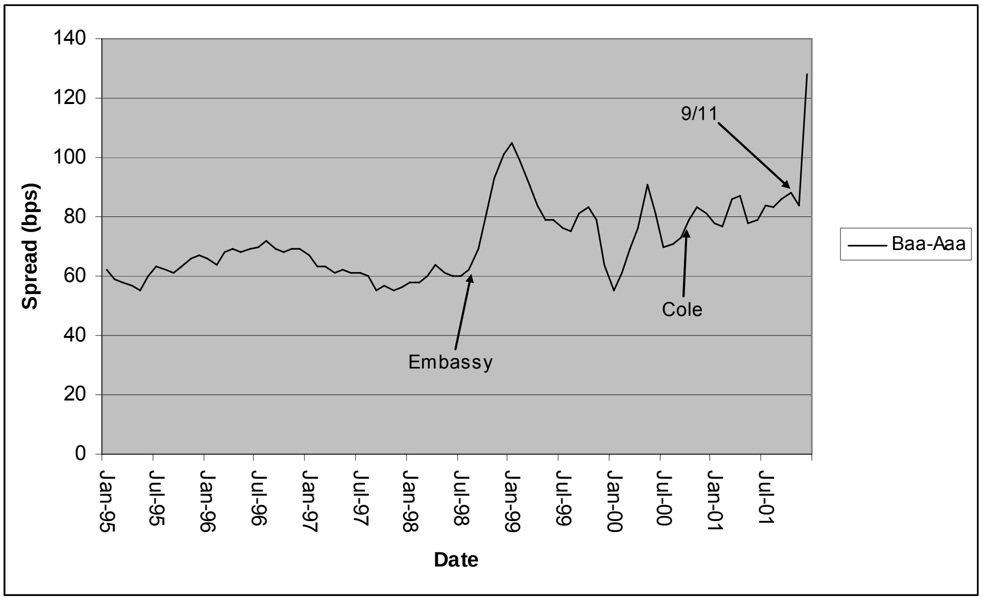

Figure 18 Baa-Aaa credit spread (bps) from 1995-2002

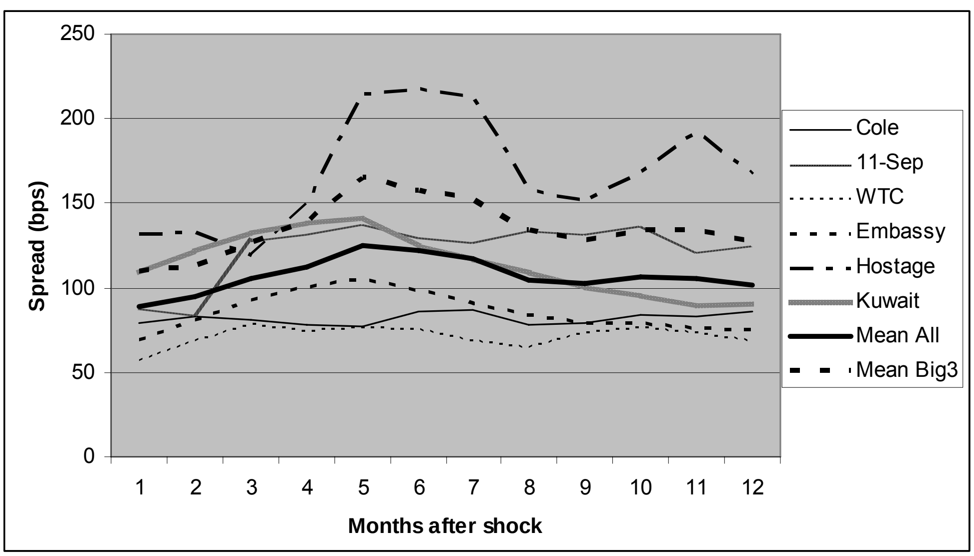

Figure 19 Baa-Aaa corporate interest rate spreads (bps) post-shock

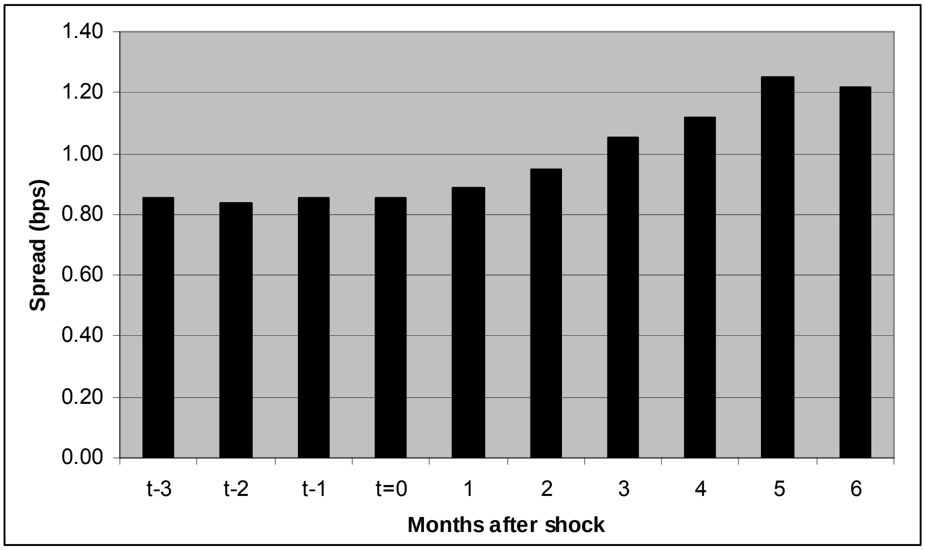

Figure 20 Average Baa-Aaa credit spreads (bps) over 6-month post-shock period

The U.S. 10-year Treasury note has become the security that is most often quoted when examining the performance of the government bond market and is used to express the longer-term expectations of future macroeconomic activity. It is also significant to the mortgage market, which uses the yield on the 10-year Treasury note as a benchmark for establishing mortgage interest rates. Bond ratings measure the quality of the bond, based on the debt issuer's financial condition and the extent to which the issuer will be able to meet interest and principal repayments. Investment grade bonds are considered high-quality bonds and typically have the smallest amount of risk and lower corresponding rates of interest.

Intermediate-grade bonds have good short-term security but increasing risk as the bond matures, and thus the issuer pays a higher interest rate. Aaa corporate bonds are deemed to be the best quality and carry the smallest amount of investment risk. Interest payments on these bonds are protected by a stable margin and secure principal. Baa corporate bonds are deemed medium-grade obligations, and they are neither highly protected nor poorly secured. Interest payments and principal security associated with Baa bonds are often sufficient in the near term, but certain risk protections may be inadequate over longer periods of time.[19]

Financial market variables often contain useful information to help predict real economic activity. This information is readily accessible, and the variables are quite reliable, because market players base investment decisions on their forecasts of economic activity.[20] Saito and Takeda (2000) use empirical studies to find that the yield spread of corporate bonds is a better predictor of future economic activity than government bonds. They also suggest that given the relatively stable credit risk premium observed in corporate bond yields, more emphasis should be given to the information present in the yield spread of corporate bonds for future economic activity.

The authors argue that although the theoretical background for the predictive power of the yield spread is not clear, there tends to be a flight to quality during periods of crisis and uncertainty. During such times, investors shift away from high-return asset classes such as equities and high yield bonds to intermediate-grade bonds and government bonds. The investment performance of equities and higher-yielding bonds is variable on a monthly basis, but the returns exceed those offered in high-quality fixed income investments. Bonds would represent attractive wealth preservation vehicles that would enable investors to receive stable income in a declining market environment following the agroterrorist attack.

In addition to the impact on fixed income asset classes, Figure 20 shows that instead of strengthening, the value of the dollar versus currencies of major trading partners actually weakens slightly. The curve representing the mean values for all six

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[19] The two main services that rate bonds are Moody’s and Standard and Poor’s. The ratings systems are similar but are given different letter codes.
[20] This notion is covered in detail by Kozicki, Sharon (1997), “Predicting Real Growth and Inflation with the Yield Spread,” Federal Reserve Bank of Kansas City Economic Review.

events follows a similar shock pattern to the Kuwait event, although muted in depth. Following the attack, the U.S. market becomes a somewhat riskier investment relative to baseline conditions, thus improving the relative attractiveness of foreign markets and currencies of major trading partners. In addition to the U.S. dollar, the Federal Reserve refers to seven of the 26 broad index currencies as “major” currencies. These include the euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar, and Swedish krona. The remaining 19 currencies are referred to as “other important trading partners” of the United States.

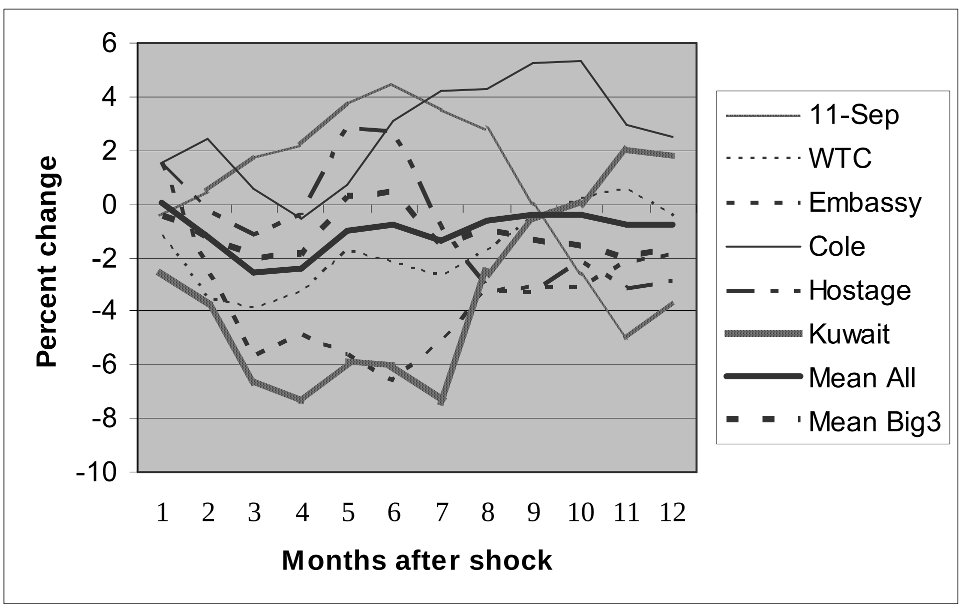

Figure 21 Monthly percent changes in the value of the dollar versus currencies of major trading partners post-shock

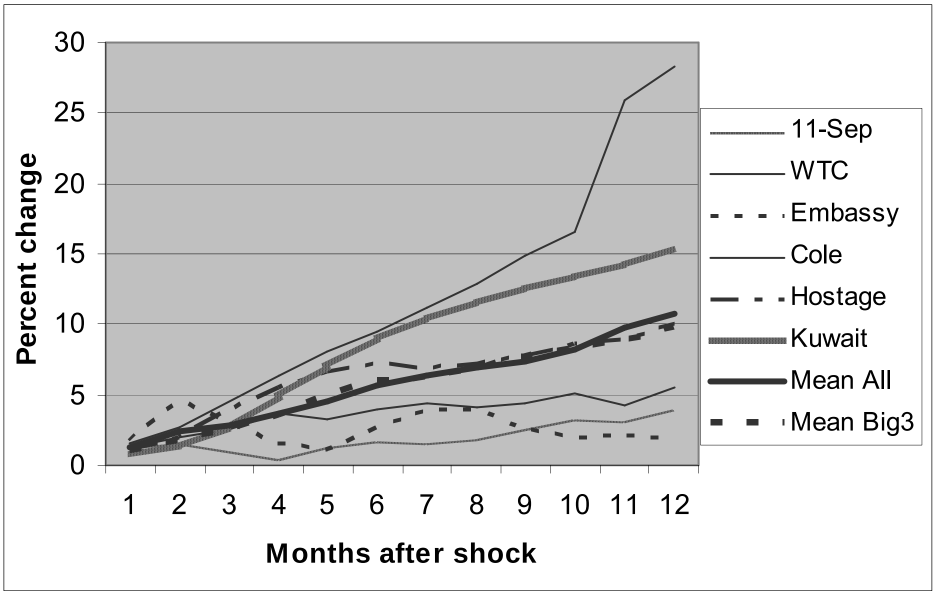

Figure 22 Monthly percent change in the value of the dollar versus currencies of other important trading partners post-shock

When compared to currencies of other important trading partners, the value of the dollar strengthens significantly following Iraq's invasion of Kuwait. Both the mean of the "Big 3" major events and the mean of all six events, depicted in Figure 21, show an increase in the value of the dollar of more than 10 percent after 12 months. The U.S. Federal Reserve calculates a separate trade-weighted dollar index composed of 19 "other important trading partners" (OITP) which generally include Mexico, China, Taiwan, Korea, Singapore, Hong Kong, Malaysia, Brazil, Thailand, Philippines, Indonesia, India, Israel, Saudi Arabia, Russia, Argentina, Venezuela, Chile and Colombia. The U.S. dollar remains, for the most part, the world's reserve currency, and thus the health of the U.S. dollar impacts all economies, currencies, and global investments.

The theoretical explanation of the foreign exchange adjustment is that during periods of crisis and uncertainty, there is flight to quality in the international currency market similar to the flight to quality observed in the fixed income market. Following the 9/11 attacks, for instance, emerging markets were impacted by slowing external demands and a flight to quality in the financial markets (Johnston and Nedelescu, 2005). Flight to quality episodes are a major driver of financial instability, and involve higher perceived risk that does not circumscribe purely fundamental shock, but rather centers around the financial system (Caballero and Krishnamurthy, 2005). Although the attack increases the level of financial uncertainty around the domestic U.S. economy, the impacts ripple throughout the international financial system.

The occurrence of an unanticipated attack on U.S. agriculture causes an increase in agents' risk perception. This effectively lowers portfolio demand for emerging market currencies and increases demand for safer and more liquid currencies, such as the euro and U.S. dollar, because major currencies are perceived as safe havens and typically trade in liquid financial markets. Investor conservatism and appetite for quality and liquidity increases demand for major currencies relative to emerging market currencies, and hence increases the value of the dollar relative to currencies of other important trading partners.

10.2 Interpreting the Results: Impact on Real GDP Growth Rates

This section provides estimates of the financial impacts of a terrorist attack on U.S. agriculture. The impacts in my model are based on add factor changes derived from historical financial variable averages presented in section 9.1. The total economic impact of the terrorism event is assumed to be the difference between real GDP growth in the baseline (sans terrorism) scenario and the post-terrorism scenario. Further, the add factor adjustments were the only revisions to the model, and thus represent the only differences between the two scenarios. Other exogenous variables, such as oil prices and policy parameters, remain fixed at baseline levels.

The proposed attack is assumed to occur during the beginning of the third quarter of 2005. The projected 2005 annual real GDP growth rate falls slightly, from 3.56 percent in the baseline forecast to 3.48 percent in the post-shock forecast. As shown in Table 37, the economic impact on 2005 full-year real GDP will be muted, because included in this projection are two full quarters of pre-shock growth. Looking ahead to 2006 projections, annual real GDP growth falls from an estimated 3 percent in the baseline forecast to an estimated 2.66 percent in the post-shock forecast. This one-third of one percent decline in the projected annual real GDP growth is slight, but translates into significant output losses. On a fourth quarter over fourth quarter basis, real GDP growth falls from 3.34 percent in the baseline forecast to 3.1 percent the post-shock forecast in 2005. The estimated 2006 real GDP growth on a fourth quarter over fourth quarter basis again falls about one-third of one percent, from 2.86 percent in the baseline forecast to 2.52 percent in the post-shock forecast.

Table 37 Projected Real GDP 2005-2010: Baseline versus post-shock (trillions $)

Year	Baseline	Post-shock
2005Q1	11.0888	11.0888
2005Q2	11.1745	11.1745
2005Q3	11.2796	11.2701
2005Q4	11.3620	11.3357
2006Q1	11.4437	11.4121
2006Q2	11.5267	11.4906
2006Q3	11.6011	11.5514
2006Q4	11.6872	11.6255
2007Q1	11.7706	11.7004
2007Q2	11.8749	11.7992
2007Q3	11.9701	11.8915
2007Q4	12.0752	12.0008
2008Q1	12.1701	12.1057
2008Q2	12.2769	12.2244
2008Q3	12.3690	12.3289
2008Q4	12.4604	12.4329
2009Q1	12.5490	12.5322

Table 37 (Continued)

2009Q2	12.6425	12.6338
2009Q3	12.7269	12.7227
2009Q4	12.8235	12.8214
2010Q1	12.9130	12.9092
2010Q2	13.0121	13.0064
2010Q3	13.0968	13.0897
2010Q4	13.1911	13.1829

The shocks were imposed on the model by adjusting appropriate add-factors for one year following the attack. This adjustment restricted the direct impact to the first four quarters following the attack; however, the total impacts extend for more than two years. The terrorist attack reduces U.S. economic growth rates for 9 consecutive quarters, from the third quarter of 2005 through the third quarter of 2007. By 2010 the model reaches a longer-term equilibrium, and the economic growth rates in the two scenarios are roughly equivalent. As noted, the decline in annual real GDP growth rates is modest, but in dollar terms the losses are substantial. The cumulative current value loss in real GDP from the third quarter of 2005 through the fourth quarter of 2009 amounts to approximately $190 billion.

The estimated $190 billion in lost output is never recovered despite estimates showing that economic growth rates beyond 2010 are roughly equivalent in both the baseline and post-shock forecasts. Although growth rates eventually recover from the shock, the economy is growing off a lower base level of output. Figure 24 illustrates this result. The area between the two curves represents cumulative losses in real GDP. Figures 25 and 26 provide the distribution of projected short-term annual losses in real GDP over time. Approximately 13.7 percent of the total losses accrue in 2005, 32.1 percent accrue in 2006, 38.8 percent accrue in 2007, 14.4 percent accrue in 2008, and 1.1 percent accrue in 2009.

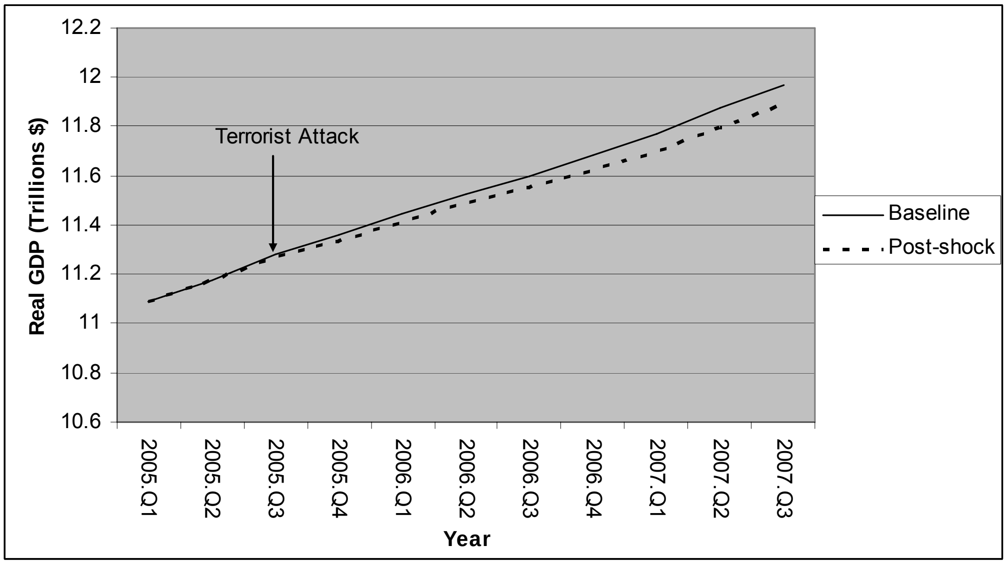

Figure 23 Projected Real GDP: Baseline versus post-shock scenarios (trillions $)

Table 38 Projected short-term annual losses in real GDP on a fourth quarter over fourth quarter basis from 2005-2009

Year	**Annual losses in billions $**	**Percent of total**
2005	-26.22	13.67
2006	-61.65	32.12
2007	-74.45	38.79
2008	-27.58	14.37
2009	-2.02	1.05
Total	**-191.92**	**100.00**

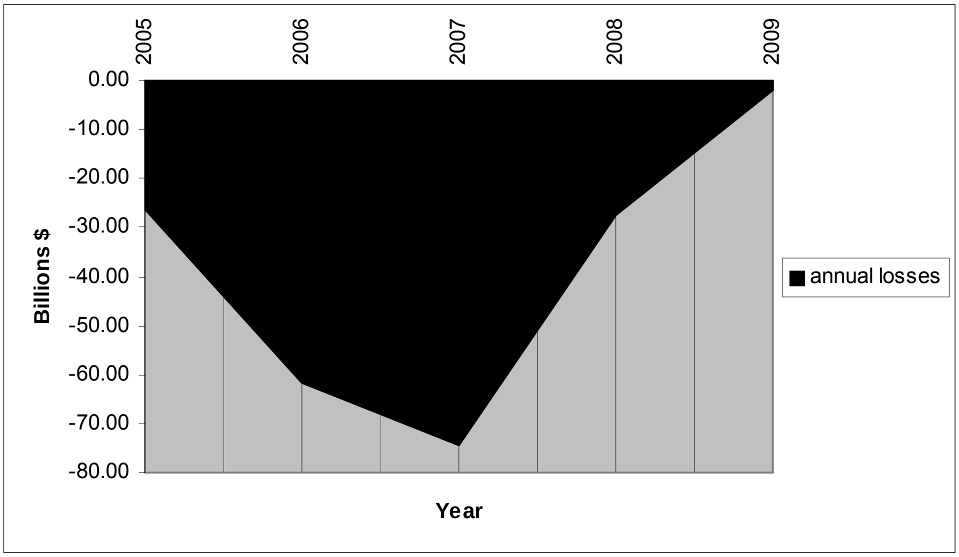

Figure 24 Projected short-term annual losses in real GDP from 2005-2009

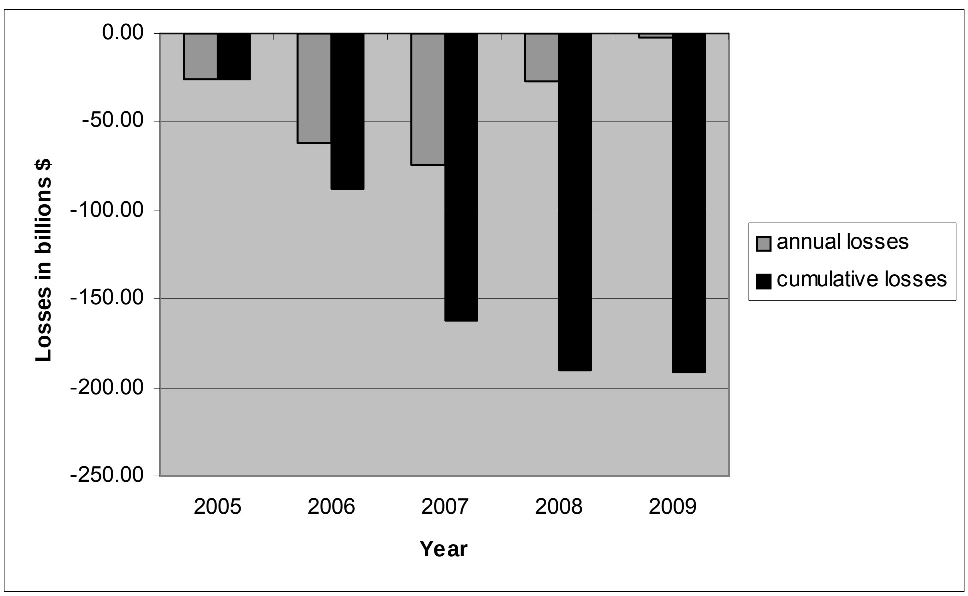

Figure 25 Projected annual and cumulative losses in real GDP (2005-2009)

10.3 Alternative Simulations

Through measuring statistical responses against a linear regression line we might improve model robustness for the first-quarter monthly response values. However, given that the historical response path requires a full 12 months to return to pre-shock levels – and perhaps longer under more extreme assumptions – there is little evidence to suggest that linear time trend analysis improves accuracy among the longer-term add-factor estimates. Given that add factor adjustments are imposed for the entirety of one year, it makes little sense to compromise the integrity of medium-term shock estimates for the sake of improved short-term model accuracy. Instead, we can change the model assumptions regarding the severity of the attack in order to improve model robustness and produce a distribution of output losses.

The $190 billion estimate is based on mean changes to the financial variables, and can be considered a statistically conservative estimate. To that end, a catastrophic agroterrorism event would not necessarily yield data responses that track the historical mean precisely. To account for this, I have isolated the “Big 3” events in the model output displays to illustrate a more probable response for events that are more extreme than all events taken collectively. For example, the results provided in section 10.1 support the notion that a more serious attack would deepen the impact on investor risk preferences and widen credit spreads more dramatically.

Further, we can adjust the parameter add-factors to reflect a shock one-half or one full negative standard deviation from the mean to generate model results that reflect more serious impacts than historical averages. Such scenarios are not unrealistic, considering the high vulnerability and importance of agriculture and related industries to the broader national economy. In previous chapters I discussed these vulnerabilities as well as the high-probability, high-consequence nature of U.S. agroterrorism. If the proposed attack is larger than mean levels indicate, then the total impacts will be magnified. Figure 27 shows the distribution of losses for alternative assumptions regarding the level of impact to the consumer sentiment variable, based on the statistics provided in Table 29.

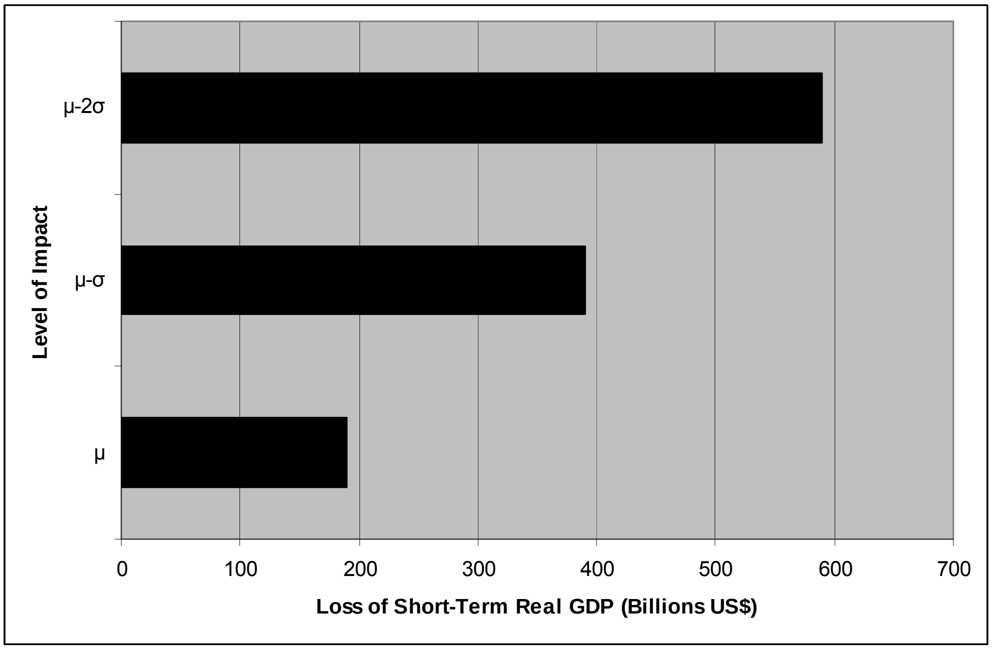

Figure 26 Distribution of output losses

Imposing a shock to consumer sentiment one negative standard deviation beyond the mean, while holding the other adjusted add-factors at average shock levels, decreases real GDP by an additional $200 billion over four years. Imposing a shock to consumer sentiment two negative standard deviations beyond the mean decreases real GDP by an additional $400 billion over four years. If we run post-shock simulations for each individual parameter, while holding the other model add-factors at baseline levels, we can isolate the marginal impacts over consecutive time periods and determine the timing of real GDP losses. The losses attributable to consumer sentiment are concentrated in the first 12 months following the attack. After 24 months the marginal impacts become negligible. The marginal impacts of higher interest rates, a flight to quality in the fixed income markets, and a weaker equities market remain negative throughout the entire forecast time period. Not surprisingly the losses attributed to the stock market decline do not factor in significantly two full years after the attack, which speaks to the efficiency of the broader market for equity securities.

The impacts in the foreign exchange markets associated with the increased value of the dollar against currencies of other important trading partners are greatest in year two. Projected losses attributed to foreign exchange exceed projected losses attributed to any individual parameter, totaling almost $60 billion after two years. The estimated losses attributed to lower consumer sentiment total $30 billion after two years, or roughly half of the amount attributed to foreign exchange. Together, consumer sentiment and foreign exchange effects constitute nearly 50% of the total impact, with the remainder coming from the stock market, interest rates, and bond yields. The marginal impact of the trade sector becomes positive in the fourth and fifth years after the attack, reflecting movement of the U.S. dollar to more normal levels versus currencies of other important trading partners.

CHAPTER ELEVEN

CONCLUSION

11.1 Summary of Findings

Using SAM modeling techniques and the IMPLAN database, I have assessed the general equilibrium impacts of a terrorist attack on agriculture in St. Lawrence County, New York. Assumptions were made about the severity of the FMD attack, and each FMD attack simulation was coupled with a 10-percent reduction in tourism demand. This reduction in tourism demand stems from government enforcement of restricted access areas, ongoing food safety concerns, and fears over potential recurrence of the disease.

The regional analysis illustrates that although various industries seem unrelated to livestock and thus insulated from impacts on agriculture, the inter-connectedness of industries within the local economy leads to outcomes in which the total economic impacts are widespread. Although economic losses of the proportion suggested here could arise from a number of exotic animal diseases, the thesis focused on an FMD attack scenario given the severe economic losses associated with the virus and the high priority of preventing the outbreak.

The macro analysis illustrates that the impacts of agroterrorism across the national economy would overshadow the regional impact estimates across all model assumptions regarding the severity of the attack. Although the economy has shown resilience to economic disruptions, the economic damage associated with an attack on U.S. agriculture has been projected to slow economic growth rates into the future. These adjustments in quarterly real GDP growth estimates are slight, yet translate into significant present value losses in output. Although growth rates are estimated to recover within 9 quarters of the attack, the cumulative losses in national output are never fully recovered. The results suggest that an agroterrorist attack would increase investor uncertainty, and that this prevailing condition would in turn generate impacts to consumer sentiment and to financial asset classes in stocks, bonds, and currency markets. In the face of financial uncertainty, investors attempt to withdraw from medium to long-term capital commitments in favor of safe and liquid financial claims.

11.2 Policy Implications

The regional simulation results suggest that the impact on the tourism industry would likely dwarf the impact on the livestock industry. From an economic point of view, policy makers should take account of the impact on outside industries when formulating response procedures to agroterrorism. Because animal products from countries that have earned FMD-free status sell at a premium, and because countries that adopt a full vaccination approach restrict their access to high-value markets in the short-run, there exists a shortsighted focus on fully eradicating the disease through total stamping out, which may or may not be economically optimal from a cost-benefit perspective. Furthermore, the likelihood of tourism-related activities effectively spreading the disease between animal herds has not been adequately established, and remains a topic of future research. While steps should be taken to lessen the impact on agriculture, these steps could quickly amplify the economic damage if tourism is negatively impacted as a result of the response measures.

A complete study of alternative response measures is not the focus of this research, yet given these results, government officials might reevaluate the assumed policy of mass slaughtering of exposed animals, and consider partial stamping-out (slaughter of only clinically infected livestock) procedures or eradication through vaccination. These alternatives would mitigate the losses to agriculture while simultaneously preserving the economic vitality of tourism and other industries. The assumed direct impacts to tourism, which are conservative by design, have significant general equilibrium impacts that are imposed not by the terrorist, but by the government in response to the initial attack. In the event of an FMD attack, it is recommended that government officials actively pursue strategies aimed at dual goals: eradicating the FMD virus, and minimizing damage to nonagricultural industries.

Given the results of the macro analysis, policy makers should widen their focus from a firm-level or county-level view to a macro-level view of terrorism. The macro results show that the costs to the national economy are significant in terms of slower growth and lower output levels. The macro component focuses initially on projections based on mean historical averages for the sake of conservatism, and as we allow for shocks beyond the mean, the model estimates grow significantly. The macro component also places a valuable benchmark in the process of estimating the economic impacts of agroterrorism, using a methodology that captures the probable impacts to broad asset classes within U.S. financial markets.

11.3 Directions for Future Research

The macroeconomic research might be extended to foreign countries that have experienced shocks affecting financial variables in order to increase the number of observations and to compare the movement of foreign financial variables against what I have projected for the U.S. economy. In terms of future regional analysis of agroterrorism, steps can be taken to formulate an operational research question aimed at addressing if other sectors, in addition to livestock, dairy, and tourism, would experience direct, initial impacts. I am careful not to claim that an FMD attack would be contained and prevented from spreading to neighboring regions. Indeed, given the various avenues through which the virus could be spread following the initial introduction, it is unlikely that in the long run the disease would be limited to the region under study. Further research may build on the model presented here, in an attempt to simulate regional impacts beyond a single round and to estimate the inter-regional effects of agroterrorism. Although the regional model applied in this thesis depicts diminished expenditures within the agricultural and tourism sectors, it does not take measure of the impact to surrounding regions or to the overall national economy.

Future research could examine the impact of agroterrorism on the distribution of income among households, including Gini coefficients, to see whether inequality changes under the different scenarios. This task could be accomplished using the SAM model described in Chapter Two. Future research might also model the impact on tourism as a function of the impact on livestock dairy output. To my knowledge there is no study that models an FMD attack under variable impacts to the tourism industry, and it seems plausible that the impact on tourism would directly relate to the severity of the initial attack. As the disease spreads, the size of the infected area grows and the reach of the quarantine enforcement expands, which further disrupts tourism activity.

The methodology follows previous studies recorded in the literature, by imposing a 10-percent shock to tourism that is fixed across all simulations. However, larger impacts on livestock might translate into larger impacts on tourism, because the volume of slaughtering, burning, and burying would increase, along with heightened fears over the safety of the food supply and the threat of re-infection. Further research might explore a scenario in which the medium-term impact no longer assumes that the smallest of livestock impacts translates into the same tourism reduction as the largest of livestock impacts. Future research could perhaps relax the 10-percent tourism impact assumption and provide a model specification that varies the direct impact on tourism with the severity and scope of the attack

REFERENCES

"Bioterrorism: A Threat to Agriculture and the Food Supply," 2003 GAO Testimony Before the Committee on Governmental Affairs, U.S. Senate

Blake, A. et al. (2003). "Quantifying the Impact of Foot and Mouth Disease on Tourism and the UK Economy," *Tourism Economics*

Breeze, R. (2004). "Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science," Agroterrorism: Betting Far More than the Farm, vol. 2, no. 4: 251-264

Bruck, T. and Wickstrom, Bengt-Arne (2004). "The economic consequences of terror: guest editor's introduction," The European Journal of Political Economy, Vol. 20, pp. 293-300.

Caballero and Krishnamurthy (2005). "Financial System Risk and Flight to Quality," NBER Working Paper No. 11834

Casagrande, R. (2000). "Biological terrorism targeted at agriculture: The threat to U.S. national security," Nonproliferation Review: 95-105

Chalk, P. (2001). "Terrorism, Infrastructure Protection, and the U.S. Food and Agricultural Sector," *Testimony before the Subcommittee on Oversight of Government Management, Restructuring the District of Columbia, U.S. Senate*

Chen, A. and Siems, T. (2004). "The effects of terrorism on global capital markets," European Journal of Political Economy, Vol. 20, pp. 349-366

Cho and Moreno (2003). "A Structural Estimation and Interpretation of the New Keynesian Macro Model" Faculty Working Paper No. 14/03

Cupp et al. (2004). "Agroterrorism in the U.S.: Key Security Challenge for the 21st Century," vol. 2, no. 2: 97-105

Ekboir, J.M. (1999). "Potential Impact of Foot-and-Mouth Disease in California: The Role and Contribution of Animal Health Surveillance and Monitoring Services." Davis, California: University of California Agricultural Issues Center

Enders, W. and Sandler, T. (2002). "Patterns of Transnational Terrorism, 1970-99: Alternative Time Series Estimates," International Studies Quarterly, vol. 46, pp. 145-165

Enders, W. and Sandler, T. (2004). "An Economic Perspective of Transnational Terrorism," European Journal of Political Economy, vol. 20, no. 2: 301-316

Enders, W. and Sandler, T. (2005). "Transnational Terrorism: An Economic Analysis," in H.W. Richardson, P. Gordon, and J.E. Moore II (eds.), *The Economic Impact of Terrorist Attacks*

FAS Online (1997). "Foot-and-mouth disease spreads chaos in pork markets," USDA Livestock and Poultry: World Markets and Trade, http://www.fas.usda.gov/dlp2/circular/1997/97-10LP/taiwanfmd.htm

Frey and Luechinger (2004). "Calculating Tragedy: Assessing the Costs of Terrorism." CESinfo Working Paper No. 1341

Friedman, B. and Kuttner, K. (1993). "Economic Activity and the Short-Term Credit Markets: An Analysis of Prices and Quantities," Brookings Papers on Economic Activity, vol. 2, pp. 193-283

Fuhrer, J.C. (2000)."Habit Formation in Consumption and its Implications for Monetary-Policy Models," American Economic Review

Garner, A. (2002). "Consumer Confidence After September 11," Federal Reserve Bank of Kansas City Economic Review

Gatev, E. and Strahan, P. (2006). "Banks' Advantage in Hedging Liquidity Risk: Theory and Evidence from the Commercial Paper Market," Journal of Finance," vol. 61, issue 2, pp. 867

Global Insight, Travel & Tourism (2003). "The Delaware Tourism Satellite Account: A Comprehensive Understanding of the Economic Contribution of Travel and Tourism in the State of Delaware."

Harvey, D. R. (2001). "What Lessons from Foot and Mouth? A Preliminary Economic Assessment of the 2001 Epidemic," Center for Rural Economy, Working Paper No. 63

Hoffman, B. (1988). *Recent Trends and Future Prospects of Terrorism in the United States*, RAND Corp. Santa Monica, CA

Jensen, K. et al. "Projected Economic Impacts of a Foot and Mouth Disease (FMD) Outbreak in Tennessee," *Industry Brief*, AIM-AG

Johnston, R.B., and Nedelescu, O.M. (2005). "The Impact of Terrorism on Financial Markets," IMF Working Paper WP/05/60. Available at IMF: http://www.imf.org/external/pubs/ft/wp/2005/wp0560.pdf

Karolyi, G.A. (2006). "The Consequences of Terrorism for Financial Markets: What Do We Know?" Available at SSRN: http://ssrn.com/abstract=904398

Khan, A. et al. (2001). “Precautions against Biological and Chemical Terrorism Directed at Food and Water Supplies,” *116 Public Health Reports 4*

King, B.B. (1985). “What is a SAM?” in Pyatt, G. and Round, J.I. (ed.), Social Accounting Matrices: A Basis for Planning. Washington: World Bank

Kohnen, A. (2000). "Responding to the Threat of Agroterrorism: Specific Recommendations for the United States Department of Agriculture," BCSIA Discussion Paper 2000-29, ESDP Discussion Paper ESDP 2000-04, John F. Kennedy School of Government, Harvard University

Kozicki, S. (1997). “Predicting Real Growth and Inflation with the Yield Spread.” Federal Reserve Bank of Kansas City Economic Review
Krishnamurthy, A. (2002). “The bond/old-bond spread,” Journal of Financial Economics, vol. 66, pp. 463-506

Longstaff, F.A. (2004). “The flight-to-liquidity premium in U.S. Treasury bond prices,” Journal of Business, vol. 77, pp. 511-526

Ludvigson, S.C. (2004). “Consumer Confidence and Consumer Spending,” *Journal of Economic Perspectives*

“The Macroeconomic Impacts of a Foot-and-mouth Disease Outbreak: An Information Paper for Department of the Prime Minister and Cabinet,” Prepared by the Reserve Bank of New Zealand (2003)

Manning, B. and Chad, S.A. (2005). “Deliberate contamination of the food supply chain,” British Food Journal, vol. 107, no. 4: pp. 225-245

Mickolus, E. (1982). *International Terrorism: Attributes of Terrorist Events, 1968-1977.* ITERATE 2, Ann Arbor, MI: Inter-University Consortium for Political and Social Research

Miernyk, W.H. (1965). *The Elements of Input-Output Analysis*, New York: Random House.

Minnesota IMPLAN Group (2000). IMPLAN Professional 2.0 User Guide, Analysis Guide, Data Guide. Stillwater, MN: Minnesota IMPLAN Group.

Okubo, S., and Planting, M.A. (1998). *U.S. Travel and Tourism Satellite Accounts for 1992: Survey of Current Business.* Washington, D.C.: Bureau of Economic Analysis, U.S. Department of Commerce

Parker, H.S. (2003). “Agricultural Bioterrorism: A Federal Strategy to Meet the Threat,” *McNair Papers*

Pate, J. and Cameron, G. (2001). “Covert Biological Weapons Attacks Against Agricultural Targets: Assessing the Impact Against U.S. Agriculture.” Discussion Paper 2001-9, John F. Kennedy School of Government, Harvard University, August 2001

Pate-Cornell, E. and S. Guikema (2002). “Probabilistic Modeling of Terrorist Threats: A Systems Analysis Approach to Setting Priorities Among Countermeasures.” *Military Operations Research,* The Military Operations Research Society

Phillips, M.B. (2005). “Bioterrorism: A Brief History,” *Northeast Florida Medicine,* Focus on Bioterrorism 2005

Richardson, H.W., P. Gordon, and J.E. Moore II (eds.) (2005). *The Economic Impact of Terrorist Attacks*. Northampton, MA: Edward Elgar.

Rickman, D. and Schwer R.K. (1993). “A Systematic Comparison of the REMI and IMPLAN Models: The Case of Southern Nevada,” *Review of Regional Studies*, Fall 1993, pp. 148-149.

“Risk Assessment for Food Terrorism and Other Food Safety Concerns,” U.S. Food and Drug Administration Center for Food Safety and Applied Nutrition (2003)

Rose, A. and Liao, S. (2005). “Modeling Regional Economic Resilience to Disasters: A Computable General Equilibrium Analysis of Water Service Disruptions,” *Journal of Regional Science,* 45(1), 75-112.

Saito, Y., et al. (2000).“Predicting the US Real GDP Growth Using Yield Spread of Corporate Bonds,” *International Department Working Paper Series 00-E-3*, Bank of Japan

Schmid, A. and Jongman, A. (1988). *Political Terrorism: A New Guide to Actors, Authors, Concepts, Data Bases, Theories and Literature.* New York: North-Holland Publishing Company

Sirkin, G. (1959). “The theory of the regional economic base,” *Review of Economics and Statistics*, vol. 59, pp. 426-429.

Sobol, J. et al. (2002). “Threat of a biological terrorist attack on the U.S. food supply: the CDC perspective,” *Lancet*

Spake, A. (2001). “Food Fright: Terrorism Spotlights the Risks in the Food Supply.” *US News & World Report*

Stock, J.H. and Watson, M.W. (1989). "New indexes of coincident and leading economic indicators," in Fischer, S. (eds.), NBER Working Paper No. R1380 (MIT Press, Cambridge, MA)

Throop, A.W. (1992). "Consumer Sentiment: Its Causes and Effects," *Federal Reserve Bank of San Francisco Economic Review*

Trajtenberg, M. (2004). "Defense R&D Policy in the Anti-Terrorist ERA," NBER working paper

U.S. Department of State (2001). Significant Terrorist Incidents, 1961-2001: A Chronology, Office of the Historian, Bureau of Public Affairs, Oct. 31

The Voice of Agriculture (2001). "Foot-and-mouth surveillance may prevent attacks," Farm Bureau News, vol. 80 No. 19.

Wein and Liu (2005). "Analyzing a bioterror attack on the food supply: the case of botulinum toxin in milk," Proceedings from the National Academy of Sciences

Wilkerson, C. (2003). "Travel and Tourism: An Overlooked Industry in the U.S. and Tenth District," Federal Reserve Bank of Kansas City, Third Quarter 2003 Economic Review

Wilson et al. (2000). "Agroterrorim, biological crimes, and biological warfare targeting animal agriculture," Brown C., Bolin (eds): Emerging Diseases of Animals. Washington, ASM Press, pp. 23-57