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Agro-terrorism and the Grain Handling Systems in Canada and the United States

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The Issue

The grain handling sector in Canada and the United States is vital to agriculture and trade. In a typical year on the Canadian prairies, about 140,000 producers deliver some 20 to 30 mmt of grain for export to primary elevators. In the United States, about 2.1 million producers deliver about 300 mmt of grain to primary elevators. Canadian grain is moved to export position using more than 400,000 hopper cars and marine containers, where about 1,200 ships per year are loaded. In the United States, about 1.08 million rail carloads of grain are originated per year, and about 23 mmt of grain are shipped on barges per year. These U.S. figures are in addition to trucks, which, more so than in Canada, are also used to deliver grain to primary processors and to terminal and export markets.

The volume of grain trade gives rise to concern about risks of terrorism in the sector.[1] From a security perspective, the grain, pulse and oilseed supply chain is noteworthy because much of it is characterized by relatively long-term, insecure, bulky storage (particularly on farms) along with numerous modal and inter-modal product transfers. These factors suggest there are many places where chemical or biological contaminants could be introduced into this supply chain. From the perspective of the United States, security throughout the Canadian system as well as the U.S. system is a concern, since cross-border traffic in these products is significant, with an average of about six million tonnes of grain products alone imported into the U.S. each year (USDA-FAS, 2003).

Numerous interventions to enhance food safety and mitigate the risk of terrorism have been adopted or are in the process of being developed. Some of these are private initiatives and voluntary, as a component of firm-level security processes. Others are being adopted in response to legislated initiatives. The stakes are large, and there are likely to be substantial differences in costs and effectiveness of different approaches.

To frame the analysis, we begin with a brief discussion of current initiatives to mitigate agro-terrorism risks. Next, a real-options analytical framework is developed to evaluate, in terms of cost effectiveness, investment strategies to mitigate agro-terrorism risks. Finally, simulation results are used to describe management and policy implications of investment in risk mitigation with respect to agro-terrorism/food safety.

Implications and Conclusions

As time passes, risk management related to the potential for terrorism in the grain supply chain will escalate in importance. While current initiatives to mitigate agro-terrorism risks are important, are they appropriate? How do we prioritize investment in mitigation strategies to account for risks, costs, and benefits? To help answer these questions, we evaluate the overall need for investment in terror mitigation in the grain sector using a real-options framework. We develop a prototypical example, using best estimates of parameter values, which tracks millions of bushels from producers to end-users. Our model and results indicate that a sector with high volatility and a high net present value (NPV)/cost ratio (such as the rail transportation sector) provides valid real-option opportunities for mitigating agro-terrorism risk in the grain supply chain.

A major problem with using financial data generated by engineers on the different segments in the grain handling and transportation system is to account explicitly for the linkages between segments (from producers to end-users) and sectors. Results indicate that an agro-terrorism attack in the livestock sector will have indirect effects that necessitate investment in hedging, using futures or options, for corn producers. Investment strategies should not overlook such linkages. As well, research on real-option investment strategies, using the "tomato garden" framework described by Luehrman (1998), that explicitly accounts for such linkages, is illustrated in this article; further

research of this sort is highly encouraged. Regardless, it is important for the rail system and other sectors in the grain handling and transportation system to invest in tamper-proof seals, as suggested by the World Health Organization (WHO).

What is Being Done about Agro-terrorism in the Grain Handling Sector?

Varying forms of intervention might mitigate risks of terrorism, including high profile public and legislated initiatives. There are also numerous examples of private initiatives. These are noteworthy in the transportation sector; for instance, some railroads have embarked on thoughtful and carefully coordinated initiatives. Typically, these involve security, surveillance, sealed cars and periodic forms of testing. Food companies also engage in efforts to mitigate risks associated with the possibility of food terrorism, but these are predominantly voluntary and are difficult to monitor (U.S.-GAO, 2003). Finally, one of the higher profile risk mitigation efforts is the FDA's set of regulations that apply to imported food, requiring permits, testing, and registration of the food plant. These will affect exports of Canadian grain to the United States.

Thus far, the reaction of the Canadian government to the perceived terrorist threat has been mostly directed toward guaranteeing modal security within the transportation industries. However, modal security related specifically to trade has received far less attention and money from the Canadian government than from the U.S. government. The United States and Canada signed the so-called Smart Border Declaration (SBD) in late 2001, with the goal of negotiating a joint industry-government set of guidelines to enhance the security of U.S.-bound trade. In 2002, Transport Canada formed the National Road Security Team (NRST) to handle pressing trucking industry security concerns, from infrastructure to border delays (Transport Canada, 2003). Under these agreements, particular security focus will be given to what are referred to as "high-risk" containers crossing the border (Canadian Pacific, 2003). More definitive action for railways was taken in April 2003, when the U.S. and Canadian customs agencies, along with the two Class I Canadian railways, signed an extended version of the SBD tailored to the needs of the railway industry (Canadian Pacific, 2003). At that time, both railways also obtained accreditation with the U.S. Bureau of Customs and Border Protection (CBP) under a security program called C-TPAT (Customs-Trade Partnership Against Terrorism). In sum, the private sector in Canada appears to be taking the major initiative on security measures for surface transportation modes.

Not surprisingly, U.S. reaction to freight transportation security has been more pronounced. Under the auspices of the new U.S. Department of Homeland Security, security initiatives that will affect agricultural supply chains are those aimed at enhancing general port security along with other programs that specifically address the issue of marine container security. The Container Security Initiative (CSI) was begun in early

2002 (United States, 2002) and is intended to better identify and target "high-risk" containers coming from abroad. Security agreements have been reached with major ports around the globe, including many in Europe and Asia. Several of these ports actually have U.S. customs officers on site to monitor container traffic (Canadian ports are not part of this program). In June 2003, $170 million in general funding was awarded for port security enhancements across the United States. These grants will fund security upgrades such as harbor patrols, surveillance equipment and command and control facilities (Transportation Security Administration, 2003).

Clearly, many of the transportation-related security measures initiated by the United States will by extension provide more security for Canada, while the converse is not necessarily the case. If we consider recommended policy responses to the possibility of agro-terrorism (i.e., directives from the WHO), the potential contamination of the Canadian grain and specialty crop supply chain via the transportation system has not been taken very seriously. While this understated approach may be a reasonable policy response, Canada continues to be a weak link in the growing U.S. security network.

The other segment of the grain supply chain that appears to be susceptible to agro-terrorism is the elevator system. With just under 400 elevators in western Canada (Nolan, 2003) and 9,525 off-farm grain storage facilities in the United States (315 state-licensed grain elevators in North Dakota alone), adding protection against deliberate contamination for each elevator would be costly. Elevators are usually well monitored by staff, but have little formal security in place; thus, while it would be tricky to add contaminants without being noticed, it would not be impossible, for instance, to spread anthrax spores on top of grain waiting in an elevator for shipment.

Given the ways in which grain is moved and blended, it is unlikely that contamination at the elevator level would seriously affect any particular group of consumers; however, public concern about food contaminants at the moment is significant. The recently settled StarLink case where genetically modified corn accidentally entered the human food chain showed just how visible any contamination, no matter how benign, has become (Congressional Research Service, 2003). The StarLink case also showed that, so long as changes or additives to products are not visually observable, there is a chance that a malicious intrusion in the supply chain could propagate enough to be nominally detectable by, if not unsafe for, the consumer.

Why Is the Real-options Approach an Appropriate Tool for Evaluating and Mitigating Risks of Agro-terrorism?

Public and private sector investments in agro-terrorism surveillance, preparedness and response create real-option opportunities along the food supply chain. Such investments have heightened following the September 11th terrorist attack. While few reliable estimates of the total economic cost of the terrorist attacks have been completed, on the

transportation side, conservative estimates of the delay costs for the trucking industry alone in the weeks following September 11th are in the tens of millions of Canadian dollars (Goldfarb and Robson, 2003).

Public sector investments in the United States include the Public Health Security and Preparedness Act of 2002, the aforementioned C-TPAT, the CSI and several federally funded and state-funded research initiatives (Dorgan, 2003; Trotter, 2002; and Koch, 2002). Blandford (2002) indicated that private companies are taking steps toward adopting measures (such as contracting and identity preservation) to minimize exposure to lost sales. These public and private sector investments in agro-terrorism safeguards indicate that real-options investment opportunities exist to mitigate uncertainty about future returns in the grain supply chain.

Challenges associated with data availability and with the complexities of estimating costs and benefits have handicapped studies of cost-effective risk mitigation strategies. However, recent advancements in the area of real-options research using financial data from engineering techniques provide a systematic framework for evaluating cost-effective agro-terrorism risk mitigation strategies. In addition, complex problems can be analyzed using a nest of options as discussed in the "tomato garden" metaphor (Luehrman, 1998).[2] This framework is used here to identify and prioritize hazards among seven critical sections along the grain supply chain system to help determine cost-effective strategies for mitigation of agro-terrorism threats to the U.S.-Canadian grain handling system.

A Real-options Approach to Managing the Risks of Agro-terrorism

We focus our research on key economic entities/agents in the wheat and corn marketing and transportation chain: grower, country elevator, railway, domestic user/processor, export elevator, ship and importer. Basic requirements of a system that is intended to prevent agro-terrorism would normally include the installation of new equipment or procedures. This sunk cost could be specific to the economic agent or firm. Market risk and residual agro-terrorism risk comprise the main sources of uncertainty associated with the returns from an investment in increased food protection. Large positive opportunity costs or option values could arise from these uncertainties. The firm must cover these costs as well as the sunk costs.

The real-options approach to agro-terrorism investment assumes that 1) an investor has the opportunity to invest in a prevention strategy and 2) the investor prefers reduced income volatility. Although the value of the project cannot clearly be known at the time of the investment, the effect on investment behavior of the uncertainty related to agro-terrorism/food safety can be valued using real options. In the mixed stochastic process outlined by Salin (1998), future returns to such an investment are assumed to follow a mixed Brownian motion (continuous) and a Poisson (jump) process. Continuous

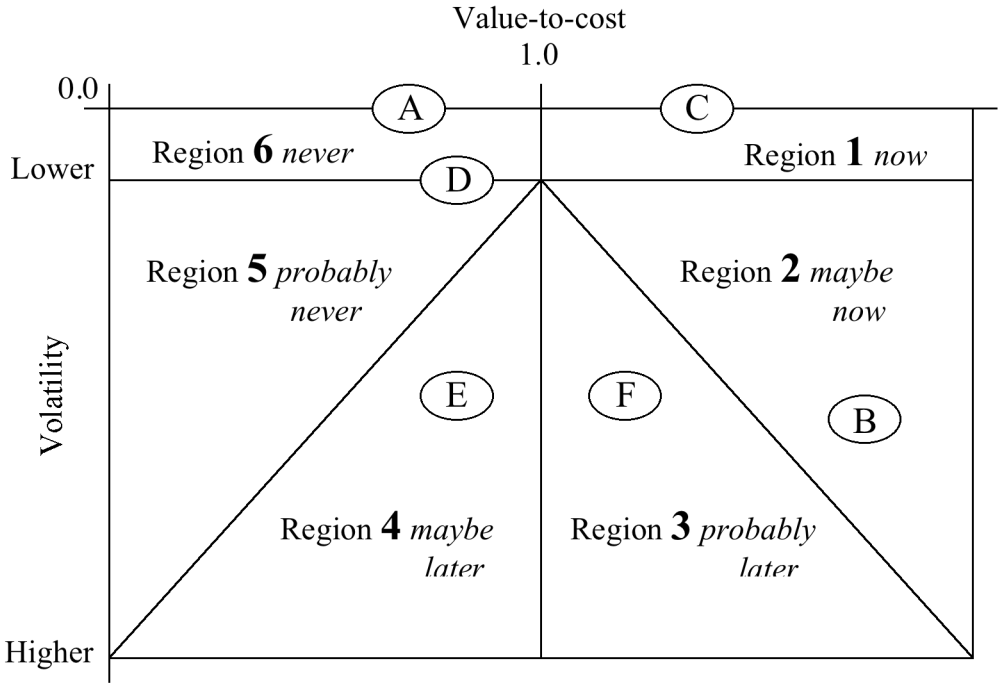

Figure 1 A stylized mapping of projects into option space
Source: adapted from Luehrman (1998)

movement of the process is due to price and production variability while the discrete jump can be attributed to uncertain agro-terrorism events.

Methods that employ data from financial engineering or risk-neutral valuation techniques are used to estimate real-option values for the economic entities using the "tomato garden" framework (Luehrman, 1998). This model requires the estimation of two variables: a value-to-cost matrix (ratio of NPV of investment in mitigation of agro-terrorism to the cost of this investment) and a volatility matrix (product of standard deviation of returns and the square root of time). Figure 1 shows both variables graphed in a two-dimensional representation called the "option space". The first variable contains not only all the data typically captured in net-present-value and real-option problems but also adds a time value associated with being able to defer the investment. The second variable measures how much the state of the world can change before an investment decision must be made. The option space is characterized by these two variables, with value-to-cost on the horizontal axis and volatility on the vertical axis.

Traditional NPV models used in real-options formulations provide only two options: invest or don't invest. Extending real-options analysis in the framework used here gives the investor an added advantage of having NPV, two extra metrics, plus six possible actions that not only reflect what should be done immediately but also indicate the likelihood that an investment will be beneficial in the future. Another advantage of the

"tomato garden" matrix is that public investment strategies for all economic entities/sectors in the grain supply chain can be represented as nested options, a series of options explicitly designed to affect one another (Luehrman, 1998). This strategy allows a sequence of contingencies, for alternative economic entities, to be added in to public or private sector investment decisions. For example, public investment may target sectors with greatest risk, evaluate how investments in these sectors mitigate agro-terrorism risk and then decide to invest in other sectors with the potential to further mitigate risks. In sum, the nested options formulation allows the aggregate investment in agro-terrorism mitigation to be evaluated more effectively than other formulations allow.

Case Study of the U.S. Grain Marketing System

To illustrate the methodology, two numerical simulations were developed with respect to agro-terrorism surveillance for U.S. wheat and corn production and associated handling and transportation systems.[3] The limited literature on the topic suggests that agro-terrorism attacks might be made directly on the grain sector using chemical or biological weapons such as anthrax, cyanide, etc., or alternatively that the grain sector may suffer indirectly as a result of an attack on the livestock sector. We used wheat data to simulate investments to mitigate direct agro-terrorism on the grain sector. Corn data were used to simulate investments to mitigate indirect effects from an attack on the livestock sector, such as introduction of foot-and-mouth disease. Real options were developed for all economic functions along the grain production and logistic supply chain in both examples.

Distributions and correlations for and between yields and prices were estimated for a typical wheat grower utilizing U.S. averages for 1993/94 to 2002/03 (USDA-ERS, 2003). The average size of farm was assumed to be 294 acres planted to wheat (Ali, 2002). Costs of surveillance equipment and monitoring at the grower level were assumed to be $11,570 for equipment and $18,250 for a review of tapes on each farm over a five-year period (Gustafson, 2003).

At the level of handling and transportation, surveillance costs were assumed to be 10 cents/bu for country elevators, 50 cents/bu for rail shippers, 5 cents/bu for export elevators and 50 cents/bu for ocean shipping. Additional monitoring and surveillance costs for country and export elevators were assumed to be double those for farms, or $59,640 over a five-year period (Mauch, 2003). Testing costs were assumed to be 5 cents/bu at each location. These costs were applied to the proportion sampled of the total volume of bushels handled at each location over the five-year period. We assumed that only 10 percent of bushels handled were sampled for bio-terrorist attacks at each location (Koo and Matson, 2002).

Parameters for secondary or indirect impacts were adopted from Huff, Meilke and Turvey (2003). Primary yield effects were assumed to decrease volume by 5 percent at all locations (table 1). Price effects for growers, domestic users and importers were assumed

Table 1 Parameters for Direct and Secondary Yield and Price Effects of Bio-terrorist Attacks.

	Direct		Secondary*	
	Quantity	**Price**	**Quantity**	**Price**
Grower	-5%	-.04%	-0.1%	-0.4%
Country elevator	-5%		-0.1%	
Rail	-5%		-0.1%	
Domestic user	-5%	-0.4%	-0.1%	-0.4%
Export elevator	-5%		-0.1%	
Ship	-5%		1.5%	
Importer	-5%	-0.4%	1.5%	-0.4%

*Secondary impacts taken from Huff, Meilke and Turvey (2003, 29).

to be equivalent to secondary impacts on prices. As an approximation, country elevators, rail movement, export elevators and ocean shipping were all assumed to be competitive markets operating on pricing margins, so no price effect was included for these sectors.

For corn growers, distributions and correlations for yields and prices were estimated for an average corn grower utilizing U.S. averages for 1993/94 to 2002/03 (USDA-ERS, Feed Situation and Outlook Yearbook, 2003). Average farm size was assumed to be 162 acres planted to corn (USDA-NASS, 1999).

The optimal NPVs for both wheat and corn sectors were simulated using @Risk Palisade Decision Tool Software. The simulation model was iterated 5,000 times for each element of the supply chain; at this point, the results were within optimum stopping criteria. Table 2 presents the base-case results for both wheat and corn. A graphical breakdown of our real-option simulation results (presented in figures 2 and 3) indicates that in the current analysis only one link/location in the grain supply chain (the rail sector) needs to be considered for immediate investment in strategies to mitigate agro-terrorism. This conclusion is based on the high volatility and high NPV/cost ratio in that sector; these factors yield valid real-option opportunities for mitigating risk. The rail transportation sector and other sectors in the grain handling system should undertake investments in tamper-proof seals for shipping containers, as suggested recently by the WHO.

We find that related investments in other locations along the grain supply chain can be postponed. While it may be beneficial to invest in agro-terrorism protection for producers and grain handlers, it certainly will not be beneficial to make such investments at all the locations examined here.

Table 2 Base Case Results for Wheat and Corn

	Wheat			
	NPV	Cost	NPV/cost	Volatility
Grower	0	102	0.00	0.82
Country elevator	70,430	184,640	0.38	0.31
Rail	492,753	136,364	3.61	3.30
Domestic user	0	184,640	0.00	0.67
Export elevator	33,040	184,640	0.18	0.30
Ship	0	126,136	0.00	0.46
Importer	0	184,640	0.00	0.59
	Corn			
Grower	0	187	0.00	0.77
Country elevator	70,430	184,640	0.38	0.31
Rail	492,753	135,714	3.63	0.30
Domestic user	0	184,640	0.00	0.59
Export elevator	33,040	184,640	0.18	0.30
Ship	0	126,136	0.00	0.46
Importer	0	184,640	0.00	0.51

The grain handling industry in Canada and the United States is vital to agriculture and trade. Though this industry is not necessarily the most likely target for food terrorism, the volume of trade provides some concern about the risks of terrorism. While the United States has been more aggressive in initiating risk mitigation than Canada has, the enormous trade interdependence between the two countries makes the issue important to Canada as well.

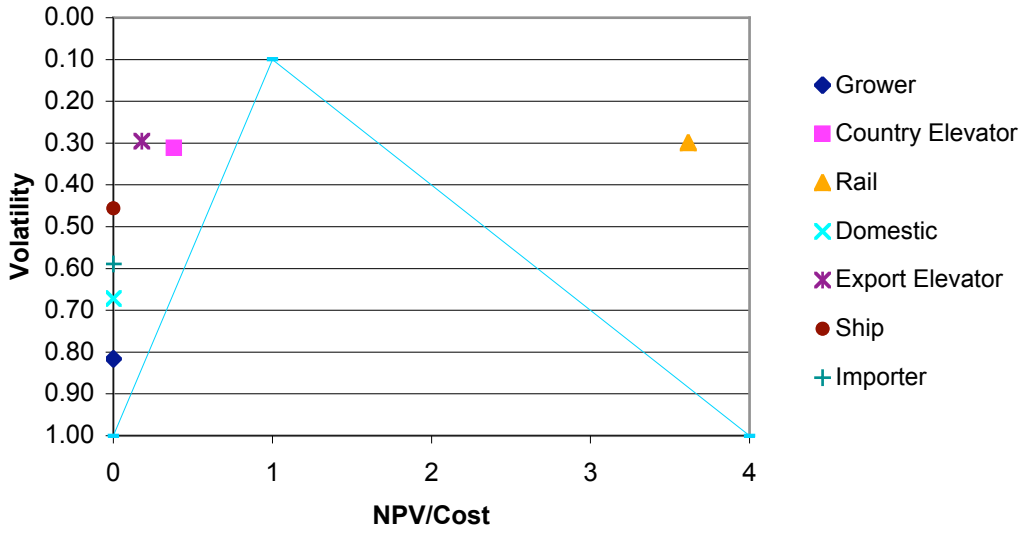

Figure 2 NPV/costs vs. volatility for wheat investments at all seven locations

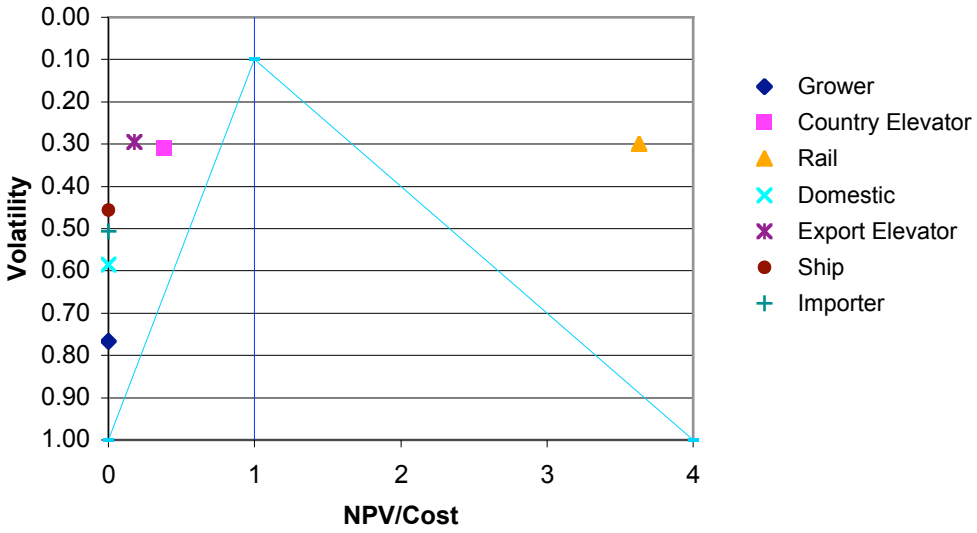

Figure 3 NPV/costs vs. volatility for corn investments at all seven locations

This article has focused on terrorism in the grain handling system, which includes not only distribution at elevators but also trucking and rail transportation and the supply chain flow to food products. Ideally, resources would exist to protect all the locations along the supply chain against agro-terrorism risks. However, limited resources in the public and private sectors imply that investment should be targeted to the entities that are exposed to most risk and will incur the least investment expenses. The "tomato garden" real-options framework provides an appropriate evaluation method to help policy makers prioritize investments aimed at mitigating agro-terrorism risk in the multi-tiered grain handling sector.

References

Ali, Mir. 2002. Characteristics and production costs of U.S. wheat farms. USDA, Economic Research Service, Statistics Bulletin 974-5. July.

Blandford, David. 2002. Bioterrorism and food security – Trade dimensions. Conference proceedings, CAPTS, NDSU, October 28-29, 2002.

Canadian Pacific Railway. 2003. U.S. and Canadian customs agencies, and Canada's two largest railways reach agreement to strengthen security measures for transborder rail shipments. News release, April 3.

Chatterjee, A. 2003. An overview of security issues involving marine containers and ports. In proceedings of the 2003 Transportation Research Board annual meeting (CD-ROM).

Congressional Research Service. 2002. StarLink corn controversy. Available at: www.cnie.org/nle/crsreports/agriculture/ag-101.cfm. Accessed June 25, 2003.

Dorgan, Byron. 2002. Keynote address: Bioterrorism and food security – Issues and challenges. Conference proceedings, CAPTS, NDSU, October 28-29, 2002.

Goldfarb, D. and W. Robson. 2003. Risky business: U.S. border security and the threat to Canadian exports. C. D. Howe Institute Commentary (The Border Papers), No. 177. Available at www.cdhowe.org.

Gustafson, Cole. 2003. Breached bio-security at the farm gate: A Minnesota dairy case study. Working Paper, Department of Agribusiness and Applied Economics, North Dakota State University.

Huff, Karen, Karl D. Meilke, and Calum G. Turvey. 2003. Issues in modeling bio-terrorism in the agrifood sector. Paper presented at WCC-72, Western Coordinating Committee on Agribusiness, Las Vegas, Nevada. June 9.

Koch, Becky. 2002. EDEN: The land-grant system's outreach effort for disasters including homeland security. In Bioterrorism and food security – Trade dimensions. Conference Proceedings, CAPTS, NDSU, Oct. 28 – 29.

Koo, W. Won, and Jeremy Mattson. 2002. Bioterrorism and food security: Issues and challenges. Executive summary, Conference Proceedings, CAPTS, NDSU, Oct. 28 – 29.

Luehrman, Timothy. 1998. Strategy as a portfolio of real options. *Harvard Business Review* Sept.-Oct.: 89-99.

Mauch, Sid. 2003. (General manager Prosper Farmer Co-operative Elevator). Personal Communication.

Nolan, J. 2003. The impact of Bill C-34 on the grain handling and transportation system in the province of Saskatchewan. Unpublished working paper, Department of Agricultural Economics, University of Saskatchewan.

Salin, Victoria. 1998. A real option approach to valuing food safety risks. In *The Economics of HACCP: Costs and Benefits*, edited by Laurian Unnevehr. MN: Eagen.

Transport Canada. 2003. *Transportation in Canada, 2002: Annual Report*. Ottawa: Minister of Public Works and Government Services.

Transportation Security Administration. 2003. Secretary Ridge announces new initiatives for port security. Press release, June 12.

Trotter, Robert. 2002. Risk of bioterrorism: Issues and challenges. Bioterrorism and food security – Trade dimensions. Conference Proceedings, CAPTS, NDSU, October 28-29, 2002.

United States. 2002. Fact sheet: Container Security Initiative guards America, global commerce from terrorist threat. Available on-line at: http://ww.customs.ustreas.gov/xp/cgov/newsroom/press_releases/03122003.xml. Accessed June 25, 2003.

United States Department of Agriculture. Economic Research Service (USDA-ERS). 2003. *Wheat Situation and Outlook Yearbook 2003*. Market and Trade Economics Division, ERS, U.S. Department of Agriculture, WHS-2003, March.

United States Department of Agriculture. Foreign Agricultural Service (USDA-FAS). 2003. Foreign countries' policies and programs. Available at http://ffas.usda.gov/grain/circular/1998/98-05/dtricks.htm. Accessed June 25.

United States Department of Agriculture. National Agricultural Statistics Service (USDA-NASS). 1999. *1997 Census of Agriculture: North Dakota State and County Data.* NASS, U.S. Department of Agriculture, AC97-A-34. Volume 1, Geographic Area Series. Part 34.

United States. General Accounting Office (U.S.-GAO). 2003. Food processing security: Voluntary efforts are under way, but federal agencies cannot fully assess their implementation. GAO-03-342, February.

World Health Organization (WHO). 2002. Terrorist threats to food: Guidance for establishing and strengthening prevention and response systems. Geneva: Food Safety Department, WHO.

Endnotes

[1] For our purposes, food terrorism is defined as the "act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian populations and/or disrupting social, economic or political stability" (World Health Organization, 2002, 3).

[2] The tomato garden metaphor illustrates the real-options approach by likening a portfolio of options to a garden of tomatoes in an unpredictable climate. On any given day, the gardener will find some tomatoes are ripe and perfect for harvest while others are at different stages and either will require more time to ripen or must be discarded because they are rotten. The active decision maker (the gardener in this case) has the liberty to assess each tomato's prospect as the season progresses, and to decide which to pick and which to leave on the vine.

[3] While the appropriate data could not easily be found, we expect that a similar study done with respect to the Canadian grain handling and transportation system (for wheat) would yield very similar results.