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Optimal Public and Private Sector Investment in Mitigating Risks along the Food Logistic System

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Why should businesses and small firms in particular, invest in food security measures? Why should they? If I ask that question around the room some of you will say, it's for the best interest of our national security. But for small businesses, they don't see it that way. The first thing they want to do is understand the cost. They want to understand the cost of security measures. The second goal is to understand how implementation of security measures will affect their bottom line, profits. In other words, how much savings will investment in security measures provide to my business?

The outline of my presentation is; we'll look at some issues that small businesses in particular face in terms of investing in security measures. We will outline the objectives. Next, we will examine examples of security measures that are currently being adopted, like RFID (Radio Frequency Identification) or RFEM (Radio Frequency Electro-Magnetic) technology. Then we will examine a model that can be used to evaluate incentives for small businesses. The conclusion and suggestions section will wrap up my presentation.

So what are the issues? The first issue is that food terrorism risks are real and the economic impacts can be significantly large. Prior presentations have highlighted the potential economic impacts. Hamid talked about some of the food terrorism events that have occurred around the world. For example, we had the Tylenol poison case that happened in 1982 in the US, the mercury poisoning of vine yards by terrorists in Israel, and the cyanide poisoning of Indonesia grapes. Grapes that were imported into the United States from Indonesia were contaminated in 1987. All these cases are documented in the World Health Organization report. They estimated that the cyanide poisoning cost the Indonesian government about one hundred of million dollars, as U.S. consumer boycotted grape imports from Indonesia. The economic impacts can be severe; and terrorist can inflict similar harm to the United States agriculture sector or to U.S. exports. Some of the agents of interest for the grain sector, in addition to mercury and cyanide, are weaponized rust and DON (a toxin from scab). So these treats are real and some have occurred in the past.

What efforts are used by the public sector and the private sector to prevent or mitigate potential agroterrorism risks? This is the next question I want to address. The public sector has increase investments and funding in security measures along the grain logistics system/food supply chain in the United States. A paper by Schendier (2004) pointed out that civilian defense funds increased from $414 million to about $5 billion in 2004. The U.S. public sector is investing heavily to mitigate terrorism risk. So is the Canadian government and other countries around the world. There are investing billions of dollars to mitigate terrorist and agroterrorism risks. On the private side, we can evaluate the impact of regulation. An example of new regulation is the 2002 Public Health Security and Bioterrorism Preparedness Act. One challenge of this particular regulation is its potential to perturb global trade flows. International governments were worried that this regulation will impact trade flows since foreign companies that ship to the United States are required to keep record "one step forward and one step backward." They caution that such regulation should be based on sound risk assessment. The FDA said the cost concerns are negligible as they are already embedded in the existing system. Worries about perturbing trade flows still persist. In this particular study, we will evaluate private sectors incentives to adopt RFID or RFEM technology along the grain logistic chain. We'll compare the cost of current security system, random testing, to the "one step forward and one step backward regulation." The big challenge in the valuation literature is to value the cost of a dynamic or evolving technology.

How do we quantify the costs and benefits of new technology when the risks or probability of terrorist attacking the sector is unclear? As Hamid pointed out, if we can not quantify the probability of terrorism attacks to the food supply it becomes difficult to assess how much to invest into security measures. The second challenge is that with new technology like RFID and RFEM, most companies are not certain about their effectiveness. So we don't know the probability or the effectiveness of evolving new technologies. That poses some challenges. The good news is that advancements in the optimization and in the finance literature provide models to value investments under risk and uncertainty. For example, the stochastic optimization and real option techniques used in this study. We will use these new methods to quantify investment in security measures (RFEM) along the grain logistic chain. The optimization models will enable us to estimate firm level cost and benefits. This study will focus on firm level specific costs and benefits for businesses that invest in security measures.

In the analysis we compare three strategies: random testing (the way the system currently operates), "one step forward and one step backward regulation," and the RFEM systems. It is important to compare the RFEM to the other tracking systems. Like Susan mentioned, we don't have enough money to put security measures everywhere in the grain logistic system or the food system. So where will investment reduce the most risk? Let's discuss how the stochastic optimization and the real option model operate. The model can help us determine where to invest and whether to invest now, delay investment

or don't invest in a particular sector, when the risks are too low and the costs are too high. We will evaluate three results; invest now, delay investment, don't invest.

Why do we focus on the grain logistic system? There are several cases we have analyzed and the one presented is just one particular case. Other sectors being investigated are the green onion and milk logistic system. The grain logistic system is characterized with bulk transportation. Grains are used in many different other industries. The example of unintentional contamination of dog food with higher levels of DON (7 to 15 ppm) resulted to about 10 million dollars in losses because it caused the feed manufacturer to shut down; it killed somebody's dog. So economic or ripple effects of a single contamination can be huge. The September 11th attack resulted cost billions of dollars just in border security or delayed transportation for the grain sector. Bulk transportation can magnify economic losses and make these very important.

How can RFEM help with tracking and mitigating risk along the grain supply chain? What is RFEM? It's a real time devised for monitoring and recording and transmitting data on environmental variables like temperature, relative humidity, carbon dioxide and oxygen concentration. Why is this important and different from RFID? You can compare it to security at your home; if somebody tampers with your home the security alarm sets off and signal to a computer base to initiate further testing of the grain. We can call it smart seals, or seals with RFEM. Again, for companies they are more interested in maximizing their profits. How will RFEM affect their bottom line? We used data on shipment and flow of grains through the supply chain; data on the effectiveness of RFEM technology, and data on the cost of installing RFEM and on the probability of food terrorism. We will conduct sensitivity on the cost and the probability of attack, as these variables are uncertain.

The results for the three cases are presented, random testing; one step forward and backward; and tracking with RFEM system. If an alarm goes off, then you test for contaminant along the grain logistic system. For the one step forward and one-step backwards you track grain quality and test to conform to the one-step forward and one-step backward regulation. We hypothesis that the RFEM tracking system is cheaper compared to the one-step forward and one-step backward regulation. Results indicate that the RFEM tracking system is cheaper or cost-effectiveness for private sector investments. The sensitivity analyses were consistent with the finding. The risk premium or cost firms are willing to pay to avoid food terrorist increases as the probability of attack increases. The risk premium did not vary significantly as the cost of RFEM increases since these costs can be distributed over the bulk volume shipped. We also examine sensitivities with respect to the effectiveness of the technology. As the effectiveness of the RFEM technology increase from 90-percent effective to 95% effective and 97.5% effective the risk premium showed moderate changes. We validated our findings with data from firms already experimenting on the RFID technology and our results were robust. Summary of the risk premium results, the cost, and other risks are found in the Tables. The RFEM tracking system can increase security along the grain logistic system and be cost-effective. It's more cost-effective compared to the one-step forward, one-step backwards tracking system. One advantage of the RFEM tracking system is that it can prevent trade dispute that arise with regulation. The last question to address is when and where should investment on RFEM be made along the grain logistic system? A real option, tomato garden, model is used to address this question. The model assumes that firm-level revenue may experience two fluctuations, random price movements and shocks from food terrorism events. Shocks from food terrorism events can be modeled as a Poison jump or extreme value distribution as specified by Hamid.

We simulate the NPV from investments in RFEM tracking as a function of the cost to implement the RFEM system and the value of risk reduction generated from our stochastic optimization model. Then we graph the results in a 'tomato garden' framework to determine when to invest and where to invest. As you can see from the graph, the model recommends areas along the grain logistic chain where investments should be done now. If this occurs, food terrorism risk increase as you wait to invest in the future, and that greater risk reduction is achieved if investments are made now. The tomato garden graph shows panel where investments can be postponed or not necessary.

We use the real option model to evaluate investments for companies that ship commodities within the United States and those that ship commodities out of the U.S. Food terrorism may lead to a boycott of U.S. exports by foreign governments. It is important to analyze domestic and foreign shipment. Results indicate that companies that to domestic markets only should invest now while those that export can delay investments and do it later.

To conclude, the rewards to investment in RFEM for the domestic market are considerably higher than those for export markets at this point. The results show that it may be cost effective to invest in RFEM or smart technology now to mitigate food terrorism risks. Private sector investments in RFEM technology is beneficial to both domestic and export markets. I will now welcome some questions.

Optimal Public and Private Sector Investment in Mitigating Risks along the Food Logistic System

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Outline

- Introduction
  - Issues and Motivation
  - Objectives and Hypothesis
- Investment in RFEM for the Grain Logistics System
- Stochastic Optimization Model
- Simulated Costs and Risk Premium of Alternative Mitigation Strategies
  - Sensitivity of results
- Real Option Results on Where and When to Invest in RFEM Security Measures
- Conclusions and Suggestions

Issues and Motivation

- **Food terrorism risks are real and the economic impacts can be significant**
  - **WHO suggestions and guidelines to address issues of weak security in the food logistic system**
  - **Examples of historic attacks to the food sector**
    - **Tylenol poisoning scare of 1982 was followed by stricter packaging regulations that were enacted to counter that perceived threat,**
    - **Mercury poisoning of vine yards in Israel**
    - **Cyanide poisoning of Indonesia's grapes**
  - **Potential agents suggested for the grain sector**
    - **Biological agents (Scab, Kernel Burnt, etc)**
    - **Chemicals (Weaponized rust)**
    - **Radio-nuclear agents**

Issues and Motivation

- **Risk mitigation strategies are costly and system-wide adoption are problematic**
  - **Public strategies include**
  - Increase funding in security measures by the U.S. and other countries
    - Billions of dollars spent by the U.S. on bioterrorism surveillance
    - Government civilian biodefense increased from $414 million in 2001 to $5 billion in 2004 (Schuler, 2004).
    - Canadian government committed C$1 billion over five years to purchase and upgrade explosive detection systems at Canadian airports and C$172.5 million marine security initiative (Transport Canada, 2003; Government of Canada, 2003).
  - Increase regulation and food security policies with varying trade implications
    - Public Health Security and Bioterrorism Preparedness Act of 2002 and its potential trade impacts
  - **Private strategies include**
    - Investment in seals and smart seals (RFEM).

Issues and Motivation

- **Challenges to quantify costs and benefits of food terrorism risk mitigation strategies**
  - Uncertainty about the probability of attack.
  - Uncertainty about the cost and efficacy of new technology
- **Advancement in the optimization and finance literature**
  - Stochastic optimization techniques
  - Real option models

Objectives and Hypothesis

- **Use stochastic optimization model to simulate the cost effectiveness of RFEM technology in mitigating food terrorism risks.**
  - **Food bioterrorism regulation, random testing and testing with RFEM systems**
- **Use real option models to determine when and where to invest in RFEM infrastructure**
  - **Tomato Garden real option Model and results**

The Case of the Grain Logistic System

- **Bulk transportation of grains in the domestic and international markets and its use by several other sectors.**
  - About 2.1 million producers deliver about 300 mmt of grain to the primary elevators.
  - About 1.08 million rail carloads of grain are originated per year, and about 23 mmt of grain are shipped on barges per year.
  - **Potential terrorism attack to the grain logistic sector may cost billions of dollars**
    - Cross-border traffic in grain products is significant, with an average of about 6 million tons of grain products alone exported into the U.S. each year (USDA-FAS, 2003).
    - Delay costs for grain trucking following September 11 terrorist attack resulted in millions of dollars in losses (Goldfarb and Robson, 2003).

What is RFEM?

- **Radio Frequency Environmental Monitor (RFEM) is a real time device used for measuring, recording and transmitting data on environmental variables such as temperature, relative humidity, carbon dioxide and oxygen concentration (Thompson, 2004).**
  - **Records real time data**
  - **Could be used to screen for malicious tampering of food containers or package**
  - **Could pinpoint the location of tempering or more importantly could indicate the possibility that a toxic material or infectious agent was added to the product**
  - **Could be used for traceability, from planting to commercialization**
  - **Could be used to monitor and record weather conditions; types, amounts, and timing of chemicals applied; disease incidence; insect infestations; and harvest date.**

Stochastic Optimization Model and Cost of RFEM Systems With Underling Uncertainties

$$\text{Max} = E(U(W)) = (\lambda\text{-EXP}(-\Phi W_i^{\eta}))$$

s.a. $X_i \in Y_j$

Where:

W_i = Grain Firm wealth in each nature (i = No RFEM, RFEM);

E (.) = Expect Value;

U (.) = Utility Function;

X_i = Decision variable vectors of the model;

Y_j = Opportunity set of the model;

EXP = Exponential;

λ = Parameter determining positiveness of the utility function; and

Φ and η = Parameters which affect the absolute and relative risk aversion of the utility function.

The parameters of λ, Φ, η is set to 2, 0.01, and 0.5 respectively following Wilson and Dahl (2005).

Data to Simulate RFEM Costs

- The cost of Diversion included buy back and clearing cost $0.25 and $0.10 respectively (Lueck, Merrick, Millman, and Moore, 2005).
- Testing cost of Anthrax range from $30-34 per sample (Michelle S. Mostrom, 2005).
- Size of grain at each location
  Rail = 89.811 MT
  Barge = 900 MT
  Truck = 21.772 MT
- Reliability and Accuracy of RFEM (Personnel Comm). The reliability of RFEM is 97% using uniform distribution. Test accuracy is 95% using uniform distribution.
- The parameter of reliability and Accuracy of RFEM (.95, .99) and (.90, .99) respectively.
- The potential level of contamination at various locations has a passion distribution and parameter of 0.01.

Risk Premium and Cost of RFEM Systems

- **Three models were simulated using stochastic optimization**
  - **Grain flow with no testing to serve as the base model**
  - **Grain flows with random testing for toxins and chemical agents (as the system currently operates)**
  - **Grain testing with RFEM installed and testing when RFEM signals indicate tempering.**
  - **Risk premium (Expected returns – Certainty Equivalent) was estimated for each system and the values compared.**
  - **Sensitivities were conducted to determine variations of the risk premium with the cost of the RFEM system, the probability of an attack to the grain logistic system, and the reliability of the RFEM system.**
- **Results are presented in tables 1 – 4.**

Resulting indicating higher utility and premium for RFEM system

Table 1. Base Case, Testing without RFEM, and Testing with RFEM: Domestic Wheat Model Results

Variables	Base Case	Testing No RFEM	Testing with RFEM
Utility	1.20037	1.19936	1.20019
Test (1= yes/0= No)			
On Farm Storage	0	0	0
C.E Receiving	0	0	0
C.E load out	0	0	0
D.U. NSig Rail	0	1	0
D.U. NSig Barge	0	1	0
D.U. NSig Truck	0	1	0
D.U. Sig Rail	0	0	1
D.U. Sig Barge	0	0	1
D.U. Sig Truck	0	0	1
Buyer Risk of flow Cont.	0.00015	0.00015	0.00372
Seller Risk of flow Rejected	0.03283	0.03283	0.01596
Total Vol. Diverted	0	1011.58	491.699
Costs ($/MT)			
Cost of Testing	0	0.00045	0.00000
Cost of RFEM	0	0	0.00405
Cost of Quality Loss	0	5.61413	2.71765

Results indicating the risk premium increases as the probability of an attack increases

Table 2. Export Model: Sensitivity to alternative Probability of Contamination (Testing RFEM)

Variables	Pr (0.01)	Pr(0.001)	Pr(0.0001)	Pr (0.1)
Buyer Risk of flow				
Cont.	0.00001	0.00000	0.00000	0.00011
Seller Risk of flow				
Rejected	0.00019	0.00002	0.00000	0.00229
Total Vol. Diverted	8.45634	0.94499	0.01796	104.066
Costs ($/MT)				
Cost of Testing	1.14852	1.14842	1.14836	1.14877
Cost of RFEM	0.00546	0.00546	0.00546	0.00547
Cost of Quality Loss	0.04479	0.00501	0.00009	0.55373
Risk Prem ($/MT)	1.1989	1.1589	1.1539	1.7092

Results indicating the risk premium increases as the cost per unit of RFEM increases

Table 3. Export Model: Sensitivity to alternative Cost of RFEM (Testing RFEM)

Variables	0.45 ($/unit)	0.50 ($/unit)	1.50 ($/unit)
Buyer Risk of flow			
Cont.	0.00001	0.00001	0.00001
Seller Risk of flow			
Rejected	0.00019	0.00019	0.00019
Total Vol. Diverted	8.45634	8.45634	8.45634
Costs ($/MT)			
Cost of Testing	1.14852	1.14852	1.14852
Cost of RFEM	0.00546	0.00273	0.00819
Cost of Quality Loss	0.04479	0.04479	0.04479
Risk Prem. ($/MT)	1.1989	1.1962	1.2016

Results indicating the premium does not change significantly with slight changes in reliability of the test

Table 4. Export Model: Sensitivity to alternative Reliability of RFEM Signaling (Testing RFEM)

Variables	0.95	(0.90)	(.975)
Buyer Risk of flow			
Cont.	0.00001	1.02738	0.00001
Seller Risk of flow			
Rejected	0.00019	0.00019	0.00020
Total Vol. Diverted	8.45634	8.62847	8.65062
Costs ($/MT)			
Cost of Testing	1.14852	1.14852	1.14852
Cost of RFEM	0.00546	0.00546	0.00546
Cost of Quality Loss	0.04479	0.04580	0.04580
Risk Prem ($/MT)	1.1989	1.1999	1.1999

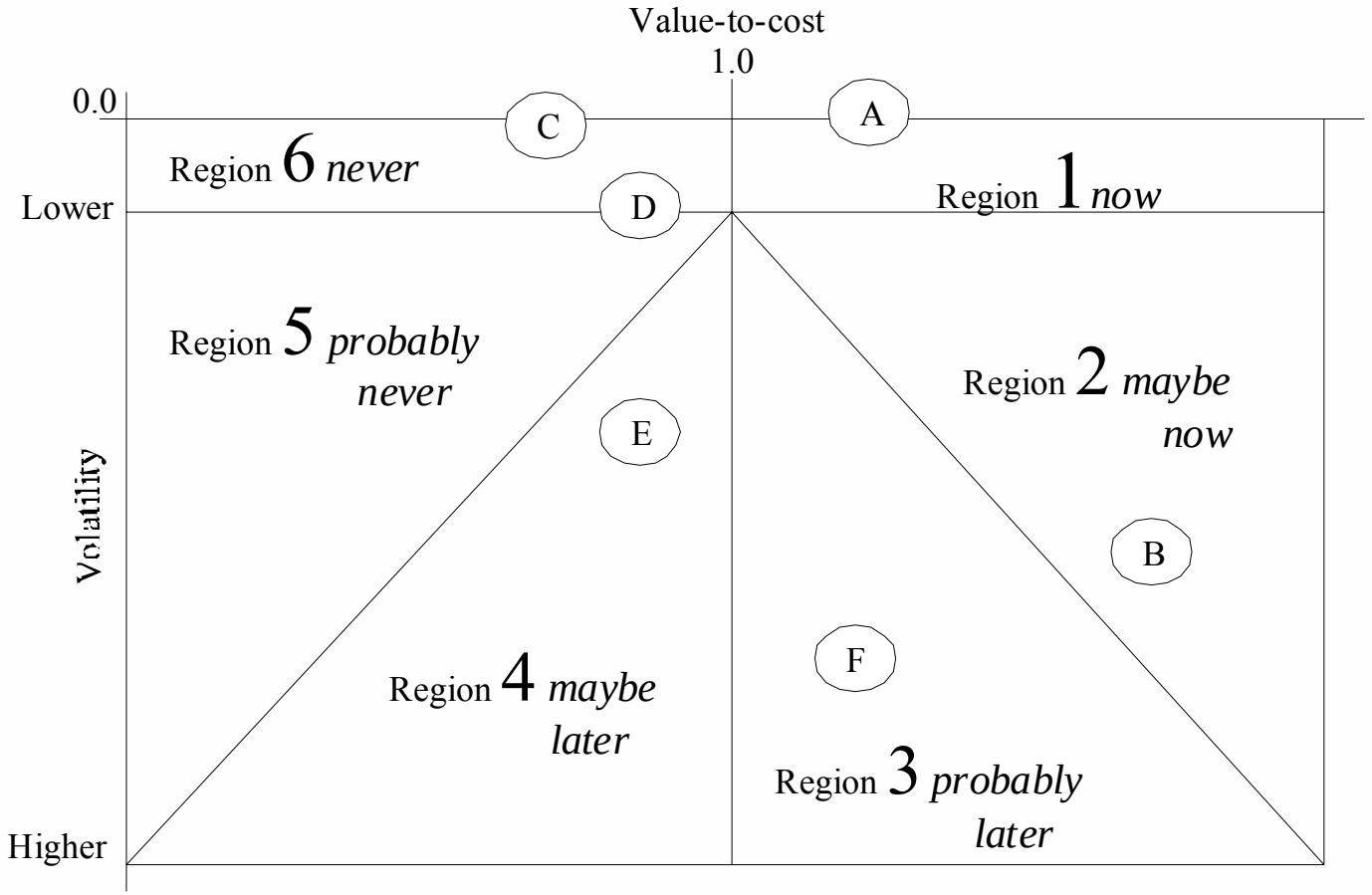
Summary Results of Risk Premium and Costs

- **Risk premium is a proxy for expenses private sector is willing to pay to mitigate food terrorism risks.**
- **RFEM can increase security along the grain logistic system and increase economic benefits.**
- **Smart seals are less costly compared to random testing and testing that may be required by mandatory record keeping.**

When Should Private Firms Invest in RFEM Security Measures

- **A Real Option Model to value Investment to Mitigate Agroterrorism Threats**
  - **Model**
    - **Financial engineering model with stochastic simulations**
    - **Prioritize hazards along the grain supply chain (grower, country elevator, rail transit, domestic user/processor, export elevator, ship and importer).**
  - **Model Assumptions**
    - **Market and food terrorism risks comprise the main sources of uncertainty about the returns from the investment.**
    - **Large positive opportunity costs or option values could arise from these uncertainties.**
    - **Future returns are assumed to follow a mixed Brownian motion and Poisson process. Continuous movement of the process is probably due to price and production variability while the discrete jump process can be attributed to food terrorism events.**
  - **The "Tomato Garden" framework.**

The "Tomato Garden" Real Option framework: Used to Determine Where and When in Invest



Data to Simulate the timing of investment

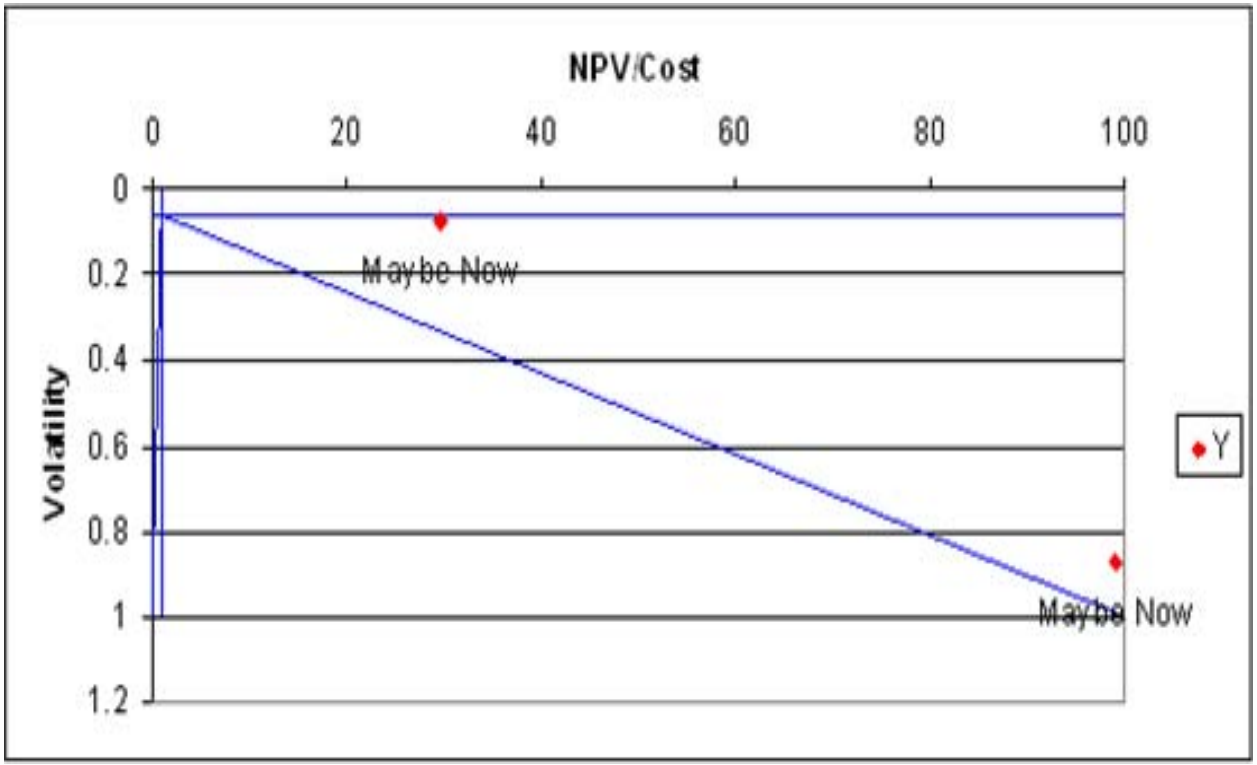
- Data: In addition to data used for RFEM cost simulation.
- Total cost of smart seals (seals plus RFEM system) for export and domestic model were estimated as $1.1932/mt and $0.392808/mt respectively.
- Volume of wheat flow for export and domestic were assumed to be 31802.3923 mt and 30805.2793 mt transported by rail, barge, and truck respectively.
- Discount rate was assumed to be $0.06/mt for both the export and domestic models.
- Export and domestic system risk premium were estimated to be $1.20/mt and $0.39749/mt respectively.
- The current NPV of smart seals plus RFEM system for export and domestic models were estimated to be $-217,182.14 and $-153,716.95, respectively.
- The life of smart seals plus RFEM system was assumed to be 5 five year (export and domestic models).
- Finally, the optimal NPV for both export and domestic models were simulated using @Risk Palisade Decision Tool Software.

Timing of Investments for Domestic and International Trader

Export and Domestic Wheat Model Results:
Smart Seals plus RFEM System

Variables	Export	Domestic
Current NPV of Smart Seals plus RFEM System	$1,667,686	$18,425,807
Value of Smart Seals plus RFEM System in 5 Years	$2,264,639	$24,872,238
NPV in Year 5 of doing New Project	$2,047,457	$24,718,521
Discounted NPV of doing New Project	$1,516,794	$18,311,931
Simulated Option Value (NPV)	$6,422,068	$15,237,360
Year 5 Cost of Smart Seals Plus RFEM System	$217,182	$153,717
NPV/Cost	$29.57	$99.13
Volatility	0.073133	0.875418

Timing of Investments for Domestic and International Trader



Conclusions

Timing of Investments for Domestic and Export Trader

- **Rewards to investment in the domestic market are considerably higher than those for the export market.**
- **The results show that it may be cost-effective to invest in smart seals and RFEM technology now.**
- ***Private investment in RFEM technology is beneficial to both domestic and export wheat.***