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REGULATING TRADE WITH A SYSTEMS APPROACH: THE CASE OF CHINESE FRESH APPLES

By

Lili Gao

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ABSTRACT

REGULATING TRADE WITH A SYSTEMS APPROACH: THE CASE OF CHINESE APPLES

By

Lili Gao

The potential for fresh apple imports from China is very contentious in the U.S. It is likely that any future imports will be governed under the regulation of a Systems Approach (SA) to manage the risk of introducing exotic pest(s) or disease(s). This study analyzes issues related to such a regulation for Chinese fresh apple trade. Three parts are included in the study: first, analysis of the current fruit market situation and supply organization in China. Despite the coexistence of three market forms and two supply chain organizations, China is improving its phytosanitary control capacity under the support of Chinese administrative government and regulatory laws and regulations. Second, a hypothetical SA policy is developed (including potential pests of concern) for regulating potential Chinese fresh apple imports, which provides a general idea of what kinds of phytosanitary measures might be taken to prevent the introduction of exotic pests or diseases. Third, methods for linking economics to the pest risk assessment included in a SA are evaluated. A static multi-scenario partial equilibrium model is a useful method to link economic evaluation to pest risk assessment; however, case-to-case differences and data sensitivities limit feasibility as a template for empirical assessment of other potential sanitary phytosanitary issues.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

ALOP	Appropriate Level of Protection
AMS	Agricultural Marketing Service
AQIS	Australian Quarantine and Inspection Service
APPPC	Asian and Pacific Plant Protection Commission
APHIS	Animal and Plant Health Inspection Service
AQSIQ	General Administration of Quality Supervision, Inspection and Quarantine of the People Republic of China
CABI	Commonwealth Agricultural Bureau International
CFIA	Canadian Food Inspection Agency
CIQ	Entry-Exit Inspection and Quarantine Bureau of the People's Republic of China
CPPC	Caribbean Plant Protection Commission
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agricultural Organization
FAS	Foreign Agricultural Service
IAPSC	Inter-African Phytosanitary Council
IPPC	International Plant Protection Convention
MOA	Ministry of Agriculture, the People's Republic of China
NAPPO	North American Plant Protection Organization
NASS	National Agricultural Statistics Service
NBT	Non-Tariff Barriers to Trade

ORISA	Organism International Regional De Sanidad Agropecuaria (OIRSA)
PPPO	Pacific Plant Protection Organization
PPQ	Plant Protection and Quarantine
PRA	Pest Risk Analysis
SA	The Systems Approach
SENASA	Secretariat of Agriculture, Livestock, Fisheries and Food of the Argentine Republic
SPS	Sanitary and Phytosanitary
TBT	Technical Barriers to Trade
USDA	United States Department of Agriculture
WTO	World Trade Organization

CHAPTER 1

INTRODUCTION

1.1 Background of the study and problem statement

The new economy of globalization has promoted the development of world economic integration. At the same time, varieties of barriers to trade continue to be imposed, and have even escalated in some cases. Traditional trade barriers, like tariffs, which have been, and still are, a commonly applied restrictions to trade are losing their relative importance and being increasingly replaced by non-tariff barriers. Sanitary and phytosanitary (SPS) measures, one type of non-tariff barrier to trade, have gained importance as trading nations pay more attention to risks from foreign pests or other invasive species that might be associated with the traded commodity. These exotic invasive species can have significant impacts on a country's economy, agriculture, public health and environment.

The WTO Agreement on the Application of Sanitary and Phytosanitary Measures (SPS agreement), which was negotiated during the Uruguay Round of the GATT and implemented by the WTO in 1995, provides guidelines for World Trade Organization members who apply sanitary and phytosanitary measures to protect human, animal and plant life and health, and to help ensure that food is safe for consumption (WTO, 1995).[1] Based on these guidelines, importing countries usually sign bilateral protocols with an exporting country to control the risk of introducing exotic invasive species. Like other trade barriers, these SPS measures do influence patterns of trade and can further affect national welfare. For example, implementing such measures can increase corresponding

[1] The SPS agreement just provides the general guidelines rather than specific numerical limits, such as those set for tariffs under the Agreement on Agriculture.

costs from the exporting country providing an opportunity to use SPS concerns as a barrier to isolate domestic industries from international competition (Thornsbury and Minton, 2002). Quantitative estimates of the gains from trade for cases of SPS regulatory reform are rare (Roberts and Krissoff, 2004). Therefore, a challenge faced by policymakers when designing policies to mitigate the risk of introducing exotic invasive species is how to reach an appropriate level of protection (ALOP)[2] without high compliance costs that are unduly restrictive to trade.

There are a number of policy measures which can be employed to manage invasive species risk.[3] One approach, gaining in frequency of use, has been referred to as a "Systems Approach." The Systems Approach (SA) is a multi-step set of procedures, at least two of which have independent effects on mitigating pest risk associated with the movement of commodities (USDA/APHIS/PPQ, 2002). SA is recommended by WTO as one option for pest risk management. Differences between the Systems Approach and other pest risk mitigation measures are that 1) the required measures in a Systems Approach are multiple; and 2) at least some measures are independent. How many measures should be included in any particular Systems Approach is a critical decision dependent on pest and risk conditions within the trading countries, and difficult to evaluate for policymakers. Too few measures will fail to protect human and animal health or the domestic environment from

[2] Appropriate Level of Protection (ALOP) or an acceptable level of risk is defined by SPS agreement as "the level of protection deemed appropriate by the member establishing a sanitary or phytosanitary measure to protect human, animal, or plant life or health". The SPS Agreement recognizes and maintains the right of countries to determine and set what is an appropriate level of protection for them, while containing several disciplines to prevent countries from setting their levels of protection in an arbitrary or discriminatory fashion (USDA/APHIS, 2007a).

[3] For example, product bans can be used to prohibit or restrict entry of foreign pests.

exotic invasive species damage. Too many measures will raise the cost and lead to unnecessary impediments to trade.

SA policies are particularly relevant for countries that trade in fresh produce where phytosanitary concerns are common. Potential for trade presents both opportunities and challenges for horticultural industries, natural environment, and national welfare. While the U.S. market has opened to many horticultural products, there are still some fresh produce items, banned from entry due to phytosanitary concerns. There is an expectation that the U.S. markets will open to additional products in the future and it is likely that the potential imports would be regulated under a Systems Approach. One product under consideration is fresh apples from China.

China is currently the largest apple producing country in the world and has been asking for consideration to export fresh apples to the U.S. for more than ten years. However, for fresh apples, entering the U.S. market is still a big challenge due to strict phytosanitary measures resulting from concerns over potential pest infestation. How trade patterns would change or how U.S. horticultural markets might be affected, especially in the apple industry, is an issue of importance to both U.S. and Chinese apple growers and policymakers. As a result of economic reform and opening-up in the late 1970s, the economy of China has developed at an unprecedented rate especially for the vegetable and fruit sector. For example, China's apple juice industry has expanded aggressively and continues to be the driving force in world markets for apple juice concentrate.

1.2 Objectives and methodologies

The potential for fresh apple trade presents both opportunities and challenges for U.S. and Chinese horticultural markets. As invasive species concerns will almost certainly be governed by a Systems Approach, the particular form of the policy eventually adopted has implications for policymakers and industry participants in both counties. The objectives of this study can be expressed as:

(1) to provide an overview of the current fresh apple market and supply chain situation in China;

(2) to develop one hypothetical Systems Approach policy by evaluating current existing pest risk management policies for similar products relevant to Chinese fresh apples; and

(3) to evaluate methods for risk assessment and economic evaluation of a SA using the case of Chinese fresh apples and to estimate economic welfare from implementation of the hypothetical SA developed using one method.

Since the U.S. market is currently closed to fresh apple trade with China, a Systems Approach has not yet been officially developed. To evaluate such a policy, a number of steps are needed. First, since the hypothetical systems approach will be designed for Chinese fresh apples, it is necessary to understand the supply chain relationships to make sure that the policy is relevant and implementable to the Chinese apple industry. Important information includes Chinese apple production trends, current market situation, horticultural supply chain organization, trade patterns, existing pest risk polices, and governance structure related to apples.

Second, to identify the measures most likely to be included in a future SA, current existing pest risk management policies related to fresh apples or similar products from China are analyzed. These policies or regulations will be the best reference because: 1) they are designed for Chinese horticultural products; 2) they have been implemented and some have been proven efficient in mitigating pest risks; and 3) a critical review of these policies might reveal some areas of particular concern.[4]

1.3 Conceptual framework

According to WTO rules, a pest risk assessment is the basis for establishing phytosanitary regulations among trade partners. Based on current pest risk assessments for like products, a list of pests of concern will be developed for potential imports of Chinese fresh apples. This list includes most common pests/diseases that have been mentioned by these reference policies or have been evaluated as high risk. The hypothetical Systems Approach policy would include steps contained in the corresponding management strategies and Pest Risk Assessments. Suppose there are a total of N steps after summarizing the phytosanitary measures included in the appropriate current regulations. Among these N steps, there are $m(m \leq N)$ common steps across each regulation. These common measures (steps) are currently being used to mitigate the risk of introducing pest(s) associated with like products from China and should be included in the hypothetical U.S. SA for Chinese apples.

[4] In reality, numerous scientific studies will be likely implemented as the evaluation and political processes continue. Existing policies will draw on the scientific literature and studies in place at the time they were enacted.

In addition, there are $N - m$ measures that are different from one (or some) regulation to the others. Some measures are being used by multiple countries, but not all, to mitigate the risk of introducing pests. Suppose there are n of the $N - m$ measures of this kind; they are the additional options for a hypothetical SA besides the m basic common steps already defined. As for the remaining $N - m - n$ measures, they are unique for some certain pest or are only necessary under some limited conditions and hence only mentioned by a single reference policy. Therefore, m basic steps and n optional steps are adopted for our hypothetical SA for Chinese apples.

Like any policy adjustment, potential future trade will have economic impacts for the U.S. and Chinese apple industries and consumers. Concerns are raised over possibilities for introduction of exotic invasive species associated with the apple trade. Economic theory suggests this might have great negative impact on the U.S. apple growers and positive impact on consumers. Based on the hypothetical SA, methods that link the economic evaluation to pest risk assessment in this specific case will be evaluated.

1.4 Implications

The results and conclusions from this paper will provide important information for both U.S. and Chinese policymakers seeking to reduce invasive species risk while complying with WTO guidelines to not unnecessarily constrain agricultural trade. This study will provides policy makers, apple growers and researchers an overview of Chinese fruit market forms and supply chain organization. Evaluation of methodology provides researchers insights how the economics could be linked to pest risk assessment.

1.5 Organization of the thesis

The thesis is organized as follows: Chapter 2 provides a general background literature review which includes the plant quarantine laws and regulations, implementation of SPS agreement, and the Systems Approach. Chapter 3 discusses the apple production and market supply chain organization in China. The government administrative system with respect to plant quarantine in China is also introduced in Chapter 3. Chapter 4 provides a list of potential pests of concern and a hypothetical Systems Approach for Chinese fresh apples. Chapter 5 evaluates methods for economic evaluation of a Systems Approach and how it can be applied to the case of Chinese apples. Finally, Chapter 6 gives discussion and suggestions for future research work.

CHAPTER TWO

LITERATURE REVIEW

This chapter begins with a brief review of how international and regional plant quarantine laws and regulations are governed. Then a discussion of the implementation of SPS agreement as it relates to Harmonization and Scientific Risk Assessments. Finally, the chapter provides a more detailed review of the Systems Approach, which includes the basic principles of a systems approach, designing a systems approach and the economics of a systems approach.

2.1 International and regional plant quarantine organizations and regulations

International Plant Protection Convention (IPPC) is an international treaty that aims to prevent the introduction and spread of pests of plant products among contracting governments, and to promote appropriate measures for their control (IPPC, 2007). There are currently nine regional plant protection and quarantine organizations in the world. They are: Pacific Plant Protection Organization (PPPO), North American Plant Protection Organization (NAPPO), Asian and Pacific Plant Protection Commission (APPPC), Caribbean Plant Protection Commission (CPPC), European and Mediterranean Plant Protection Organization (EPPO), Comunidad Andina, Comite Regional de Sanidad Vegetal para el Cono Sur (cosave), Inter-African Phytosanitary Council (IAPSC) and Organism International Regional De Sanidad Agropecuaria (OIRSA). As of August 2006, there were 157 governments in the Convention including China and the United States (IPPC, 2007). IPPC provides a series of recommendations about plant quarantine and inspection for contracting governments, such as recommendations for phytosanitary certification, imports, regulated pests, international cooperation, regional plant protection organizations, and international standards for plant quarantine.

2.2 Implementation of the SPS Agreement

The necessity of introducing trade restrictions to protect a country's food safety and health was recognized in the General Agreement of Trade and Tariff (GATT) in 1947. A specific agreement on sanitary and phytosanitary measures (SPS agreement) was negotiated during the 1986-1994 Uruguay Round and came into effect on January 1, 1995. The term "Sanitary" refers to measures related to animals and the term "phytosanitary" refer to measures related to plants. The SPS agreement provides guidelines for WTO members in implementing sanitary and phytosanitary measures to mitigate risk and harm to a country's humans, animals and plants caused by invasive species associated with traded commodities. The SPS agreement is supported by, the Codex Alimentarius (Codex), the International Plant Protection Convention, and the International Office of Epizootics (OIE) in terms of establishing international standards, guidelines and recommendations.[5] The SPS agreement restates earlier commitments under the General Agreement on Tariffs and Trade (GATT) and the Tokyo Round Agreement on Technical Barriers to Trade to apply technical restrictions only to the extent necessary and to avoid unjustifiable discrimination

[5] According to the SPS agreement, the Codex Alimentarius establishes the standards, guidelines and recommendations for food safety; the secretariat of the International Plant Protection in cooperation with regional organizations sponsors the development of international standards, guidelines and recommendations for plant health; the international office of Epizootics sponsor the development of standards, guidelines and recommendations for animal health and zoonoses. For other matters not covered by these three organizations, appropriate standards, guidelines and recommendations can be promulgated by other relevant international organizations open for membership to all members, as identified by the committee.

among WTO members where identical or similar conditions prevail (Roberts and Krissoff, 2004).

Harmonization

According to the harmonization principal in article 3, the SPS agreement encourages countries to use international standards when implementing sanitary and phytosanitary measures. Uniform harmonization is only recommended, but not required. Members may introduce or maintain sanitary or phytosanitary measures which result in a higher level of sanitary or phytosanitary protection which are based on an international justification like Pest Risk Assessment (WTO, 1995). Between 1995 and 2000, more than 70 percent of the food safety notifications of change[6] reported that no international standards existed for the referenced measures (Roberts and Krissoff, 2004). One of the reasons to explain a low adoption rate even when international standards exist is that most of the standards are providing common approaches but specific ones may be needed to mitigate the unique risks between two trading partners. WTO members are required to make sure that SPS measures are applied only to the extent necessary and are not more trade-restrictive than necessary. Standards should be established based on the scientific Pest Risk Assessment developed by relevant international organizations to achieve an appropriate level of protection. Therefore, SPS measures are almost certain to vary across countries if these guidelines are followed. Members should accept the SPS measures that are different from their own measure or from other corresponding measures used by other members for same

[6] The SPS agreement requires the notification of regulatory changes affecting trade to the WTO.

product. In reality, SPS regulations are often applied in the form of bilateral agreements or protocols.

Scientific risk assessment

The use of science as criteria for policy evaluation is unique to the SPS Agreement (Thornsbury and Minton, 2002). According to the SPS Agreement, WTO members should ensure that the SPS measures are based on an assessment, as appropriate to circumstances, of the risks to human, animal or plant life or health, taking into account risk assessment technologies developed by relevant international organizations (WTO, 1995). WTO members, when determining the SPS measures, are encouraged to take into account scientific evidence, economic factors, potential risk and cost, and try to minimize the negative trade effects by comparing relative cost-effectiveness of alternative approaches to limiting risks.

In general, the Pest Risk Analysis (PRA) includes three stages: 1) initiation, 2) pest risk assessment and 3) pest risk management (FAO/IPPC, 2004). In the first stage, PRA is initiated by the definition of a pathway, a pest, or the review of a policy or policy revision. In the second stage, pest risk assessment is a process of identifying the pest category, assessing the probability of entry, establishment and spread of a pest/disease and assessing the potential economic consequences. The risk assessment can be either qualitative or quantitative and can vary from country to country. In reality, trading countries increasingly use scientific risk assessment even if the assessment is not very complex. Concerns over pest/disease risk are frequently mentioned when entry of an imported commodity is prohibited. For example, China prohibits the import of U.S. plums and nectarines produced in California due to quarantine concern relating to the bacterial disease, fire blight, despite U.S. attempts to provide sufficient scientific information regarding the host status of domestic stone fruit. In 2002, a Chinese delegation visited the U.S. to collect scientific data and review pest mitigation practices for a pest risk assessment of U.S. stone fruit before making the final decision whether or not the ban would be lifted (Podleckis and Usnick, 2005). At last, in the third stage, conclusions from a pest risk assessment are used to decide whether risk management is required and the strength of measures to be used. Pest risk management is a process of evaluating and selecting appropriate options to reduce the risk of introduction and spread of a pest/disease to an acceptable level. This phytosanitary measure should be cost-effective and feasible, and the form of measure may include prohibition, a pre-entry or post-entry quarantine system, and specified treatment applied during the production like chemical or physical methods, etc.

Appropriate Level of Protection becomes the internal standards to which a PRA is compared. In setting the ALOP, it is often difficult to decide whose interests should be protected and what level of risk is acceptable (Thornsbury and Minton, 2002). Normally speaking, the risk estimated by an exporting country is relatively lower than the risk estimated by an importing country. The exchange of technical and scientific information occurs during negotiations and can help an exporting country to convince an importing country that the risk associated with the product is less than has been perceived, or can be safely addressed through certain risk mitigation measures (USDA/APHIS, 2004a).

2.3 The systems approach (SA)

The Systems Approach (SA) is a policy approach to pest management recommended by WTO as one of the International Standards for Phytosanitary Measures (ISPMs). The USDA first used the term "Systems Approach" in 1994 to describe an insect management system developed to reduce the risk from the invasive species. The Systems Approach is defined by the U.S. Plant Protection Act as "a set of phytosanitary procedures, at least two of which have an independent effect in mitigating pest risk associated with the movement of commodities" (USDA/APHIS/PPQ, 2002) and is defined by IPPC as "the integration of different pest risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of phytosanitary protection" (FAO/IPPC, 2002). Similar to other pest mitigation measures, the focus of the SA is to reduce the probabilities of introduction and establishment of an exotic invasive species associated with the traded commodities. As of February, 2002, there were 12 Systems Approaches used by the U.S. for regulation of plant product imports: Unshu Oranges from Japan and Korea, Irish potato True seed, grafted lilac from Netherlands, Chinese Ya pears from China, etc.

Like all SPS policies, one of the targets of the Systems Approach is to maximize the risk reduction to an acceptable level. A distinction of the Systems Approach is the multiple (at least two) independent and effective measures, which can reduce the pest risk. This means, first, a Systems Approach is a multiple-step SPS regulation. There must be at least two steps to reduce the pest risk in a SA; second, at least two of these multiple risk-reducing steps are independent from each other, which means some (but not all) of these measures are dependent on the result of other measures. For the independent measures, the success or failure of one measure has no effects on the other measure's result. It is just like a pyramid: the multiple independent mitigation measures together decrease the probability of pest entrance and establishment. Here is a simple example to show how the SA will decrease probabilities.

Suppose there are m steps to mitigate the pest risk in a Systems Approach for a particular commodity. Define dummy variable x_i in the following way:

$x_i = 0$, the i^{th} step fails to eliminate the pest (there is pest infestation)

$= 1$, the i^{th} step succeeds to eliminate the pest (there is no pest infestation)

Each of these variables has a Bernoulli distribution. Define $P(x_i = 1) = p_i$ as the probability that there is no pest infestation after the i^{th} independent phytosanitary measure (the probability that the i^{th} step successfully eliminate the pest); then define $P(x_i = 0) = 1 - p_i$, the probability of pest infestation after the i^{th} independent measure (the i^{th} measure fails to eliminate the pest). Define variable p_0 as the initial probability of pest infestation before any phytosanitary measure is in place.

During agricultural production, the mitigation measures in Systems Approach are, by definition, applied according to a certain sequence starting from pre-harvest, then harvest, post-harvest, storage, and shipment. The additive effects are sequence-specific with each succeeding mitigation effect being a probability conditional upon the preceding mitigation effect(s) (USDA/APHIS/PPQ, 2002).[7] Here $m = 5$, $p_i = 0.9$ for each i and $p_0 = 1$. Results are given below in Table 2.1.[8]

Tale 2.1 Comparison of probability of pest avoidance between a single phytosanitary measure and a systems approach

Mitigation measure (steps)	Single measure		A systems approach	
	Probability of pest invasion	Probability of pest avoidance	Cumulative probability of pest invasion	Cumulative probability of pest avoidance
None	1	0	1	0
X_1	0.1	0.9	0.1	0.9
X_2	0.05	0.95	0.1x0.05=0.005	01-0.1x0.05=0.095
X_3	0.15	0.85	0.005x0.15=0.00075	1-0.005x0.15=0.99925
X_4	0.20	0.80	0.00075x0.2=0.00015	1-0.00075x0.2=0.99985
X_5	0.10	0.90	0.00015x0.1=0.000015	1-0.00015x0.1=0.999985

Source: Calculated by author according to Table 3 on page 13 in "Preventing the Introduction of Plant Pathogens into the United States: The Role and Application of the "Systems Approach" (USDA/APHIS/PPQ, 2002).

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7 n measures $\{x_1, x_2, \ldots x_{n-1}, x_n\}$ are statistic independent iff $P\left(\bigcap_{i=1}^{n} x_i\right) = \prod_{i=1}^{n} P(x_i)$.

While n measures $\{x_1, x_2, \ldots x_{n-1}, x_n\}$ are statistic dependent iff

$$P\left(\bigcap_{i=1}^{n} x_i\right) = P(x_1)P(x_{2/1})P(x_{3/1,2})\ldots P(x_{n/1,2,\ldots n-1}).$$

8 More detailed calculations for this example are shown in Appendix A.

From Table 2.1, the Systems Approach as a set of five independence measures, can reduce the probability of infestation to 0.000001, which is much lower than 0.1, the probability of infestation simply from applying a single measure; or the certainty of infestation when no measures are applied. The independence of these measures can cumulatively increase the mitigation effect. In this example, by assumption, all these measures are mutually independent, however, some measures in reality might not be purely independent. Even though, it shows that the additive affect of these dependent and independent measures in mitigating the risk is still higher than the effect of a single measure as long as at least two of these measures are independent.

Of course, in reality, designing a SA is much more complex than this simple example. When designing a SA for particular commodity, basic data and information about the pests associated with the commodity are needed including the list of pests, the climate information in the production areas, the knowledge of the pest and disease life cycle, the situation of harvesting, packing, storage and shipping, etc (USDA/APHIS/PPQ, 2002). Multiple pests, multiple hosts, environmental and commercial impacts, and the uncertainty around risk reduction probabilities all add complexity. The pest risk assessment should be the base for designing a SA and, in general, a SA includes the mitigation measures at pre-harvest, harvest, post-harvest, and during storage, shipping and distribution. Still, decisions about the proper phytosanitary measures to be included in a specific Systems Approach (for example, governing the import of Chinese apples) and the optimal combination of measures to mitigate the pest risk at the maximum level are controversial and difficult to evaluate.

Economics analysis of SPS issues

Risk caused by the pest/disease associated with traded commodities could not only have potential negative impacts on a county's human, animal or plant health, the risk can also affect a county's national welfare by increasing the potential cost, reducing the quantity of imports, increasing import prices either in the short run or the long run. To assess the trade off in these impacts, economic assessment of a pest mitigation policy is important, but difficult. There is limited literature about economic evaluation of a pest mitigation policy that links economic assessment and pest risk assessment.

Non-tariff barriers to trade (like sanitary, phytosanitary and technical barriers to trade) have drawn attention from some researchers. Beghin and Bureau (2001) summarizes the methodologies used to modeling and quantifying non-tariff barriers to trade. They mentioned several methods like price-wedge method, inventory-based approaches, survey-based approaches, and risk-assessment-based cost-benefit measures, stylized microeconomic approaches. Among these methods, tariff equivalent is a price edge method used to measure the trade impact of technical barriers to trade issues. Krissoff, Calvin, and Gray (1997) stated that technical trade barrier measures might be a social welfare enhancing policy in the importing country if the expected gains associated with reducing the risks over the cost of a pest infestation. Carvin and Krissoff (1998) quantified the phytosanitary barriers to U.S. apple exports to Japan by calculating tariff-rate equivalents to measure the magnitude of the trade barriers. They showed that both in short run and long run, Japanese apple imports would increase if eliminate phytosanitary tariff-rate equivalences and tariffs. Therefore, it is intuitive that there is a way to estimate the impact of SPS issue on international trade. However, compared with tariffs, phytosanitary issues might be more complex since it is related to the risk of probability, the environmental impact, and the economic consequences.

Adding risk analysis into the traditional welfares analysis is a natural idea and is used by several people to evaluate phytosanitary measures. A model of quarantine policy was developed by Glauber and Narrod in 2001. In this model, probabilistic risk assessments are combined with economic analysis to show that the USDA would have reached different conclusions if they had incorporated risk into the benefit-cost analysis of Karnal Bunt. Bigsby (2002) developed an Iso-Risk framework for quantifying technical trade barriers that contain elements of risk of occurrence and economic impacts. The Iso-Risk framework combines the two basic components of pest risk assessment, probability of establishment and economic effects, into a single management framework.

Extending the welfare analysis in a partial equilibrium model is being used by several people to link economic assessment and risk assessment. Paarlberg and Lee (1998) used a partial equilibrium model to determine the welfare maximizing level of U.S. tariffs by estimating the Foot and Mouth Disease risk, losses due to infection and trade elasticity. They showed that the magnitude of the tariff in the presence of an FMD risk is very sensitive to the specification of the risk of importing FMD and to the magnitude of losses expected from an FMD outbreak. Wilson and Anton (2006) have tried to find an optimal set of SPS measures considering total welfare and mitigation strategies by using a partial

Equilibrium model in the case of beef import to the U.S. They showed that the mitigation strategies could generate net welfare gains. It is optimal to apply mitigation strategies first. In addition, they provide a new point that an additional tariff as a complement can be added into the mitigation measures if additional SPS protection is needed.

Peterson and Orden (2006) developed a static, multi-season partial equilibrium model to evaluate the effects of allowing fresh Hass avocados from approved orchards in Mexico to be imported into the U.S. under alternative Systems Approach pest risk mitigation measures. Different from previous research, the probability of introducing the pest is calculated for each step in a SA and for each selected pest making this model a good source of reference for evaluating a hypothetical SA for Chinese fresh apples. In the model, three scenarios are evaluated: unlimited access to the U.S. market with the Mexican systems approach compliance measures in effect as specified in the 2004 rule, further removal of the compliance measures directed specifically toward Mexican fruit flies, and elimination of all systems approach requirements. Results indicate that the substantially expanded trade when geographic and seasonal restrictions are rescinded lowers Mexican per-unit compliance costs in half, from nearly 20 percent to about 10 percent of their producer prices. Pest risks are low with the systems approach compliance measures still in place and estimated annual net U.S. welfare gain from eliminating all geographic and seasonal restrictions is calculated as approximately US$70 million.

In addition, Wittwer, McKirdy, and Wilson (2005) use a dynamic multiregional computable general equilibrium (CGE) model to estimate the micro- and macroeconomic effects of Karnal bunt incursion in wheat in Western Australia. They decompose the contribution of individual direct effects, like the response of buyers, the costs of eradication and the time path of the scenario contribute to outcomes to the overall impact of the incursion.

2.4 Summary

The SPS agreement provides guidelines for WTO members in implementing sanitary and phytosanitary measures to mitigate risk of introducing exotic invasive species associated with traded commodities. Pest Risk Analysis is an important component for trading countries in the implementation of the SPS Agreement. The conclusions from PRA are used to decide whether risk management is required and the strength of measures to be used. Relatively little research has been done to link the economic assessment and risk assessment when evaluating the impacts of an SPS policy on trade or a country's welfare change. As one type of multi-step SPS regulation, the Systems Approach, which includes at least two mutually independent measures, is recommended by WTO as one of the International Standards for Phytosanitary Measures. The multiple independent mitigation measures in a Systems Approach together increase the probability of preventing pest entry and establishment.

CHAPTER THREE:

APPLE PRODUCTION AND SUPPLY CHAIN ANALYSIS

As the largest apple producing country in the world, China is asking for consideration to export fresh apples to the U.S. Since no fresh apple trade currently exists, background information is needed before developing and evaluating a hypothetical Systems Approach for Chinese fresh apples. This chapter begins with the introduction of China's fruit sector and apple industry, which includes production and consumption trends, and trade information.[9] This is followed by a discussion of the supply chain organization for fresh apples in China. Three markets are described: traditional fruit market, new emerging modern market, export market and the new emerging coordinated supply chain organization is discussed. Finally, a discussion of the quarantine administration system and regulations in China is provided, which includes existing pest risk policies and the implementation of other phytosanitary measures related to fresh apples.

3.1 Fruit and apple industry in China

The economy of China grew at an average annual rate of 8.9 percent[10] between 2001 and 2005 (the period of the tenth Five-Year plan).[11] This rate is among the highest in the world

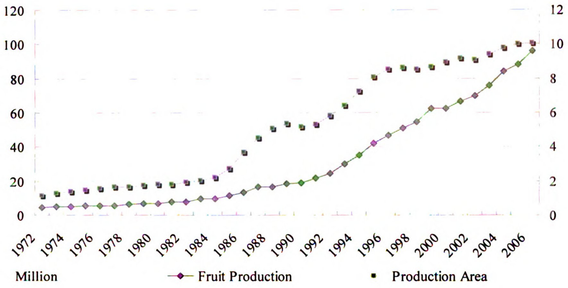
[9] We only focus on "fresh" apple trade and associated phytosanitary measures in this paper. Discussion of processed products including concentrate apple juice issue is omitted because it is not the emphasis of our study.

[10] Annual rates were 7.5, 8.3, 9.5, 9.5 and 9.9 percent respectively during the period 2001-2005 (National Bureau of Statistics of China, 2006).

[11] The Five-Year Plans are a national economic development plan, which was first introduced in the Soviet Union. China introduced its own five-year plan in 1953. Chins is during the period of its eleventh five-year plan (2006-2010).

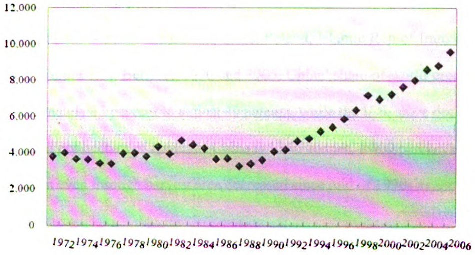
and illustrative of the rapid economic development of China since market reform opened up in 1978. Fruit production has been increasing rapidly since 1978 and came into a stable development stage during the 1990s. The production of fruit in China was 4.4 million tonnes in 1972 and 9.6 million tonnes in 2006, an increase of 20 times in only three decades (Figure 3.1). China became the world largest fruit producing country in 1994 (MOA, 2005). Over the same period, area planted to orchards increased from 1 million hectares to 10 million hectares (Figure 3.1), and yield came into a steady increasing period after 1990s (Figure 3.2). Shandong, Shaanxi, Guangdong, Henan Guangxi, Fujian are the main fruit producing provinces. China now has become a fierce competitor in the international fruit markets. The total export value of fruit was US$2.5 billion in 2004, an increase of 21.7 percent compared with year 2005 (MOA, 2007). The main imported fruits are grapes, bananas, and gooseberries. Primary suppliers are Thailand, Chile, the United States, Philippines, Vietnam, Brazil and New Zealand. Shandong, Shaanxi and Guangdong provinces are the main apple exporting areas with most fruits going to Japan, the United States, Russia and Germany. And the main exported fruits are apples, oranges and apple concentrates.

Figure 3.1 Fruit Production and Area in China (1972-2006)



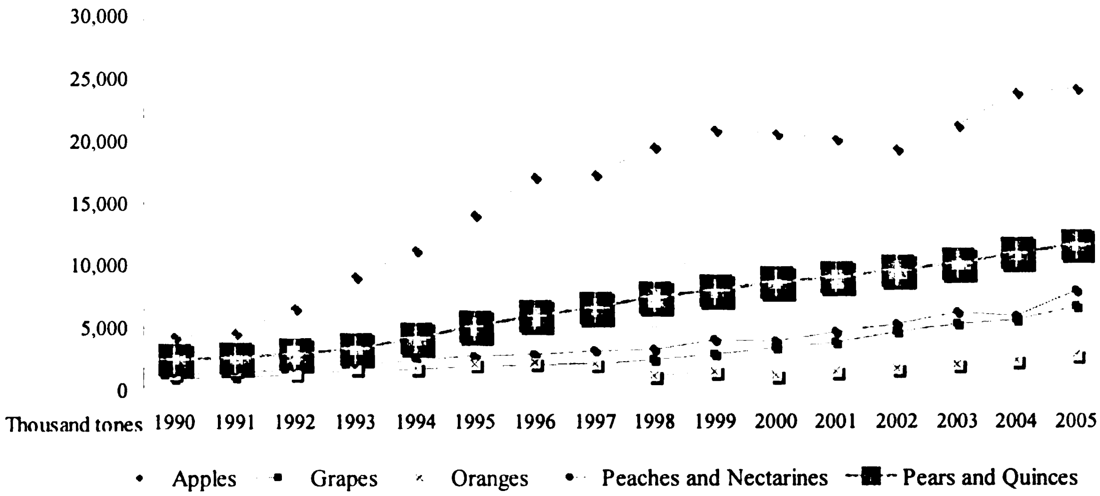
Source: Fruit Area and Production Online Data Sets (Crop Cultivation in China, 2007). Total fruit production includes melons.

Figure 3.2 Fruit yield in China (1972-2006)



Source: Fruit Area and Production Online Data Sets (Crop Cultivation in China, 2007). Total fruit production includes melons.

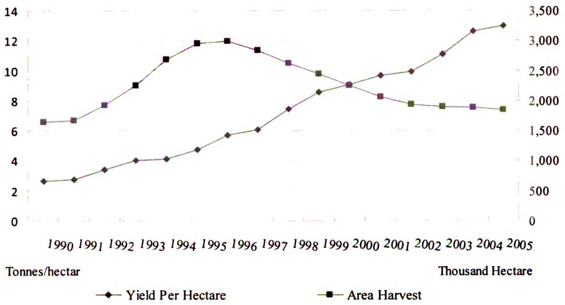
Figure 3.3 Main fruit production in China (1990-2005)



Source: Author's calculations. FAO online data source.

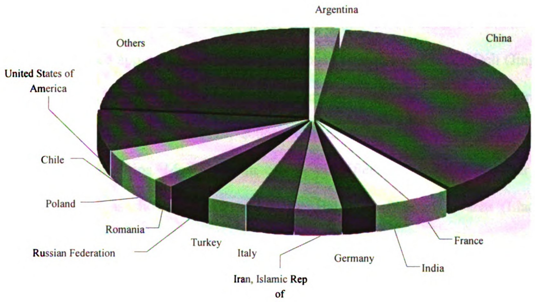
Apples are the leading fruit produced in terms of volume (Figure 3.3) in China. Production and is growing rapidly, far ahead of other fruits. Over the past two decades, the production of apples in China has rapidly increased. In 2005, China, the world's largest apple production country, had a production of 24 million tonnes, which accounted for 38 percent of world's total followed by the United States, Poland, Islamic Rep of Iran, France, Italy, and Poland (Figure 3.5). Between 1990 and 2005, China' share of world production grew from approximately 13 percent to almost 40 percent, while the U.S. share declined (Figure 3.6). The yield per hectare of apples in China is 12.97 tonnes, a 400 percent increase from 1990 as shown even through harvest area decreased since mid of 1990s as shown in Figure 3.4.

Figure 3.4 Yield and area harvest of apples in China (1990-2005)



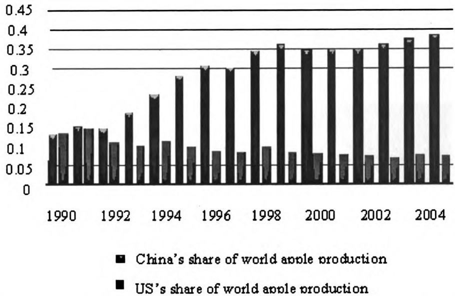
Source: FAO online data source.

Figure 3.5 World apple production, 2005



Source: Author's calculations. FAO online data source.

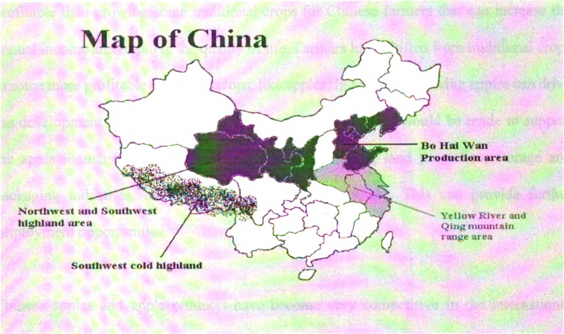
Figure 3.6 U.S and China's share of world apple production (1990-2005)



Source: Author's calculations. FAO online data source. World production includes the production of all the 176 countries listed in the FAO online database.

China, especially the loess plateau areas, is suitable for apple growing with over 700 varieties grown in that region. In terms of varieties, Fuji is the primary apple variety in China, with production area accounting for almost half of the total for China. Other common improved apple varieties include Delicious (Yuanshuai), Golden Deli (Jinguan), Jiaona Jin, Gala. In addition, Granny Smith seems to become an increasingly attractive apple variety in China (USDA/FAS, 2006a). Currently, there are 25 (of 34) provinces growing apple in China. Most of them can be classified in the following four main production areas as shown in Figure 3.7: Bo Hai Wan Production area (Liaoning, Shandong, Hebei province, Beijing and Tianjin, etc.); Northwest and Southwest highland area (Shanxi, Gansu, Shaanxi, Ningxia and Qinghai province, etc.); Yellow River and Qing mountain range area (Eastern Henan, southwestern Shandong, northern Jiangsu and northern Anhui Provinces); and Southwest cold highland area. Bo Hai Wan area is one of the biggest traditional apple production areas. Shaanxi, which replaced Shandong province after 2001, becomes the largest apple producing province in China.

Figure 3.7 Map of China

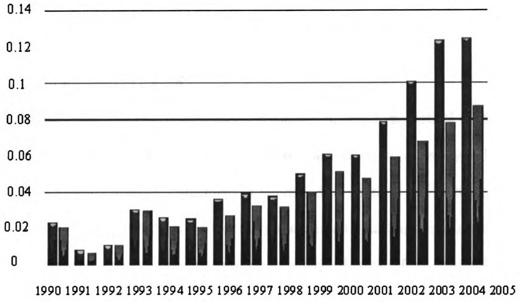


Source: Edited by author. Original map: http://linguistlist.org/emeld/school/images/map_china1.gif.

There are several factors that underlie the rapid increase in Chinese apple production. First, the Chinese government has placed a high priority on development of the fruit industry, including apples. Chinese government has identified apple production competitiveness in world markets and its potential for driving economic development. For example, the government encourages fruit production in mountains and hilly areas, which are mainly the Yellow River and Qing mountain range area and Northwest and Southwest highland areas. These areas have great geographic and topographic advantages for apple growing, like higher land quality, more exposure to sunlight, greater variation in daily temperatures resulting in better shape and higher sugar content (World Bank, 2006). A series of policies were enacted to support development, including provision of subsidized production materials like fertilizer, seeds, assistance to build up the greenhouses for some commodities, financial support, and market information, etc. Growing apples is more profitable than growing some traditional crops for Chinese farmers that can increase the annual income and improve the quality of life. Farmers have shifted from traditional crops to some more profitable economic crops, like apples. In addition, growing apples can drive the development of other industries. Comparable investments would be made to support the apple industry development, like water conservation, land protection, storage and packaging industries, and road improvement projects, etc. This can provide further employment opportunities.

Chinese apples and apple products have become very competitive in the international market, especially after China entered the WTO in 2001.Chinese apple export increased rapidly and as well as the share of world market in terms of export volume and export value (Figure 3.8). The export quantity of fresh apples increased almost 12-fold from 69 thousand tonnes in 1990 to 832 thousand tonnes in 2005 but the average per unit value decreased due to lower export prices (FAO, 2007). Southeast Asia, Russia and Canada are the main export destinations for Chinese apples. While Chinese apples account for 12 percent of the world's total export quantity, this is much smaller than the 37 percent share of world production in 2005. Currently, most of the production is consumed domestically even though Chinese apple growers are eager to open the international market due to the higher price and value-added compared with the domestic market. While quality and food safety issues have been relatively lagging, Chinese apples are stronger in global markets where prices count more than, quality and safety (World Bank, 2006). China has a long-term comparative advantage in labor, a source of competitiveness for many Chinese products, which results in relatively low apple prices in the international market.

Figure 3.8 Chinese apple shares of the world's export volume and value (1990-2005)



Source: FAO, 2007.

The meteoric rise in apple production and the gradually open market present both opportunities and challenges for the U.S. horticultural industry. The United States is one of the most important fresh apple imported countries for China. China imported 18,972 and 19, 465 metric tons of fresh apples from the U.S. in 2003 and 2004, which accounts for 45 and 52 present of the total imports separately. The other countries for fresh apple import are France, Japan, New Zealand, Chile and Australia. The Red Delicious is the most common variety that have been imported but the flavor of Red Delicious does not appeal to most Chinese consumers. Most people buy it as gift for its deep red color. The U.S. red Globe is well known to Chinese for the good taste and high quality (USDA/FAS, 2006a).

China is now requesting approval to export fresh apples to U.S. and it is likely that U.S. market will open to Chinese apples in the near future. At present, U.S. federal Animal and Plant Health Inspection Service (APHIS) is looking into developing the specific "Systems Approach" the certification process for Chinese apples.

3.2 Fruit markets in China

Since the corresponding phytosanitary measures of any hypothetical systems approach policy are related to how fruit is produced and handled, it is necessary to look at supply chain organization and management in Chinese fruit markets. At present, Chinese fruit markets can be divided into three categories: traditional fruit market, new emerging modern market, and export or industrial market (World Bank, 2006). A simple introduction of these three markets is given first in this section and followed by more detailed discussion of some issues regarding supply chain organization.

Traditional fruit markets

Traditional local fruit markets have been the most popular market format in the last decades and even now still retain the largest market share. This market consists of millions of small-scale farmers, who normally have less than 0.5 hectares per person on average.[12] A small portion of the fruit is consumed for home use but most of the fruit is collected by

[12] In 2004, the population of China was 1,299,880,000 with 720,850,000 were employed in agriculture (28 percent). Among all the people employed, 50 percent are employed in agriculture sector (primary industry).

fruit dealers or farmers themselves. Sales are to local urban and rural markets, including restaurants, street market, or grocery stores. The farmers in this market have less consistency in pesticide, lack market supply and demand information, and have relatively less technical and policy support from the government. Most of the fruit is sold through outlets that combine retail and wholesale functions. Traditional fruit markets are characterized by little food safety control, heterogeneous quality, absence of standardization, low prices for growers and consumers, very low value-added, and a lack of long term relationships between buyers and sellers.

New emerging modern markets

China's food retail markets have experienced remarkable transformation after the economic liberalization starting in the early 1980s. One of the most evident examples of rapid development is the spread of supermarkets. Over the last decades, especially in the last five years, supermarkets have replaced most of the traditional wet and flea markets in urban centers. Supermarket sales are growing at a growing rate 30-40 percent per year. The supermarket revolution in China is spreading faster than anywhere else in the world (Hu, *et al.*, 2004). When compared with traditional fruit markets, modern domestic supermarkets are characterized by better food safely control, convenient shopping environment, emerging awareness of tighter supply-chain organization, sharing market information and trust between buyers and sellers, increased value-added, and existence of market leaders. Several reasons can explain rapid growth of the supermarket. First, rapid urbanization and the increase in women employment. Like other market forms, supermarkets require a certain number of consumers to be profitable and the increasing urban (as well as the nearby rural) population provides a minimum clientele for the development of supermarket (Hu, *et al.*, 2004). In addition, employed women are seeking more convenient shopping options with lower transportation cost to save the opportunity cost of food preparation. Second, increase in household income. In the last two decades, the rural per capital income increased by six-fold and urban per capital income increased by 12-times (MOA, 2005).[13] Generally speaking, urban residents have stronger purchasing power than people in rural areas; in 2004, the urban per capital income was three times the rural per capital income (MOA, 2005). Third, increase in Foreign Direct Investment (FDI). Foreign-owned supermarket chains, i.e., Wal-Mart (USA), Carrefour (France), Metro (Germany), 7-Eleven (Japan) and some new emerging domestic supermarkets, like Hualian, Lianhua, Nong Gong Shang, Suguo, Huarun have dramatically changed the retail food sector in China. Government support is a forth factor as more active government policies are helpful in converting informal wet markets to supermarkets. For example, a program called "Nonggaizhao", which means changing farmers market into supermarket, was applied in 2003 in some big cities in China (Hu, *et al.*, 2004). In rural areas, like Sichuan and Zhejiang province, the government supports the development of small-scale "rural supermarket" by providing financial subsidies and management training. Finally, there are a number of other reasons like liberalization of retail and wholesale sectors, westernization of life styles, and increasing proportion of young people in the population. These reasons combined shift food purchase from traditional fruit markets to new emerging supermarkets. Compared with the small local traditional fruit market, the supermarkets attract consumers

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[13] Income was 547 RMB per capital in rural area and 739 RMB per capital in urban area in 1985 and, corresponding, 4040 RMB and 9422 RMB per capital in 2004. Here it is better to keep the Chinese currency just to see the increase. Because Chinese exchange rate system in 1985 was quite different with the one in2004, it is not compatible if we change it into US dollars.

with more varieties of food, higher food quality, convenience of one-stop shopping, and a better shopping environment.

However, the development of supermarket sales in the fruit sector, especially for fresh fruit, has not been as fast as other sectors in general. Not all the supermarkets in China sell fresh fruit. The fruit sector in supermarkets still has limited market share in terms of sales due to the difficulties of quality and safety control of fresh fruits and higher prices. Even though the improved infrastructure and increased capacity of cold storage have helped enhance the distribution networks in China (USDA/FAS, 2006a), only specialized wholesale markets or big-scale dealers are able to afford the expensive cold store or facilities. Supermarkets are better able to handle processed foods and fresh products with a longer shelf life, but they have major difficulties in handling fresh vegetables and fruits (World Bank, 2006). In addition, from the consumers' perspective, they prefer to go to traditional wet markets for fruit due to cheaper prices but still go to supermarkets for other goods.

Export market

Over the last decades, with the privatization and economic liberalization, producers in China have been increasingly able to respond to foreign demand in Japan, Korea, Hong Kong and Chinese ethnic markets in Southeast Asia and North America, because of cultural closeness, similarities in food consumption and crops grown (World Bank, 2006). Export supplies are mainly provided from bigger domestic fruit companies. The current export fruit markets themselves are still developing and improvements in quality, safety, and technology are under way to meet requirements in different international export markets and higher international standards. Export fruit markets are even more demanding than domestic supermarkets in terms of quality and safety requirements. They are characterized by the highest standards, food safety control systems, higher requirements for grading and supply schedule, higher value-added, relatively higher price levels, for existence of trust between buyers and sellers. Even within the broad category of export markets, there are still big differences in the demands from buyers from different countries. Markets in North America and Europe are generally more demanding than the markets in Russia, Middle East and some Asian countries. At present, the export market probably constitutes not more than two percent of the volume of fresh fruits and vegetables (World Bank, 2006). Even with the limited share of product distributed through export market, these supply chains are playing a critical role in promoting the overall development of the fruit industries in China. Chinese government provides great support to the development of export market for agricultural products. In 2006, the Chinese Ministry of Commerce issued the first Five-Year Development Program (2006-2010) for Agricultural export.

Table 3.1 Comparison of characteristics of three market forms in China: traditional local market, new emerging modern market, and export market

Characteristics	Traditional fruit market	New emerging modern market	Export market
Supply chain leader	No	Large fruit company	Exporters
Market share	Has the largest market share in China	Small but increasing market share	Small market share
Participation of small-scale farmers	Consist of million of small scale farmers; No constraints to enter the market	Small scale farmers are gradually excluded from the market due to the high requirements for quality, food safety control	Farmers enter the market only by signing the contact with the companies to guarantee the quality and food safety
Standardization and grading	Almost no standards for supply	Emerging higher standards for quality	Highest standards
Food safety control capacity	Low	Moderate	High
price level	Relatively low; low market value added	Higher	Highest but still low in global market
Value added	Low	Moderate	High
Trust between the partners	Not important	Emerging importance	Important for long term cooperation
Government support	Relatively low	Moderate	High
Global competitiveness	Very low	Moderate, but developing very fast	High

Source: Edited by Author according to Table 15 "Three types of markets and their characteristics", China: Compliance with food safety requirements for fruits and vegetables (World Bank, 2006).

3.3 New emerging coordinated supply chain

Coordinated supply chains are durable arrangements between producers, traders, processors and buyers about what and how much to produce, time of delivery, quality and safety conditions, and price (Word Bank, 2006). Based on the discussion in section 3.2, traditional supply chains in Chin have not been able to satisfy the increasing higher requirements of supermarket and export markets, which requires the consistency of quality, safely, volume, requires a strict delivery schedule, and even tracking systems throughout the whole supply chain. Coordinated and integrated upstream and downstream relationships satisfy requirements of the modern fruit domestic and export markets and have become the dominant institution in these supply chains. The participants have durable relations in a coordinated supply chain by exchanging information and consulting each other. For example, a fruit company might be responsible for some of all the activities in a supply chain, like production, processing and wholesaling. Some key characteristics of coordinated supply are discussed below.

Centralized procurement system

The procurement system trends to shift away from the traditional wholesale system towards use of large, centralized distribution centers with specialized/dedicated wholesalers-operating preferred supplier system (Hu, *et al.*, 2004). In such a centralized procurement system, transaction costs can be largely reduced; there are fewer suppliers and wholesalers, which result in an easier control over the quality and food safety; standards are generally higher than those in traditional markets.

Standards and food safety

The standards in China can be grouped into two categories in China: private standards and official standards. The official standards refer to the published laws and regulations and as well as the updated standards published by Chinese government. Private standards refer to the requirements set by supermarkets or exporters themselves (or importers) when they are sourcing the fruit. Generally speaking, the private standards are more demanding than the national official standards in China. In terms of fresh apples, the definition of standards includes not only food safety related requirements, like pesticide residuals level, hygienic standards, heavy chemical residuals, but also includes the grading standards, like appearance and freshness. The rapid development of supermarket and export market contributes to increasing the overall standards in Chinese fruit sector. The increase in standards pushes farmers to shift from traditional supply chains to the new emerging coordinated supply chain.

The participation of small-scale farmers

Individual small–scale farmers in traditional fruit markets are gradually excluded from the new emerging modern markets and export markets even though they have relatively low production cost. New emerging supermarkets and export market do not want to source their fruit from individual small-scale farmers due to high transaction costs, lower quality, lower safety quarantine, lack of trust, and lack of settled delivery schedules.

However, as mentioned before, the traditional fruit market still has the largest market share for fresh apples. It is necessary and important to help some of small-scale farmers get involved into the new emerging modern market and export market. Contract farming is becoming more common in China. Especially for those farmers that are capitalized and organized, signing a contact with large fruit companies is a great opportunity to adjust themselves to the new market format. Sometimes, farmer organizations coordinate small growers with these larger fruit companies to sign the contracts. Commonly, with a contract, the fruit company provides the farmers guidance for production, fertilizer, and technical support for quality control. Normally these companies have their own laboratory, which is partially sponsored by the government, to inspection products and thus address food safety issues, like high chemical residue. In such a system, the whole production is under the supervision of technicians from the fruit company. This can also compliment the growers' lack of market information and guarantee market access if quality standards are met.

The emergence of association

Another important characteristic of the coordinated supply chain is the emergence of associations in China's fruit sector. Most of the associations are established by the government as an official organization in order to promote the overall development of a specific industry. In addition, there are some other associations that are established by farmers themselves to increase sales and competitiveness. The Chinese Apple Association was established by the Ministry of Agriculture (MOA) in 2002 to promote the national development of apple industry. It consists of voluntary growers, dealers, companies, researchers, and other organizations that are related to apple production, storage, shipping, import or export from all over the country. In addition, there are some smaller regional apple associations, such as the Shandong Yantai Xixia Cuiping apple association. This group was founded in 2003 in Shandong Yantai city, one of the biggest apple producing areas in China and has its own production base, cold storage, and distribution center. It also serves a role in coordinating local apple farmers with importers and companies.

Guanxi- a special social relationship in China

The presence of trust between supply chain members is an important factor in an efficient and effective coordinated supply chain. In China, “Guanxi”, which means “Interpersonal Relationship”, is an interpersonal and characteristic-based trust, and has been an important part of Chinese business society (Xin and Pearce, 1996). “No friends, no business”. If you don’t have a good relationship, there is really no way to survive in China. Guanxi can be the relationship among the relatives, friends, classmates, people from the same region, teachers and the class, employees and employers, husband and wife, or even the people who have the same hobbies. Once you have established a relationship of trust, things would become much easier. Here it should be mentioned that "Guanxi" is not equal to a bride or some other illegal relationship between the supply chain partners. It is just a Chinese special term used to express this important social relationship in China. Guanxi plays a very important role in the coordinated supply chain of fruit sector in China, not only for the small-scale farmers, but also for the large fruit companies and exporters. Understanding the critical role of Guanxi and then setting up appropriated Guanxi with downstream and upstream partners is essential to survive in China.

Case study--- Longkou Fook Huat Tong Kee Fruit Co., Ltd

Longkou Fook Huat Kee Fruit Co. Ltd. in Shandong Province is one of the biggest fruit companies in China. It is a solely Singapore-owned fruit company that was established in 1965 and came into Shandong Province of China in 1993. This company is vertically integrated from production, packaging, storage, distribution, and exporting. Most of the products go to export markets or domestic higher-level supermarkets. Longkou Fook Huat Kee Fruit Co. Ltd. adopted two production modes to better control the quality and safety of the fruit (Hu, 2005). One is to sign contracts with small individual farmers; the other is an internal production base that belongs to the company and is directly controlled by the company. In mode one, if the farmer's cultivable land is larger than 0.82 acres (5 Mu), they are eligible to sign a production contract with Fook Huat Kee under some conditions. For example, growers must cultivate the same variety in the same region, use fertilizers and pesticides provided by the company, and the quality of the fruit must meet the requirements of the company. They provide trees, fertilizer and pesticides, but also direct supervision and technical support to the farmers in the production. The farmers themselves also need to increase their investment on production materials to follow the company's quality and safety standards according to the contracts. Sometime, the small farmers organized their own organization to better negotiate with the company. All the individual farmers are divided into small groups and there is one leader, one vice leader and one technical assistant in each group. In mode 2, local farmers are employed to work in the work in the company's production base and the average income for them is US$50-75 per month.[14] This company also has their own storage, packaging, and distribution facilities. Storage capacity is 35,000 tonnes with 25,000 tonnes of advanced cold storage. The model of "Production Base+ Small-Scale Farmers" increases the connections between the small farmers and market demand by helping them improve production techniques and better control the safety and quality of the fruits. To meet the higher requirements of supermarkets and international buyers, the company adopted advanced techniques in their own internal farms and also provides the techniques to its contracted farmers.

[14] According to the field survey in China in 2005, for other farmers, the average salary per farmer who works outside traditional farming time is around $30 per month.

3.4 Plant quarantine systems and regulations in China

As one of the largest countries in terms of food production and consumption, China has paid increasing attention to food safety issues in recent years. At least 16 institutions, including ministries, banks, and commissions are involved in governing agriculture and its upstream and downstream sub-sectors (O'Brien, 2006). It should be mentioned that the overall government system in China is relatively complicated. The National People's Congress (NPC) ranks the highest in the administrative system pyramid. All other ministries, departments and institutes are either directly or indirectly under the NPC. These ministries, departments and institutes normally all have multiple geographic divisions (i.e. state level, provincial level, city level, county level and even village level). In addition, responsibilities among some relevant departments are not always distinct and sometimes overlapping.

With regard to plant quarantine and inspection, a series of food actions and plans are currently being implemented. In addition, a new food safety control strategy is under development, with a focus on the establishment and optimization of technical systems, standardization systems, management systems, monitoring systems, certification systems, emergency reaction systems, as well as the legal system (World Bank, 2006).

Government administrative system with respect to plant quarantine

As already mentioned, in China's administrative system, the National People's Congress is the highest organ of state power. The State Council, which is also part of the central people's government, is the highest executive organ of state power and administration. It is responsible for implementing the principles, regulations, and laws adopted by the NPC and dealing with national affairs including international politics, diplomacy, defense, economy, culture and education. In this section, discussion will focus on the most relevant departments and institutions with respect to food safety and phytosanitary control in the fruit sector. Several public government departments and institutions are involved in this area. The current Chinese food safety control system is not well developed and undergoing change, thus the responsibilities and tasks among these departments and institutions are somewhat overlapping. The followings are the list of the most relevant government departments or institutions with respect to the fruit safety control and implementation of phytosanitary measures.

1. General administration of quality supervision, inspection and quarantine of the People's Republic of China (AQSIQ)

AQSIQ, directly under the State Council, is mainly responsible for drafting laws, regulations and policies related to food safety and quality supervision, inspection and quarantine; constructing unified supervision and management of national food measurement work; coordinating and implementing and managing the formulation of state and provincial standards; reviewing, approving and issuing sanitary and phytosanitary or other safety and quality related laws, regulations and policies concerning import and export products; organizing and guiding multi-lateral and bilateral governmental and non-governmental cooperation and exchange concerning food safety and inspection; participating in major events initiated by international organizations; reviewing and issuing the food quality and safety certifications and standardization.

AQSIQ is a critical government agency in controlling food safety and implementing the phytosanitary measures during production, processing and transportation. It is one of several official representatives of the Chinese government in coordinating and negotiating bilateral agreements with other countries. The most relevant departments within the agency are the Bureau of Food Safety for Imports and Exports, the Department of Quality Supervision, and the Committee of Standardization and Administration of Certification and Accreditation.

2. Ministry of agriculture (MOA)

The Ministry of Agriculture is mainly responsible for drafting, reviewing and issuing mid-and long-term development strategies, policies and regulations; drafting and issuing policies related to the adjustments of agricultural structure, price change, financial credit, subsidies, etc; coordinating the international economics and technical cooperation with other countries and international organizations; guiding the development of safety food, implementation of food safety control measures; investing in the construction and improvement of food safety testing and inspection. The Department of Agricultural Regulations and Policies, the Department of Market and Economic Information, the Department of Crop Farming Management, and the Environmental/ Green Food Development Center are the most relevant departments in MOA.

3. State food and drug administration (SFDA).

State Food and Drug Administration, again directly under the State Council, is in charge of comprehensive supervision for the safety management of food, health food and cosmetics and is the competent authority for drug regulation. Relevant departments include the Policy, Law and Regulation Department, the Food Safety Coordination Department, and the Food Safety Supervision and Inspection Department.

4. Ministry of health (MOH).

The Ministry of Health is also a member of the State Council and is mainly responsible for drafting main health laws, regulations and policies; proposing and guiding the implementation of health development programs and strategic goals; conducting health education programs for the public; organizing and guiding governmental and non-governmental health and medical cooperation and exchanges and medical aids to other countries.

5. Certification and accreditation administration of the People's Republic of China (CNCA)

CNCA was established in 2001 and is authorized by the State Council. CNCA undertakes responsibility for unified administration and supervision system, overall coordination and accreditation of certification in China. This agency is mainly responsible for drafting and implementing laws and regulations with respect to certification, accreditation and inspection; the assessment of hygiene registration of manufacturing and processing establishments for domestic, import-export food and cosmetics; supervising certification activities; administrating the assessment and qualification approval of relevant inspection and testing bodies; coordinating international cooperation activities and signing related agreements and protocols; the notification and construction related to certification and accreditation issues with the range of WTO/TBT and SPS.

6. Others

Other relevant government departments include State Administration for Industry and Commerce, National Development and Reform Commission, State Environment Protection Administration, Ministry of Finance, Ministry of Public Security, Ministry of Water Resources, Ministry of Education, People's Bank of China, and Agricultural Development Bank of China. All of these departments and institutions have many responsibilities including some related to plant quarantine and inspection. For instance, the State Environment Protection Administration (SEPA) is responsible for drafting the laws on such issues as soil pollution, water pollution. The State Administration for Industry and Commerce (SAIC) is responsible for monitoring and managing the economic market in general.

The following table is a quick summary of the responsibilities of the departments and institutions mentioned above.

Table 3.2 Institutions in China with responsibilities related to plant quarantine

Institution	Main responsibilities
Agricultural development bank of China	Specialized in extending loans for agriculture and rural enterprises
Certification and accreditation administration of the People's Republic of China	Draft and implement laws and regulations with respect to certification, accreditation and inspection; supervise certification activities; coordinate international cooperation activities and sign related agreements and protocols; the notification and construction related to certification and accreditation issues with the range of WTO/TBT and SPS
General administration of quality supervision, inspection and quarantine of the People's Republic of China	Draft laws, regulations and policies related to food safety and quality supervision, inspection and quarantine; construct and coordinating unified supervision and management of national food metrological work; review and issue the food quality and safety certifications and standardization
Ministry of agriculture	Draft and issue policies related to agriculture structure and development, including price change, financial credit, subsidies; coordinate with other countries and organizations
Ministry of water resources	Formulating policies, regulations, and developments strategies and plans of water conservation
Ministry of education	Extension activities
Ministry of finance	Draft policies to support agriculture; formulate the agricultural development plan; allocate and manage financial funds for agriculture; and allocate the poverty reduction funds
Ministry of health	Draft key health laws, regulations and policies; propose and guide the implementation of health development programs and strategic goals
Ministry of land and resources	Plan, manage and protect the rational utilization of natural resources, including land, mineral, and marine resources
National development and reform commission	Guide overall economic reforms; propose developments strategies; Recommend agricultural reforms; coordinate agency overseeing the implementation of agricultural and rural policies;
People's bank of China	Supervise the rural financial institution system
State administration for industry and commerce	Facilitate fair trade, protect consumer benefits, register business enterprise, including foreign-invested enterprises, supervise trade marks, and market regulations, etc
State food and drug administration	Comprehensive supervision on the food safety management of food, health food and cosmetic

Sources: The central people's Government of the People's Republic of China: http://english.gov.cn/.

Current laws and regulations related to plant quarantine

Over the past two decades, the Chinese government has launched a series of laws, relegations related to plant quarantine and inspection. Several governmental organizations are involved in planning these laws: General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ), Ministry of Agriculture (MOA), State Administration for Industry and Commerce (SAIC), Certification and Accreditation Administration of the People's Republic of China (CNCA), the State Environment Protection Administration (SEPA), and State Food and Drug Administration (SFDA) (World Bank, 2006). Table 3.3 and 3.4 lists the most relevant laws and regulations concerning SPS issues related to plant quarantine in China.

1) Agriculture law of the people's republic of China was adopted at the second meeting of the Standing Committee of the eighth National People's Congress on July 2, 1993 and amended at the thirty-first meeting of the Standing Committee of the Ninth National People's Congress on December 28, 2002. Agricultural law provides the general guidance and requirements in agricultural sector such as requirements for agricultural production, circulation and processing of agricultural products, grain safety, and development of rural economy, agricultural resources and protection of agricultural environment.

2) Entry and exit animals and plants quarantine law of the People's Republic of China was issued at the twenty-second meeting of the Standing Committee of the seventh National People's Congress on October 30, 1991. This law is formulated for the purpose of preventing invasive species from spreading into or out of the country, protecting the

production of agriculture, forestry, animal husbandry and fishery as well as human health, and promoting the development of foreign economic relations and trade. This entry and exist animals and plants quarantine law provides the requirements and procedures for entry, exit and transit quarantine and the quarantine of materials carried by passengers or by post, quarantine of means of transport.

3) Food hygiene law of the People's Republic of China was initially implemented on Revised July 1, 1983 and revised on Oct. 30, 1995. This law provides the general requirements for food hygiene, hygiene of food additives, containers, packaging, utensils and equipment, formulation of food hygiene standards and measures for food hygiene control, and food hygiene supervision.

4) Import and export commodity inspection law of the People's Republic of China was adopted at the sixth meeting of the Standing Committee of the Seventh National People's Congress on February 21, 1989, promulgated by Order No. 14 of the president of the People's Republic of China on February 21, 1989, and effective as of August 1, 1989. The import and export commodity inspection law provides the general inspection requirements, supervision and administration for import and export commodities.

5) Product quality law of the People's Republic of China was adopted at the 30th meeting of the Standing Committee of the Seventh National People's Congress on February 22, 1993, promulgated by Order No. 71 of the President of the People's Republic of China on February 22, 1993, and effective as of September 1, 1993. The product quality law

provides the supervision and control over product quality, liability and obligation of producers and sellers concerning product quality and compensation for damage.

The main regulations related to plant quarantine includes the regulations for the Implementation of the Law of the People's Republic of China on the Entry and Exit Animal and Plant Quarantine (1996), Regulations for the Implementation of the Law of the People's Republic of China on Import and Export Commodity Inspection, Regulation on Administration of Sanitary Registration for Export Food Manufactories, Administrative Regulations of the People's Republic of China on Pesticides, Table 3.4 gives more detailed list of these regulations. There are approximately 3000 food quality, hygiene, and safety standards currently in practice; about half of them are international standards (World Bank, 2006). In addition, more regulations are being developed by Chinese government to help promote the implementation of some standard monitoring system, like HACCP (Hazard Analysis and Critical Control Point) and GAP (Good Agricultural Practice) in China.

Table 3.3 Current laws related to plant quarantine

Year	Laws and regulations	Contents
Issued July, 2, 1993 and revised Dec. 28 2002	Agriculture law of the People's Republic of China	Agricultural production and operation; circulation and processing of agricultural products; grain safety; agricultural science and technology and education in agriculture
Issued Oct. 30, 1991 and implementation April. 1, 1992	Entry and Exit Animals and plants quarantine law of the people's republic of China	Entry quarantine, exit quarantine; transit quarantine; quarantine of materials carried by passengers or by post, quarantine of means of transport
Revised Oct. 30, 1995, trial implementation July 1, 1983	Food hygiene law of the people's republic of China	Food hygiene, hygiene of food additives, containers, packaging, utensils and equipment, formulation of food hygiene standards and measures for food hygiene control, and food hygiene supervision.
Revised Oct. 1, 2002, 1st implementation August 1, 1989, draft trial implementation 1984	Import and export commodity inspection law of the people's republic of China	Inspection requirements, supervision and administration for import and export commodities
Issued April 29, 2006	Product quality law of the people's republic of China	Supervision and control over product quality, liability and obligation of producers and sellers concerning product quality and compensation for damage

Source: Chinese government online source.

Table 3.4 Current regulations related to plant quarantine

Year	Regulations
Issued April 27, 1999 MOA ORDER No.20	Administrative regulations for implementation of pesticide
Issued November 29, 2001 Decree No. 326 Of the State Council Of the People's Republic Of China	Administrative regulations on pesticides
Issued March 27, 2002 AQSIQ Announcement No. 20	Administrative regulation of sanitary registration for food processing establishment for export
Issued March 19, 2002	Quality control guideline of analysis for residues
Implemented May 1, 2002 CNCA Announcement No.15, 2002	Regulation for administration of domestic manufacturers regarding food export registration in foreign countries
Implemented May 1, 2002 CNCA Announcement No.3 2002	Regulation on administration of HACCP management System Certification
Issued on December 2, 1996 Decree No. 206 Of the State Council Of the People's Republic Of China	Regulations for the implementation of the law on import and export commodity inspection
Issued August 10, 2005 Decree No. 447 Of the State Council Of the People's Republic Of China	Regulations for the implementation of the law on the entry and exit animal and plant quarantine

Source: Chinese government online source.

3.5 Summary

Chinese apples that enter the global horticultural market and domestic supermarkets are mainly supplied by highly coordinated supply chains. Even though the export market has a limited market share in terms of total production volume, there is huge potential for future development with the support of Chinese government and foreign partners. More support is needed for the development of coordinated supply chain in new emerging domestic market. Especially for small-scale farmers, which dominate the traditional fruit markets, there are huge obstacles to get involved with these supply chains except through contract farming. From both the governments and industries' point of view, a well-developed administrative system is needed to guide the development of horticultural market.

From a regulatory point of view, Chinese laws and regulations do exist for fruit safety and new laws/regulations are under development by Chinese regulators. While the overall law (like Agricultural law, Product quality law) might be enough to generally govern agriculture production, inspection and safety control when the apple growers are trying to export fresh apples to the U.S. or Canada, these laws/regulations seems not stringent enough to meet the high standards and phytosanitary requirements. Update on some of these laws/regulations or just adding some particular requirements for new emerging fruit market and export market are necessary.

From an administrative point of view, due to the complexity of government administrative system responsibilities between different agencies are somewhat overlapping and confusing. Overlapping is not only from horizontal relationship between different agencies, but also from vertical relationships among different levels (central government, province, city, or country) within a single agency. China and U.S. government agencies needs to improve in cooperation and provide clear transparent communication to reduce redundancy.

From the structural point of view, coexistence of three market forms and two supply chain organizations affect the effective and efficiency of phytosanitary control. China is experiencing transformation from traditional markets to new emerging supermarkets and export markets and from traditional supply chains to new coordinated supply chains. Establishment of centralized procurement system, tracking facilities, industry associations and certification services are key factors in developing the new supply chain system. Millions of small-scale farmers participating in traditional fruit markets should eventually be replaced by, or absorbed into, the new coordinated supply chains. At last, the effect of Chinese characteristic relationship "Guanxi" should be managed to improve the transparency and justice of food safety system.

CHAPTER FOUR:

A HYPOTHETICAL SYSTEMS APPROACH FOR CHINESE FRESH APPLES

In this chapter, a hypothetical systems approach for Chinese fresh apples is developed. Since there is currently a ban on fresh apple exports from China to the U.S, no official systems approach. Expectations, however, are that the ban will eventually be lifted and replaced with a less restrictive policy to govern invasive species risk. Any economic assessment method for such a policy will first need to determine which steps might be included. As the objective is analysis of the economic assessment process, this study will not determine the validity of risk reduction or pest exposure probabilities related to individual steps already in use for other like-policies, but rather draw on results-to-date that have been accepted within the political and scientific process. Therefore, to develop a hypothetical SA example, current pest risk management regulations and policies related to export of Chinese apples and similar fruit to other markets are being used as references.

4.1 Existing regulations

Criteria used to identify existing regulations as reference policies include: first, the selected regulations or protocols should be similar to the systems approach systematically and theoretically. Since the Systems Approach is based on the International Standards of Phytosanitary Measures (ISPMs) and recommended by the World Trade Organization, the references need to follow ISPMs or other similar alternative standards. Second, selected regulations or protocols should govern trade of Chinese fresh apples or similar fresh products, such as pears. Since no fresh apples are currently exported to the United States from China, it is reasonable to consider the regulations related to Chinese fresh pears within the reference. Chinese fresh pears are among the few fresh fruits that are currently exported from China into the United States. Therefore, there already exists a Systems Approach, under which Ya pear and Fragrant pear trade is regulated. Most of the Ya pears exported from China to the U.S. are from the same production region as fresh apples. Production conditions, weather conditions, government policies and domestic inspection procedures for apples and pears are quite similar. Regulations from other countries that currently import Chinese fresh apples and pears are also included as references. Canada, Australia and Argentina, whose horticultural markets are fairly similar to U.S., all import one or both of these products from China. The policies mentioned below are regarded as references for a hypothetical SA for Chinese fresh apples.

a) Regulation for U.S. import of Chinese Ya pears and Fragrant pears

China is the world's leading pear producing country. Ya pear[15] is the most popular variety grown in China, accounting for about 30 percent of production. The only two pear varieties that can currently be exported to the U.S. are Ya pears from Hebei and Shandong provinces, and Fragrant pears from Xinjing Province. Chinese plant quarantine officials began negotiating the opening of U.S. markets to these pear varieties in the early 1990s (Table 4.1). In 1995 Ya pear imports from only the province of Hebei were approved under a systems approach for pest risk mitigation and trade began in 1997. In early 2001, there was one report of a new species of *Alternaria* sp., *A. yaliinficiens* R.G. Roberts,[16] in Ya pears

[15] "Ya" means duck in Mandarin dialect of Chinese.

[16] The disease *Alternaria sp.* is commonly found in outdoor air, on many kinds of plants and foodstuffs and prefers rotting farmland manure. The main symptom is small, round, black spots on leaves, shoots, and the surface of the fruit (Roberts, 2005). The disease poses a significant risk to the U.S. apple and pear industry but does not affect human health (USDA/APHIS, 2003b).

exported from Hebei Province. In March 2001, the U.S. banned imports of Ya pear from China. In 2002, a technical team from USDA/APHIS visited Ya pear production orchards in both Hebei and Shandong Provinces. During the visit, the delegation assessed post-harvest mitigation measures associated with black spot in the two production areas. After agreeing on the post-harvest mitigation measures, the resumption of the Hebei Ya pear export program from Hebei and the initiation of a new Ya pear export program from Shandong Province were approved in October 2002 under a bilateral agreement, The 2002/2003 Work Plan of Plant Quarantine of Chinese Ya Pears to the U.S. In November, over 2,000 tons of Ya pears grown in Hebei province of China were exported to the U.S. via Tianjin port. On June 9, 2003 USDA/APHIS removed the cold treatment requirement for Ya pears from Hebei Province after receiving data indicating that no Oriental fruit fly had been found there since 1997 (Table 4.1).

On December 9, 2003, during the period of China premier Wen Jiabao visiting U.S., China AQSIQ and the USDA signed The 2003/2004 Work Plan of Plant Quarantine of Chinese Ya Pears to the U.S. Less than one month later, on December 19, 2003, USDA/APHIS prohibited indefinitely the import, sale and distribution of Ya pears from China upon detection of serious fungal disease infestation. The USDA Agricultural Resource Service Tree Fruit Research Laboratory in cooperation with PPQ's (Plant Protection and Quarantine) National Identification Services determined that the 2001-2003 detection of the previously undefined *Alternaria* sp. that causes Ya pear fungal infection was a new pathogenic species not present in the United States. After two years negotiation, in April 2005, China and the U.S. signed The 2005/2006 Work Plan of Plant Quarantine of Chinese

Ya Pear Export to the U.S. According to the work plan, a USDA delegation would visit China to investigate the disease *Alternaria* sp. During the visit in September 2005, the USDA/APHIS delegation found disease symptoms in eight orchards in China and the U.S. continued to prohibit imports. In late 2005, during the Fourteenth China-U.S. Bilateral Meeting on Plant Quarantine in the U.S., China and the U.S. signed supplemental provisions to The 2005/2006 Work Plan of Plant Quarantine of Chinese Ya Pear Export to the U.S., which indicated that the U.S. might open the market again with stricter phytosanitary requirements. In February 2006, the U.S. finally reopened the market to Chinese Ya pears.

Another variety of pear allowed to enter the U.S. market is Fragrant pears from Korla area in Xinjiang province. Early in 1993, China began negotiating the opening of the U.S. market to Chinese Fragrant pears and kept providing materials and data to show that it had low risk of introducing invasive species. In 1994, the Plant Protection and Quarantine (PPQ) of the U.S. Department of Agriculture conducted a pest risk assessment for Chinese Fragrant pears. During bilateral meetings in 1997 and 1998, China further requested the opening of U.S. market and USDA/APHIS required evidence that there were no pests other than those listed in the original 1994 assessment. In late August 1999, a U.S. delegation visited Xinjiang province of China and in 2001 finished a trip report entitled Program Analysis: Pest Risk of the Export of Fragrant Pears from the Production Areas of Korla, China to the U.S. In December 2005, after almost thirteen years negotiation, China and the U.S. signed the Work Plan of Plant Quarantine of Chinese Fragrant Pears to the U.S. In

August 2006, a USDA delegation again visited the orchards and packinghouses in Xinjiang province and finally approved Fragrant pears for entry to the U.S. market.

Table 4.1 Summary of the export of Chinese Ya Pears and Fragrant pears to the U.S.

Variety	Date	Event
Fragrant pears	1993	China started negotiating the opening of U.S. market
	1994	USDA/PPQ conducted a PRA for Chinese Fragrant pears
	August 1999	USDA delegation visit Xinjiang province of China
	December 2005	China and the U.S. singed the "Work Plan of Plant Quarantine of Chinese Fragrant Pears to the U.S."
	August 2006	USDA delegation visited the Xinjiang province in China and finally approved the export of Fragrant pears into the U.S.
Ya pears	Early 1990s	China initiates request for export of Ya pears to the United States
	1995	Under a SA, export of Ya pears from Hebei Province to U.S. was approved
	1997	Ya pears from Hebei province in China was imported and came into U.S. market
	March 2001	U.S. banned further imports due to the disease *Alternaria* sp.
	May and September 2002	USDA/APHIS delegation visited Hebei and Shandong Provinces in China
	October 2002	China and the U.S. sign the "2002& 2003 Work Plan of Plant Quarantine of Chinese Ya Pear Export to the U.S." Export of Ya pears from Shandong province to the U.S. approved.
	November 2002	Ya pear imports from Hebei province was resumed
	June 2003	USDA removed the cold treatment requirement for Ya pears from the Hebei province; Ya pears from the Shandong province should be undergo cold treatment
	December 19 2003	USDA suspended indefinitely the import, sale and distribution of Ya pears from China
	April 2005	China and the U.S. singed " The 2005/2006 Work Plan of Plant Quarantine of Chinese Ya Pear Export to the U.S. "
	September 2005	USDA delegation found symptoms of *Alternaria* sp. and the U.S. continued to ban the importation
	Late 2005	China and the U.S. signed the supplemental provisions during the "Fourteenth China-U.S. Bilateral Meeting on Plant Quarantine" in the U.S.
	February 2006	The U.S. reopened the market to Chinese Ya pears

Based on the discussion above, following U.S. regulations related to Chinese Ya pears and Fragrant pears among our references are included (Table 4.2): 1) Decision on Entry Status of Fruits and Vegetables, Under Quarantine No.56: Ya Pears (Pyrus bretscheideri) and Sand Pears (Pyrus pyrifolia), Peoples Republic of China (USDA/APHIS, 1994). 2) Importation of Fragrant and Ya Pear Fruit from China into the United States-A Supplemental Pest Risk Assessment (Cave and Lightfield, 1997). This pest risk assessment, conducted by USDA/APHIS/PPQ, supplements the September 1994 assessment. The pest risk assessment provides the qualitative results of pest risk in terms of high, medium and low for Chinese Fragrant pears and Ya pears and also provides the pest risk potential, economic importance and likelihood of introduction and the necessity of phytosanitary measures. 3) Removal of Cold Treatment Requirement for Ya Pears Imported from Hebei Province in China (USDA/APHIS, 2003a). This regulation explains the reasons why USDA removed the cold treatment requirement. Since 1997, the export of Chinese Ya pears from Hebei and Shandong provinces should be cold treated in-transit to prevent the introducing of oriental fruit fly. Based on the information and data provided by Chinese government, the U.S. was convinced that the oriental fruit fly was not present in Hebei province. But cold treatment was still required for Ya pears from Shandong province. 4) Information Memo for the Record (Podleckis and Usnick, 2005). This memo reviews the history of negotiation for export of Fragrant pears into the U.S., the 1994, 1997 and 2001 pest risk assessments, and also provides detailed analysis of seventeen pests of concern for Fragrant pears. 5) Administrative instructions: Conditions governing the entry of Ya variety pears from China (USDA/APHIS, 2005a). This regulation provides the phytosanitary requirements under which Chinese Ya pears can enter the U.S. 6)

Importation of Fragrant Pears from China (USDA/APHIS, 2005b). This the final rule of regulating the imports of Chinese Fragrant pears into the U.S.

Table 4.2 List of references for a hypothetical systems approach

County	Year	Policy
United States	1994	Decision on Entry Status of Fruits and Vegetables, Under Quarantine No.56: Ya Pears (Pyrus bretscheideri) and Sand Pears (Pyrus pyrifolia), Peoples Republic of China (USDA/APHIS, 1994).
	1997	Importation of Fragrant and Ya pear fruit from China into the United States- a supplemental pest risk assessment (Cave and Lightfield, 1997).
	2003	Removal of cold treatment requirement for Ya pears imported from Hebei province in China (USDA/APHIS, 2003a).
	2005	Information memo for the record (Podleckis and Usnick, 2005).
	2005	Administrative instructions: conditions governing the entry of Ya variety pears from China (USDA/APHIS, 2005a).
	2005	Importation of Fragrant Pears From China (USDA/APHIS, 2005b).
Australia	1998	Final import risk analysis of the importation of fruit of Ya pears (*Pyrus bretschneideri* Redh.) from the people's republic of China (Hebei and Shandong provinces) (AQIS, 1998).
	2003	Import of Asian ('Shandong') pear (*Pyrus pyrifolia* (Burm.) Nakai and *P. ussuriensis var. viridis* T. Lee) fruit from Shandong province in the people's republic of China (Biosecurity Australia, 2003).
	2005	Draft extension of existing policy for pears from The people's republic of China (Biosecurity Australia, 2005a)
	2005	Final extension of policy for the importation of pears from the people's republic of China (Biosecurity Australia, 2005b).
Canada	2007	Plant protection import requirements for fresh apples (Malus spp.) from the people's republic of China (CFIA, 2007a).
	2007	Interim Policy for plant protection import requirements for fresh pears from china (CFIA, 2007b).
Argentina	2004	Protocol of phytosanitary requirements for the apple and pear fruits export from China to Argentina between the secretariat of agricultural, livestock, fisheries and food of the Argentine republic and the general administration of quality supervision, inspection, and quarantine of the people's republic of China (SENASA, 2005).

b) Regulation for Australia imports of Chinese pears and apples

The Australia receive an application from China in April 1992 seeking market access for Ya pears from Heibei and Shandong provinces and in 1999, Australia finished a final Import Risk Analysis (IRA) on Ya pears from these two provinces. Australia began the import of Chinese Ya pears from Hebei province in 1999 and from Shandong province in October 2000 under the requirements listed in this IRA. In January 2003, Biosecurity Australia completed a review of all existing import conditions for pome fruit imports from North Asia into Australia. Based on this review, Australia removed the requirement for petal testing to detect brown rot and black spot, and flower cluster examination at blossoming for scab on Ya pears from China.

In March 2001, during the China-Australia bilateral plant quarantine technical discussion in Beijing, China requested additional market access for Sand pears from Shandong province. After getting additional information from AQSIQ and a site visit to Shandong province by pathologists from Biosecurity Australia, the trade of Sand pears from Shandong province was regulated as an extension of existing policy for Ya pears. Therefore, the trade of Sand pears from Shandong province began in October 2003. China requested consideration for export of Sands pears and Ya pears from Shaanxi province, Sand pears from Hebei province, and Fragrant pear from Xinjiang province during the period between March 2001 and May 2004. In late July 2005, a plant pathologist from Biosecurity Australia visited pear production areas in Xinjiang Uighur Autonomous Region and Shaanxi province. In October 2005, Biosecurity Australia completed the final version of the draft extension for pears from China.

Australia currently permits the import of Ya pears from Hebei and Shandong Provinces, and Asian (Shandong) pears and Sand pears from Shandong Province. Pear exports from China have increased considerably in recent years and are becoming a larger share of Chinese production. The following Australian regulations related to Chinese pears are included as our reference (Table 4.2): 1) Final Import Risk Analysis of the Importation of Fruit of Ya Pears (*Pyrus bretschneideri* Redh.) from the People's Republic of China (Hebei and Shandong Provinces) (AQIS, 1998); 2) Import of Asian ('Shandong') pear (*Pyrus pyrifolia* (Burm.) Nakai and *P. ussuriensis var. viridis* T. Lee) fruit from Shandong province in the people's republic of China (Biosecurity Australia, 2003); 3) Draft Extension of Existing Policy for Pears from the People's Republic of China (Biosecurity Australia, 2005a); 4) Final Extension of Policy for the Import of Pears from the People's Republic of China (Biosecurity Australia, 2005b). Pest risk assessments for the import of Ya pears from Shaanxi province, Sand pears from Hebei and Shaanxi province and Fragrant pears from Xinjiang Unghur Autonomous region are still on-going by Biosecurity Australia.

c) Regulation for Canada import of Chinese apples and pears

Canada started importing Chinese Ya pears in late 2002. After the U.S. banned Chinese Ya pears due to the disease *Alternaria* sp., the Canadian Food Inspection Agency (CFIA) suspended Ya and Asian pear imports from Hebei and Shandong provinces of China respectively on January 28 and February 17, 2004 because of the same disease. In early September 2004, a CFIA delegation visited China to exchange scientific information and concluded that the import of Asian pears has a low risk for entry of the disease *Alternaria sp.* and thus removed the suspension. As for Ya pears, AQSIQ developed a Quality Management System (QMS) in September, 2005 which required auditing by CFIA. The import of Ya pears from Shandong Province was resumed as part of a one-year trial period beginning December 1, 2005. In March 2006, another audit was conducted. Beginning March 27, 2006, CFIA also lifted the ban on Ya pears from Hebei province for a one-year trial period which ends March 26, 2007. As similar, the trial period for Asian pears from both Hebei and Shandong ends January 15, 2007. Both of the trial periods were successful and the trades continued.

In November 2004, fresh apple exports from Shaanxi province were approved to enter to Canada under a two-year trial period, which ended October 2006. This trial period was considered a success and the import will continue. Apple exports from Shandong province were allowed during a shorter one-year trial period, which successfully ended October 2005 and trade continues.

Based on the discussion above, two Canadian regulations related to Chinese pear and apple exports are used as our references (Table 4.2): the Plant Protection Import Requirements for Fresh Apples (*Malus spp.*) from the People's Republic of China (CFIA, 2007a) and the Interim Policy for Plant Protection Import Requirements for Fresh Pears from China (CFIA, 2007b).

Table 4.3 Summary of the export of fresh Chinese apple and pear exports to Canada

Variety	Date	Event
Apple (*Malus* spp.)	November 2004	Apples from Shaanxi provinces was allowed during two-year trial period which ended in October 2006; Apples from Shandong province was allowed during one year's trial period which ended in October 2005
	October 21, 2006	The trial period for the importation of fresh apples from Shaanxi province; The importation continues.
Asian Pear or Nashi Pear (*Pyrus pyrifolia)*	January 28 2004	CFIA banned the importation of Asian pears from Hebei province of China due to *Alternaria* sp.
	February 17 2004	CFIA banned the importation of Asian pears from Shandong province of China due to *Alternaria* sp.
	Early September 2004	CFIA removed the suspension on Asian pears; The importation was approved both from Hebei and Shandong provinces during the trial period which successfully ends January 15, 2007. Trade continues.
Fragrant Pear *(Pyrus* sp. nr. *communis)*	2000	The xportation of Fragrant pears were approved
Ya pears (*Pyrus bretschnei*)	Late 2002	Canada started importing Chinese Ya pears
	January 28 2004	CFIA banned the importation of Ya pears from Hebei province of China due to *Alternaria* sp.
	February 17 2004	CFIA banned the importation of Ya pears from Shandong province of China due to *Alternaria* sp.
	September 2005	CFIA conducted the first audit on Quality Management System (QMS)
	December 1 2005	The importation of ya pears from Shandong Province was resumed under a one year trial period which ends December 1, 2006; Ya pears from Hebei province were still prohibited entry into Canada
	March 27 2006	CFIA conducted the second audit and lifted the ban on importation of Ya pears from Hebei province with all the shipments inspected during one year trial period which ends March 27, 2007. Trade continues.

d) Regulation for Argentina imports of Chinese apples

Argentina began importing Chinese fresh apples in November 2004. There is only one protocol governing apple and pear trade between China and Argentina: Protocol of phytosanitary requirements for the apple and pear fruits export from China to Argentina between the secretariat of agricultural, livestock, fisheries and food of the Argentine republic and the general administration of quality supervision, inspection, and quarantine of the people's republic of China (SENASA, 2005). This protocol lists thirteen required steps throughout production, storage, packing, and shipment for Chinese apples exported to Argentina. This protocol includes 12 pests of concern for the exportation of Chinese pears and apples into Argentina.

4.2 Hypothetical systems approach for Chinese fresh apples

According to International Standards for Phytosanitary Measures NO.14 (FAO/IPPC, 2002), as a pest risk management policy the SA should be based on conclusions drawn from a pest risk assessment. One of the most important results from these assessments is a list of pests of concern associated with the traded commodity. Depending on assessments of pest risk and economic consequence, the trading country decides whether or not to undertake pest risk management and the strength of measures to use (FAO/IPPC, 2002). Therefore, a hypothetical list of pests of concern will be drawn which are associated with potential fresh apple trade between the U.S and China through comparison of the reference policies. It is reasonable to include pests that are identified as pests of concern in most of these policies. In addition, some (but not all) polices provide more detailed pest risk assessment results, rating risk for specific pests, most of which are expressed qualitatively in terms of "low", "medium" or "high". In addition, those pests rated "high" by at least one of these policies are also included in the list.

After pests of concern are selected, a list of n phytosanitary measures will be identified which are used in the reference policies for Chinese apples and pears.[17] These n measures are mentioned by at least one of the policies. According to the standard Systems Approach, these n measures can be divided into four periods: pre-harvest, harvest, post-harvest, and shipping and distribution. In addition, how these measures are mentioned by each policy is discussed. A subset m of the n $(m < n)$ common measures which are mentioned more than once is also identified.

4.2.1 A potential pests of concern

According to the procedure and criteria of pest risk analysis (PRA), a long list of quarantine pests[18] is first identified by the importing country in the early stage of PRA process. The importing country will often request evidence from the exporting country to show that the quarantine pests do not pose risks associated with the traded commodities. Often a delegation from the importing country will visit the exporting country to collect corresponding information. Based on additional information and evidence, a shorter list of pests of concern will be obtained. Table 4.4 is a summary of the number and type of pests

[17] As mentioned before, as our objective here is the economic assessment process, we will not attempt to determine the validity of risk reduction or pest exposure related to individual steps already in use for other like-policies, but rather drawing on these scientific results-to-date that have been accepted within the political process.

[18] Quarantine pest is defied by FAO as "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially (FAO/IPPC, 2004).

of concern identified by policies listed in Table 4.3. Pests can be divided into arthropods and pathogens. Arthropods include acari (mites), coleoptera (beetles, weevils), diptera (flies), hemiptera (aphids, leafhoppers, mealybugs, psyllids, scales, true bugs, and whiteflies), hymenoptera (ants, wasps) and Lepidoptera (moths, butterflies). Pathogens normally include fungi and bacteria (Biosecurity Australia, 2005a).

Table 4.4 Summary of pests listed in the reference policies

Country	Policy	Quarantine Pests and Pests of Concern
U.S	USDA/APHIS, 1994	64 quarantine pests; 13 evaluated as pests of concern
	Cave and Lightfield, 1997	560 quarantine pests: 280 pests of *Pyrus,* 53 pathogens, 227 arthropods; 13 evaluated as pests of concern
	Podleckis and Usnick, 2005	17 pests of concern
Australia (Pears)	Biosecurity Australia, 2003	40 pests of concern; 32 arthropods, 1 bacteria and 7 fungi
	Biosecurity Australia, 2005b	39 pests of concern; 31 arthropods (1 acari, 5 coleoptera, 1 diptera, 8 hemiptera, 2 hymenoptera and 14 lepidoptera) and 8 pathogens (fungi)
Canada (Apples)	CFIA, 2007a	10 pests of concern (6 insects, 1 mite and 3 fungi)
Canada (Pears)	CFIA, 2007b	12 pests of concern
Argentina (Apples, Pears)	SENASA, 2005	12 pests of concern

Source: Policies and regulations in 4.2.

Appendix 1 provides more detailed information about the pests of concern listed in these policies. The 2005 Memo for Fragrant Pears (Podleckis and Usnick, 2005) shows detailed pests of concern for the import of Chinese Ya, Sand,[19] and Fragrant pears into the U.S. and summarizes previous PRA results. It also provides the latest pest risk assessment results for Fragrant pears. For similar reasons, the Australia Final Extension of Policy for Chinese pears (Biosecurity Australia, 2005b) is included as the reference for the import of Chinese pears into Australia.

There are totally 56 distinct pests mentioned in these five policies. Among these 56 pests, only one "Peach Fruit Moth" is common to all five policies; four pests are common to four of the five polices; five pests are common to three of the five policies, nine pests common to two polices, and thirty-seven additional pests are mentioned by only one of the five polices.

Some (but not all) of the policies also provide more detailed pest risk results (Table 4.5). The U.S. policies (Cave and Lightfield, 1997 and Podleckis and Usnick, 2005) and Australian policies (AQIS, 1998 and Biosecurity Australia, 2005b) provide qualitative pest risk ratings in terms of low, medium or high risk. In the U.S. 1997 decision sheet, the pest risk rating is a combination of the consequences and likelihood of introductions.[20] Each of these factors is evaluated in terms of low, medium or high and then a final pest risk potential is obtained. Among thirteen pests of concern listed in the 1997 decision sheet,

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[19] The export of Sand pears to the U.S. has not yet been approved.

[20] The consequenced introduction, also the economic importance, is evaluated again climate host, host range, dispersal, economic and environmental factors. The likelihood of introduction is rated relative to the combination of the likelihood of surviving postharvest treatment, likelihood of surviving shipment, likelihood of not being detected at port of entry, likelihood of moving to suitable habitat and likelihood of finding suitable hosts. More detailed information about methodology and rating criteria can be found in "Guidelines for Pathway-Initiated Pest Risk Assessments" (USDA, 2000).

eleven pests were rated as "high' and two were rated as "medium" (Cave and Lightfield, 1997). Similar to the U.S. pest risk assessment, in the final extension of original policy for Chinese pears by Australia (Biosecurity Australia, 2005b), the unrestricted risk is a combination of the probability of entry (import, distribution), establishment and spread, and the consequence. This 2005 Australian policy provides a list of thirty-nine pest of concern, but only provides detailed pest risk rating for three pests (Janpanese pear weevil, chocolate sport of Ya Li pear, and European pear rust with risk rating of "very low", "very low" and "low" respectively).

Table 4.5 Potential pests of concern for Chinese fresh apples

	Pest (Scientific Name)	Pest (Common Name)	Risk Potential*
Mentioned by all 5 reference policies	*Carposina sasakii(=niponensis)*	Peach Fruit Moth	High
Mentioned by 4 of 5 reference policies	*Conogethes(Dichocrocis) Punctiferalis*	Yellow Peach Moth	High
	Monilinia fructigena	Brown Rot	High
	Leucoptera malifoliella (=scitella)	Pear Leaf Blister Moth	N/A**
	Tetranychus viennensis	Hawthorn Spider Mite	High
Mentioned by 3 of 5 reference polices	*Adoxophyes orana*	Summer Fruit Tortrix (Fis1her)	N/A
	Alternaria gaisen(=kikuchiana)	Black Spot (Nagano) of Japanese Pear	High
	Bactrocero Dorsalis (Hendel)	Oriental Fruit Fly	High
	Cydia inopinata (Heinrich)	Manchurian Codling Moth	High
	Gymnosporangium asiaticum	Japanese Pear Rust	N/A

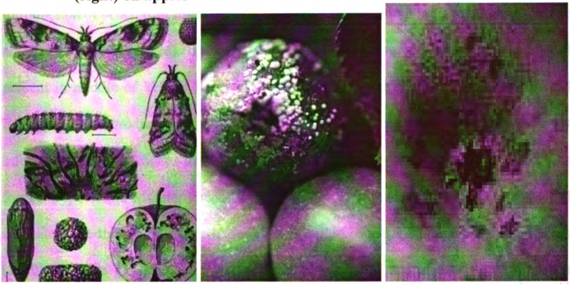
Table 4.5 Potential pests of concern for Chinese fresh apples (continued)

	Pest (Scientific Name)	Pest (Common Name)	Risk Potential*
Other pests rated as "high" by at least one of the reference policies	*Cydia funebrana (Treitschke)*		High
	Rhynchites foveipennis (Fairm)	Korean Pear Weevil/Curculio	High
	Rhynchites heros (Roel)	Japanese Pear Weevil	High
	Tetranychus kanzawai (Kishida)		High

Note:
*The pest potential is taken from the U.S. 1997 Decision sheet (Cave and Lightfield, 1997), which was the supplemental pest risk assessment for Chinese Ya and Fragrant pears. 13 pests were evaluated in the pest risk assessment and eleven of them were listed in table 4.5. The other two pests are: *Numonia pirivorella* (Medium) and Pear rusty Skin viroid (medium).
** N/A means the pest rating is not mentioned by any of our reference policies.

Among the fourteen pests/diseases in table 4.5, some particular ones are worth for further analysis. All five reference polices mentioned Peach Fruit Moth and it is rated as high risk by USDA, so peach fruit moth is included. For Brown Rot, it is the only fungi (pathogens) among all pest mentioned by four policies and it is also rated as high. Hawthorn Spider Mite is also selected since it is the only Acari (mite) among the pests mentioned by four policies.

Figure 4.1: Peach fruit moth (left), Brown rot (middle) and Hawthorn spider mite (right) on apples



Source: Peach fruit moth: http://www.invasive.org; Brown rot: http://www.dkimages.com; Hawthorn spider mite: http://www.inspection.gc.ca.

Peach Fruit Moth

Peach Fruit moth (*Carposina sasaki or niponensis)* is mentioned by all five reference polices and rated by USDA as high risk. Hosts are apples, peaches and pears, apricots, hawthorns, plums, quinces and *Ziziphus mauritiana*[21].The moths are mainly distributed in Asia (China, Korea and Japan) and North America (Canada). The larvae tunnel all parts of fruit, feeding on the fleshy parts and on the seeds. Several larvae may feed in each fruit. Larvae can survive for long periods in stored fruits, so imported fruits are the most likely means of entry (EPPO/CABI, 1996). USDA inspectors find the moth almost every year on raw fruit from Japan and Korea. In China, peach fruit moth may cause heavy losses if it is not under control and has been recorded as destroying about one-third of the apple crop in Liaoning province (Hwang, 1958). International dispersal by flight is extremely unlikely

[21] *Ziziphus mauritiana* is a tropical fruit tree species and its common name is Chinese apple or Indian jujube.

since the moth normally flies only short distance (Sun, *et al.*, 1987). In Europe, the introduction of peach fruit moth could have a severe economic impact on the fruit-growing areas (EPPO/CABI, 1996). In China, the infestation rate ranges from 10 percent to 30 percent in middle of Yellow River old riverway and Northwest Yellow Plateau area. In Bohai bay apple production area, which has relatively higher management technology, the infestation rate is as low as three percent. According to the datasheet on quarantine pests from European and Mediterranean Plant Protection Organization (EPPO), Hwang (1958) estimated one-third production losses of the apple crop in Liaoning province. Sytenko (1960), Pavlova (1970), and Gibanov and Sanin (1971) estimated 40 to 100 percent damage for apples in Russia. Sun, *et al.* (1987) state that the moth can be controlled by applying fenitrothion, parathion, fenvalerate or deltamethrin at the oviposition peaks of the first and second generations, in combination with the mechanical removal of fallen fruit (EPPO/CABI, 1996). To control the moth, Ishiguri and Shirai (2004) claim that a period of cold storage two month before export is sufficient for the apples from Japan, but harvesting in an earlier season or a shorter period of cold treatment may increase the risk of accidentally shipping apples that contain live larvae. USDA/APHIS requires that apples from both Japan and the Republic of Korea must be cold treated and then fumigated for the peach fruit moth (USDA/APHIS, 2007b).

Brown rot

Brown rot *(Monilinia fructigena)* is mentioned by four of five reference polices and rated as high risk by USDA. This species is one of three *Monilinia* fungal species responsible for brown rot, although it is a minor disease of apples and other pome fruits compared with other apple diseases. The main hosts are apples, pears, plums, and cherries. Brown rot exists and has been identified in most parts of Europe, the former Soviet Union, the middle and far east, India and North Africa, parts of the U.S. and some provinces in China. If a ripe fruit is infested, the first symptoms are small, superficial, circular brown spots that quickly turn to rotting and then the entire fruit is decayed. Diseased fruit tend to remain attached to the tree. Mummified fruit hang on branches of trees until spring or, alternatively fall to the ground where they remain throughout the winter months, partly or completely buried beneath the soil or leaf litter. Brown rot on ripening or mature fruit typically develops as a rapidly spreading, firm, brown decay. The spore can be transported by wind, rain, or insects to young fruit. Infection can take places at any stage during fruit development but only in those fruits approaching the ripening stage is the disease more severe (Podleckis and Usnick, 2005).

Brown rot can cause considerable economic losses worldwide. In Europe, brown rot causes serious losses of apples, pears and plums, particularly in hot summers. In general, fruit losses resulting from infection can range from 5 up to 35 percent (Mackie, 2000). During the pre-harvest period, Holb (2004) estimated average yield losses from the fungi of 27.2 percent in 2001 and 41.6 percent in 2002. During the post-harvest period, Berrie (1989) estimated the mean losses in cultivar Cox's Orange Pippin[22] ranged from 0.1 percent to 0.6 percent during the period 1982-1988. Literature reports that an average of about nine percent of apple fruit become infected with brown rot in a study over three consecutive seasons (Leeuwen, *et al.*, 2000). Brown rot is controlled through low

[22] Cox's Orange Pippin is a cultivar of apple, which accounts for over 50% of the UK area of dessert apples (Wikipedia, 2007).

temperatures, more readily in incipient and very early stages than after the disease becomes well established in the fruits. Practical control after harvest can be accomplished by prompt storage and rapid cooling to the desired temperature (Pierson, *et al.*, 1971).

Hawthorn Spider Mite

Hawthorn spider mite (Tetranychus viennensis) is mentioned by four reference polices. It was reliably identified by Batra in a single collection from Maryland in 1979. The main hosts are fruit trees of the family Rosaceae, like hawthorn, quince, apple, blackthorn, cherry, peach, plum, pear, and flowering quince. Hawthorn spider mite is found mainly on the leaves and stems of host plants, especially during the flowering, seeding, and vegetative growing stages (Podleckis and Usnick, 2005). It is spread mainly in Europe and Asia, like Japan and China. Injured leaves turn yellow with the underside colonized by mites and covered with webs. The number of males in a population is 3-5 times less than that of females. In the middle of the 20th century, excessive use of pesticides stimulated outbreaks of hawthorn spider mite. These were mainly connected to the elimination of entomophages in gardens and to the capability of mites to develop resistance against pesticides. Trunks and branches of fruit trees are densely covered by webs after mass propagation of mites. Strongly infested trees are defoliated and bud formation is decreased the next year. Literature reports that longevity and fecundity of hawthorn spider mite depend on ecological conditions such as temperature and host plants (Kasap, 2003). Climate conditions, especially temperature, are critical abiotic factors influencing the dynamic of the spider mite and their natural enemies. The mite is windborne and may be carried accidently by large insects, birds, and even humans on their clothing (Podleckis and

Usnick, 2005). Yield has been reported reduced by 30 to 50 percent (Wang, 2006). Biological control agents can be applied to control the mite. Acaricide treatment can be used in spring after mass appearance of the mites with an average air temperature of 10°C. Mechanical control in the packing house is also an option, the Canadian SA policy required air brushing of each fruit before packing for export.

Table 4.6: Summary of some quarantine pests

Pest name	Category	Contents
Peach Fruit moth *(Carposina sasakii(=niponensis)*	Hosts	Apples, peaches, pears; Apricots, hawthorn., plums, quinces and *Ziziphus mauritiana* are also noted as hosts.
	Geographic Distribution	Asia (Northeast part of China, Korea Democratic People's Republic, Korea Republic, Russia) and North America (Shutova, 1970); China: Fujian, Guangdong, Hebei, Heilongjiang, Henan, Jiangsu, Jilin, Liaoning, Shaanxi, Ningxia, Shandong and Zhejiang provinces (Podleckis and Usnick, 2005).
	Detection and Identification	The larvae tunnel all parts of the fruit, feeding on the fleshy parts and on the seeds. Several larvae may feed in each fruit. Infested apples exude a sticky gum, pears turn yellow and apricots ripen unevenly.
	Mitigation measures	Fenitrothion, parathion, fenvalerate or deltamethrin (Sun, *et al.*, 1987); cold storage during shipment (Ishiguri and Shirai, 2004); Fumigation: 23g/m^3 methyl bromide for 4 h at > 15^{0}C for overwinter caterpillars, with slightly lower doses (17-20 g/ m^3) for caterpillars of the summer generation (EPPO/CABI, 1996).
	Production loss	One third of production loss in China (Hwang, 1958); 40%-100% damage for apples in Russia (Sytenko, 1960; Pavlova, 1970; Gibanov & Sanin, 1971).

Table 4.6: Summary of some quarantine pests (Continued)

Pest name	Category	Contents
Brown Rot (*Monilinia fructigena* Honey)	Hosts	Apples, pears, plums, peach, nectarine, apricot, quince and cherries (Mackie, *et al.*, 2000).
	Geographic Distribution	Widely spread in Europe; the former Soviet Union; the middle and far east, India and north Africa; U.S: Florida and Maryland (Mackie, *et al.*, 2000); China: Gansu, Hebei, Heilongjiang, Henan, Jiangsu, Liaoning, Ningxia, Shandong, Shanxi, Sichuan, Taiwan, Yunnan, and Zhejiang provinces (Podleckis and Usnick, 2005).
	Detection and Identification	Brown rot develops rapidly through wounds on apples at nonrefrigerated temperatures. Enlarged rots are soft but not mushy (Pierson, *et al.*, 1971).
	Mitigation measures	Prompt cold storage after harvest (Pierson, *et al.*, 1971).
	Production loss	
	Total	Fruit losses: 5%-35% in general (Mackie, *et al.*, 2000); 9% of apple fruits become infected with brown rot (Leeuwen, *et al.*, 2000);
	Pre-harvest	Yield loss not exceed 5% in the pre-harvest stage in 1997 and 1998; Pre-harvest yield loss on average 27.2% in 2001 and 41.6 in 2002 by fruit harvest (Holb, 2004).
	Post-harvest	Mean post harvest losses: 0.1%-0.6% between 1982 and1988 (Berrie, 1989);
Hawthorn Spider Mite *(Tetranychus viennensis)*	Hosts	Fruit trees of the family Rosaceae, like hawthorn, quince, apple, blackthorn, cherry, peach, plum, apricot, pear, flowering quince, raspberry and mountain ash (Li, *et al.*, 2006).
	Geographic Distribution	England, France, Germany, Austria, Bulgaria, Northern India, Korea, Japan and China (Afonin, *et al.*, 2006); China: Anhui, Gansu, Henan, Jiangsu, Liaoning, Ningxia, Shandong, and Xinjiang provinces (Podleckis and Usnick, 2005).
	Detection and Identification	Feeds mainly on leaves and on flowers of fruit trees. It also feeds on the surface of developing fruits and may foul them with its webbing.
	Mitigation measures	Biological control agents; acaricide treatment in spring after mass appearance of the mites with an average air temperature of 10°C.
	Production loss	Yield of apples is reduced by 30%-50% (Wang, *et al.*, 2006); Yield of plum is reduced 2-3 times (Afonin, *et al.*, 2006).

4.2.2 Hypothetical systems approach measures

Pest risk assessment conclusions are used to decide whether risk management is required and the strength of measures to be used (FAO/IPPC, 2004). Pests rated with low risk potential may require only port of entry inspection to maintain phytosanitary security. However, pests with medium to high risk potentials may require more stringent phytosanitary measures (Cave and Lightfield, 1997). Reference policies provide corresponding (phytosanitary) requirements for the import of Chinese fresh apples and/or pears. A hypothetical SA for Chinese fresh apples is developed based on these policies and the standard form of systems approach developed by USDA/APHIS.[23] What to be mentioned here is individual treatment of pests is unnecessary as most management operations are applicable to a broad range of pests (AQIS, 1999). The mitigation measures included in a SA can be broadly classified into four categories: exclusion of a pathogen, detection of a pathogen, elimination of detected pathogen population, or risk reduction of establishment in the importing region. Measures in any of the categories can be applied at four time periods during the agricultural production sequence: pre-harvest, harvest, post-harvest and shipping and distribution (USDA/APHIS/PPQ, 2002). Simplified and summarized descriptions for each measure mentioned by reference polices are shown in appendix 1.1 to 1.4.

[23] The standard Systems Approach (also in the first column through Appendix A.2.1 to A.2.4) is from page 15-16 in "Preventing the Introduction of Plant Pathogen into the United States: The Role and Application of the "Systems Approach" (USDA/APHIS/PPQ, 2002).

a) **Phytosanitary measures in pre-harvest period**

According to the standard SA, pre-harvest measures normally include field certification or management (like biocontrol, treatments), protected conditions (like glasshouse, fruit bagging), resistant or less susceptible cultivars, harvesting plants at certain age or time of year, vector mating disruption (particularly efficient with insects), cultural controls, vector-and pathogen-free areas, places, or sites of production, low prevalence (continuous or at specific times), and testing and subsequent elimination of infected components (USDA/APHIS/PPQ, 2002). Pre-harvest period measures from the reference policies are grouped into the corresponding standard category (Appendix 2.1). Typical measures are not needed in every possible category and our reference policy measures fall into the categories: field certification or management, protected conditions, cultural controls, vector-and pathogen-free areas, places, or sites of production, and testing and subsequent elimination of infected components. The following measures are considered in the hypothetical SA for Chinese fresh apples.

Pest free areas (or production site)

Four of the reference polices require traded apples or pears should be from a pest-free area or pest-free production site. Argentina requires the fruit shall come from an area free of *Baclrocera dorsalis*, from production site or orchards free from *Gymnosporangium asiaticum* and the transiting host tree shall not grow within 1 km of the fruit production site. Australia requires that AQSIQ must ensure that telial hosts (*Juniperus chinensis*, *J. procumbens*) of Japanese pear rust and European pear rust occurring within 2 km of registered orchards are removed. Canada requires for apples that "cultural practices, chemical controls and field inspection (or monitoring) programs are carried out to ensure freedom from quarantine pests". The U.S. requires that all material introduced into a registered production site must be certified free of the pests listed.

The International Standard for Phytosanitary Measures No. 4 defined pest free areas as "an area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained" (FAO/IPPC, 1996). Generally speaking, the pest free area could be an entire country, or an uninfected part of a country in which a limited infested area is present, or an uninfected part of a country situated within a generally infested area. The pest free areas mentioned by policies for Chinese apples or pears can be treated as the third type mentioned above. However, to be more precise, they can be considered a "pest free place of production" or "pest free production site" instead of "pest free area" according to the definition and distinction given by FAO. [24] However since some polices use the term "pest free area" (like Argentina) and some use "pest free production site" and we don't have any official source from China about this, we keep both terms in our hypothetical SA. In China, the government plays a very important role in establishing the pest free production site and maintaining its status by providing funds for lab setup and technical support.

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[24] According to ISPM No. 10 "Requirements for the establishment of pest free places of production and pest free production sites" (FAO/IPPC, 1999), the concept of the pest free place of production is distinct from that of the pest free area. They have the same objective but are implemented in a different way. First, a pest free area is much larger than a place of production. Second, a pest free area may be isolated by a natural barrier while a pest free place of production is isolated by creating a buffer zone in its immediate vicinity. Third, a pest free area is generally maintained over many years without interruption while a pest free place of production may be maintained for only one or a few growing seasons. Forth, a pest free area is managed as a whole while a pest free place of production is managed individually by the producer.

Registration of export orchard

Almost all the reference policies require that the Chinese apples or pears should be from registered orchards in designated export areas in China. The registration of export orchards ensures that the locations from which pears or apples are sourced can be identified (Biosecurity Australia, 2005b). AQSIQ (General Administration of Quality Supervision, Inspection and Quarantine of the People Republic of China) is the official government agency responsible for orchard registration.[25] AQSIA determined the requirements for registration systems already being used by China to export Fragrant pears to Canada and other countries (USDA/APHIS, 2005b). Canada published the list of orchards for the export of Chinese fresh pears.[26] This list provides names, address, registration number, and variety of the fruit from each of the registered orchards (also the packinghouses) from Shaanxi and Shandong province. Summarizing current policies, the designated areas of export of Chinese fresh pears, including Ya, Sand and Fragrant pears, are mainly from Hebei, Shandong, Shaanxi and Xinjiang provinces. Therefore, the designated export areas of Chinese apples are mainly from Shandong and Shaanxi provinces.

Bagging of the fruit

Bagging fruit during pre-harvest period is another important measure included in most of the reference policies, although how to implement this measure varies across different

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[25] AQSIQ is also the official government representative responsible for dealing with SPS issues. As mentioned in Chapter 3, the responsibilities of MOA and AQSIQ are overlapping. MOA is responsible for general agricultural production and development while AQSIQ focus more on food safety, quality supervision and inspection.

[26] The list of orchards is available at: http://www.inspection.gc.ca/english/plaveg/protect/dir/orch-chinae.shtml. There are 25 registered orchard and 14 registered packinghouse from Hebei province,35registered orchard and 2 registered packinghouse from Shandong province, and 45 registered orchard and 6 registered packinghouse from Xinjiang province. Most of the packinghouse are registered in terms of company.

policies. Argentina requires the bag must not be removed more than four weeks prior to harvest. Australia requires bagging for Ya pear, Sand pear and Asian pear grown in Hebei, Shandong and Shaanxi provinces when the fruit is no more than 2.5cm in diameter. Canada requires that the bags must be sealed without holes around apples and must not be removed more than four weeks prior to harvest. The U.S. requires bagging pears (except for Fragrant pears)[27] on the trees to reduce the opportunity for pests to attack the fruit during the growing season. Bagging can not only beautify the shape and appearance of the fruit, but also efficiently prevents the fruit from becoming infested with certain pests or diseases during production. During 2005 and 2006 travel to China, we found that bagging apples has become a very common and popular measure widely used by Chinese farmers in Shandong province. It is also recommended by the Chinese government. The bags are normally made of paper and are affordable for most Chinese farmers with a cost of US$0.01 for a medium-quality bag. In 2005, the Chinese Ministry of Agriculture initiated an apple subsidy program in production areas with export potential. The program provides cash subsides for the purchase of apple bags and covers a total of 8,067 hectares of apple orchards in kg producing provinces including Shandong, Shaanxi, Shanxi, Hebei, Henan and Liaoning (USDA/FAS, 2006a).

Field inspection and/or monitoring system

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[27] Bagging is not required by the U.S. and Australia for Fragrant pears from Xinjiang province of China. This is due to the smaller size of the fruit, the physiology of ripening of this species and the climatic conditions and pest status of this area (Biosecurity Australia, 2005b).

The requirement for monitoring systems or inspection during pre-harvest period is another important common measure mentioned by most of the policies. Some countries require a monitoring system for certain pests. Argentina requires monitoring for *Baclrocera dorsalis*.Australia requires a pest monitoring system for fruit flies. Canada requires field inspection (or monitoring) and/or chemical control for Chinese apples , while in contrast, the U.S. requires general field inspections for signs of all pests. In addition to monitoring and inspection, Australia also state that if any pest of concern is detected, AQSIQ should immediately report results and for some certain pests, if this happens, the infected orchard will be excluded from the export program or, even worse if certain serious pests are found, all future exports might be suspended. Agencies AQSIQ, MOA and their local offices will be responsible for general monitoring and regular inspection. More detailed instructions about how to monitor the orchards are listed by some countries. The Argentine policy states that monitoring should occur within a surrounding area of 1 km radius at a density of one trap per square kilometer respectively, with the minimum of traps being 3 if the designated orchard's area is less than 3 square kilometers from June 1 to September 30". Australia requires that "a minimum of one methyl eugenol trap should be placed in each export orchard and any villages present" identified (Biosecurity Australia, 2005b). A few policies mention the use of "pesticide or fungicide" or "chemical control", which are the most basic pest control methods currently widely used in China. The monitoring record and inspection results should be available to import country inspectors.

Other measures during pre-harvest period

Australia requires "registered growers must implement an orchard control program (like good agricultural program or integrated pest management program for export pears)". Australia also requires "the notification of unusual weather conditions occurrence resulting in brown rot, black spot or scab disease" (Biosecurity Australia, 2005b).

b) Phytosanitary measures in harvest period

According to the standard SA, measures implemented during harvest period include culling, inspection or selection, stage of ripeness/maturity, timing of harvest, sanitation (like removal of reservoir hosts, "trash") and harvest technique and handling (Appendix 2.2). Comparing these standard measures in the SA, most of the reference policies do not specify the stage of ripeness or timing of harvest. Australia and the U.S. (for Ya pears) require continued bagging during harvest. Argentina requires field inspection and that "apples should be selected to ensure fruit without insects, mites, rotting fruit, leaves, twigs, roots and soil."

c) Phytosanitary measures in post-harvest period (including storage and packing)

According to the standard SA, post-harvest measures include treatment to kill, sterilize or remove vectors or pathogens (fumigation, irradiation, cold, controlled atmosphere, washing, brushing, waxing, dipping, heat, etc.), inspection and grading, sanitation including removal of parts of the host, certification of packing facilities, and testing with subsequent elimination of infected components (Appendix 2.3). After comparing the measures in the reference policies, the following measures are considered in the hypothetical SA.

Registration of packinghouse

Similar to registration of export orchards, almost all policies require registration for packinghouses. Australia in particular requires the registered packinghouse should be maintained in a condition that would provide security against infestation again.

Post-harvest inspection and monitoring

Like pre-harvest monitoring requirements, almost all the policies require post-harvest inspection or monitoring. Argentina requires that apples and pears shall be selected, sorted and processed to insure fruits are without insects, mites, rotting fruit, leaves, twigs, roots and soil. The packing and storage shall be subject to quarantine supervision by AQSIQ. Australia requires pre-clearance phytosanitary inspection and remedial action. Canada requires the apples must be subject to any post-harvest measures deemed appropriate to eliminate pests and free of quarantine pests, oil, sand, leaves, and plant debris. The U.S. requires inspection for Fragrant pears and allows USDA/APHIS to monitor the inspections.

Cold treatment

Argentina requires commercial cold treatment. Australia requires pears be stored under quarantine security and segregated by at least one meter from all other fruit in a cold storage maintained at 34~37°F (1~3°C) until loaded into containers. The U.S. removed cold treatment for Chinese Ya pears from Hebei province based on sufficient information to show that the oriental fruit fly do not exist there. However, cold treatment is still required for pears from Shandong province. During the trip to China in 2005 an 2006, cold treatment was generally used by big exporters in Shandong province.

Packing and labeling requirements

Storage, packing and processing are generally required to be isolated from fruit targeted to other destinations. Some policies include specific requirements for packing materials. The fruit should be packed in clean, new cardboard boxes or cartons. Label requirements made by some policies, like Argentina, Canada, and Australia, generally include marking in certain languages, indication of production place (provinces), orchard or its registered number and packinghouse or its registered number. These labeling requirements are designed to facilitate trace-back identification in the event of non-compliance (Biosecurity Australia, 2005b). Australia and Canada also requires a monitoring (trapping) system to maintain the packing house free of pests.

Other specific requirement for storage and packing

Even though cartons are mainly required by most of the policies, some country in particular requires more in detail about the packing material. For example, Australia requires the cartons with screened ventilation holes; the screening mesh size must not exceed 1.6mm with not less than 0.16mm strand thickness. Or, the pallet of cartons must be shrink-wrapped in plastic on all six sides; only processed or synthetic packing material can be used; Fruit must be packed and directly transferred into a shipping container sealed with an AQSIQ seal and not opened until the container reaches its destination; Canada requires additional fumigation after cold treatment for apples. Several countries require sample inspection during packing and/or storage: Argentina requires sample inspection at 2% level; Canada requires at 5% level; and Australia requires 600 units for quarantine pests, in systematically selected samples per homogeneous consignment or lot. In addition, Argentina, Australia and Canada require that fruits are not mixed with fruit for other destinations. Australia also requires that culled fruit must be removed from the packing house at the end of each day. The U.S. states "upon detection of large pear borer, pear curculio or Japanese apple curculio, USDA/APHIS may reject the lot or consignment".

d) Phytosanitary measures in shipping and distribution period

According to the standard SA, measures in the shipping and distribution period include in-transit or on-arrival treatment or processing, restrictions on end use, distribution, and ports of entry restrictions, post entry quarantine, inspection and/or testing with subsequence elimination/denial of entry, speed and type of transport, and sanitation (freedom from contamination of carriers) (Appendix 2.4).

Regulatory Inspections by the Importing Country

Argentina states that SENASA will send two quarantine experts to China to conduct an on-site visit prior to program initiation in cooperation with AQSIQ. The experts will review the phytosanitary conditions of production areas, the orchards, packinghouse, storage facility and the system of monitoring for *Baclrocera dorsalis*. AQSIQ is in charge of the invitation, agenda and pays for all the expenses. Australia also states in the policy that AQIS inspectors will visit China each year for pre-clearance inspection, both in the field and packing house, unless otherwise agreed by DAFF [28] and AQSIQ on a region-by-region basis. As mentioned earlier, the U.S. sent USDA/APHIS delegations to Hebei and Xinjiang provinces in China several times to collect pest risk evidence for Ya and Fragrant pears in the 1990s and early 2000s.

Quarantine supervision of shipment

During the shipping and distribution period, most of the policies state the shipment should be under supervision of AQSIQ, and shipment should be guaranteed free of quarantine pests. The U.S. requires Fragrant pears shipped in insect-proof containers and all pears must be safeguarded during transport to the U.S. in a manner that will prevent pest infestation.

Import permit

The U.S. permits Fragrant pears to be imported only under a permit issued by USDA/APHIS while Canada states that "a permit to import is not required" for both Chinese apples and pears. However, the U.S. requires written permits for imported fresh fruits from all foreign sources. [29] Only approved plant part(s) of the fresh fruits are authorized entry.

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[28] DAFF refers to Australian Government Department of Agriculture, Fisheries and Forestry.

[29] USDA requires written permits for imported fresh and frozen fruits and vegetables (including fresh herbs and sprouts) for consumption from all foreign sources as well as Guam, Palau, the Federated States of Micronesia, or from the Commonwealth of the Northern Mariana Islands. Refer to the Fruit and Vegetable Manual for more detail (USDA/APHIS/PPQ, 2004).

Phytosanitary certificate

A phytosanitary certificate is required by almost all the countries. Argentina requires the phytosanitary certificate be issued by AQSIQ with a sample (2 percent) provided in advance to SENASA [30] for confirmation. Australia requires CIQ [31] issue a Master Phytosanitary Certificate for all pre-export inspected lots. Canada requires the phytosanitary certificate (include English or French) for apples and pears issued within 14 days prior to shipment and bearing the official stamp of AQSIQ. The requirement for phytosanitary measure is consistent with International Standards for Phytosanitary Measures No.7 Export Certification system (FAO/IPPC, 1997).

On-arrival inspection

Argentina states "when fruit arrives at the entry port, SENASA will verify the documents, the labeling and will do the corresponding phytosanitary inspection". Australia states AQIS will examine documents for consignment verification prior to release from quarantine and may open containers to verify the contents. Sample inspection on arrival is required by Canada for both Chinese apples and pears which require 100 percent of pear shipment inspection during trial period and 5 percent after the trial period. In addition, Canada requires for Chinese apples that when a shipment is inspected, a random sample of five percent of the contents will be examined and a further five percent sample may be randomly selected and examined if there is presence of frass.[32]

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[30] SENASA refers to Secretariat of Agriculture, Livestock, Fisheries and Food of the Argentine Republic.
[31] CIQ refers to Entry-Exit Inspection and Quarantine Bureau of the People's Republic of China, which is one department belonging to AQSIQ.
[32] Frass refers to Debris or excrement produced by insects.

Other specific requirements for measures for shipping and distribution

Some country make more specific requirements for shipping conditions: Argentina requires cold treatment for shipping; Australia states the fruit must remain within intact bags and be covered by a tarpaulin if they are shipped through an unmonitored area; the U.S. requires that the fruit must be shipped in insect-proof containers. In addition, Australia requires that "If brown rot, black spot, or scab is intercepted on imported fruit, DAFF reserves the right to implement remedial measures as deemed necessary before trade commences next season".

4.2.3 A hypothetical Systems Approach for Chinese Fresh Apples

A hypothetical systems approach for Chinese fresh applies is developed based on the discussion above. There are thirty four measures in total that are mentioned by reference policies (Table 4.7) which are currently being used to mitigate the risk of introducing pest(s) associated with like products from China. Thirteen common measures are mentioned by most of the policies. Another six measures are mentioned by a few policies. And fifteen measures are only required by a single reference policy.

Table 4.7 Hypothetical Systems Approach for Chinese Fresh Apples

Harvest	
Mentioned by most of the policies (4)	-Fresh apples must be from registered orchard by AQSIQ in the desired export area (Shandong and Shaanxi Province) -Apples must be bagged without holes on the trees -Field inspection and/or monitoring System -Apples must be from pest free areas or production site free of listed pests
Mentioned by a few policies (1)	-Chemical control like using pesticide or cultural practice
Mentioned by only one policy (4)	-Monitoring program should be within a surrounding area of 1 km radius -The traps must consist of cue lure, trimedlure and methyl eugenol; a minimum of one methyl eugenol trap should be placed in each export orchard and any villages present (Australia) identified -The notification of unusual weather conditions occurrence resulting in brown rot, black spot or scab disease -Orchard control program
Post-Harvest	
Mentioned by most of the policies (0)	
Mentioned by a few policies (1)	-Continue to bag the apples through harvest
Mentioned by only one policy (2)	-Field inspection or monitoring and/or chemical control after the bags have been removed -Apple should be selected, stored and processed to ensure apples without insects, mites, rotting fruit, leaves, twigs, roots and soil
Pre-harvest	
Mentioned by most of the policies (5)	-Packing houses must be registered from AQSIQ -Cold treatment -Post harvest sampling inspection -Fresh apples must be stored in a certain container (the chamber, carton or cardboard) -Each container must be labeled in English and Chinese and marked with the production information
Mentioned by a few policies (3)	-Monitoring (trapping) system to maintain the packing house free of pests -Sampling inspection during packing and storage (Argentina: 2%; Canada: 5%; Australia: 600 units for quarantine pests, in systematically selected samples per homogeneous consignment or lot -Fruits are not mixed with fruit for other destinations

Table 4.7 Hypothetical Systems Approach for Chinese Fresh Apples (Continued)

Pre-harvest	
Mentioned by only one policy (5)	-Fumigation with methyl bromide after cold treatment -More pacific requirements for packing materials: no fresh or dried packing material of plant origin is to be used; only processed or synthetic packing material can be used; packed in cartons with screened ventilation holes; the screening mesh size must not exceed 1.6mm and not less than 0.16 strand thickness; or fruit must be packed into cartons and the pallet of cartons must be shrink-wrapped in plastic on all six sides -Fruit must be packed and directly transferred into a shipping container sealed with a AQSIQ seal and not opened until the container reaches its destination -In the packing house, culled fruit must be removed from the packing house at the end of each day -Upon detection of large pear borer, pear curculio or Japanese apple curculio, USDA/APHIS may reject the lot or consignment
Shipping and Distribution	
Mentioned by most of the policies (4)	-Shipment must be subject to quarantine supervision by AQSIQ to make sure the shipment free of other visible pests and free of soil, sand, leaves and plant debris - A permit to import issued by the plant protection regulation - A Phytosanitary Certificate issued by the plant protection regulation -On arrival, inspection of all shipments, verify the documents, labeling and corresponding phytosanitary inspection
Mentioned by a few policies (1)	-Sample inspection on arrival: Canada 100 percent of pear shipment inspection during trial period and 5 percent after the trial period.
Mentioned by only one policy(4)	-USDA/APHIS delegations will visit China to review the phytosanitary conditions of productions at certain time of a year or invited by AQSIQ (not in the table) -If certain disease is intercepted on imported fruit, USDA reserves the right to implement remedial measures as deemed necessary before trade commences next season -Transportation under the commercial cold treatment -The fruit must remain within intact bags and be covered by a tarpaulin if they are shipped through an unmonitored area

The number of measures included in a SA will not only determine the level of protection but also affect the corresponding costs for apple growers both in China and the importing country (Table 4.8). If only the thirteen common measures mentioned by most of the reference are considered in a SA, the probability of introducing certain pest/disease associated with the apples would be relatively high (compared with other two situation) since there might not be sufficient mitigation measures in place to control the pest. Thus the level of protection is relatively low. In this case, for Chinese growers, the compliance cost of implementing the SA for Chinese growers would be relatively low since fewer measures are required. The high probability of introducing the pest associated with Chinese apples would lead to a high probability of pest outbreak in the importing country. Therefore, apple growers in the importing country (like U.S.) are more likely to suffer some extra pest control cost. In addition, apple productivity would also be somewhat reduced due to the pest outbreak.

If we add the additional six measures (mentioned by a few polices) to the common measures, the probability of introducing of pest would be lower and thus the level of protection would be higher. The compliance of cost for Chinese apple growers will be increased due to more measures to be implemented. The pest control cost for apple growers in the importing country would be reduced due to the lower probability of pest outbreak. If all of the thirty four measures are included in a SA, the probability of introducing the pest will be the lowest (compared with the other two situations), which will lead to (relatively) the highest compliance cost for Chinese apple growers and lowest pest control cost for growers in the importing country.

Table 4.8: Comparison of effects based on the number of measures included in a SA

	Scenario 1	Scenario 2	Scenario 3
Number of Measures included in a SA	13	19	34
Level of protection	Low	Average	High
Probability of introducing the pest	High	Average	Low
Level of compliance cost in China	Low	Average	High
Level of pest control cost in the importing country	High	Average	Low

The hypothetical SA developed in this section provide general framework showing that what steps (measures) should be included in such a pest mitigation policy. This hypothetical SA is also the base for further economic assessment analysis in the next chapter. As discussed above, the level of protection, the probability of introducing the pests and the cost for apple growers will be determined by the number of measures included in a SA. While the change in probability, level of protection and cost will somewhat affect the producer and/or consumer surplus and thus the final welfare (detailed discussion in next chapter).

4.3 Summary

By evaluating current like-product existing policies including corresponding pest risk assessment reports, a list of pests of concern associated with potential U.S.-China fresh apple trade is first obtained. Fourteen pests are mentioned most frequently by the reference policies and six of them have been categorized by the U.S. with a high-risk rating. Three pest, Peach Fruit Moth, Brown Rot, and Hawthorn Spider Mite for further analysis are chosen for further analysis. Then, by evaluating the current existing policies, a hypothetical systems approach for Chinese fresh apples is developed. Even though these measures are described somewhat differently in the various reference policies, they can be divided into four periods in accordance with standard SA defined by USDA: pre-harvest, harvest, post-harvest (including storage and packing), and shipment and distribution. The selected measures include those that are incorporated in most of the reference (thirty four measures) or are particularly required by a few policies (six measures) or a single policy (fifteen measures) Different numbers of measures included in a SA will determine the level of protection, corresponding cost both in Chin and in the importing country. Three situations are identified in this chapter and these three situations also provide the basis for further economic assessment of SA in the next chapter.

CHAPTER FIVE:

LINKING ECONOMICS TO RISK ASSESSMENT:

AN EVALUATION

It is likely that opening the U.S. market to Chinese fresh apples will occur at some point in the future. A hypothetical SA provides a general idea of what kinds of phytosanitary measures might be taken to prevent the introduction of exotic pests or diseases. Like any policy adjustment, potential future trade, with or without transfer of pests, will have economic impacts on the U.S. and Chinese apple industries and consumers. As mentioned in Chapter Two, relatively little research work has been done using quantitative analysis to link economics to pest risk assessment. This chapter first provides a general evaluation of methods for modelling and quantifying non-tariff barriers, especially phytosanitary regulations. A comparison of available methods is provided. The multi-scenario static partial equilibrium model, a recently applied approach, is introduced and discussed in more detail. Then the model is adapted to Chinese fresh apples case. Key components of the approach are defined and evaluated. Feasibility and potential difficulties are discussed. A sensitivity analysis for selected parameters is conducted based on three different scenarios for alternative SA.

5.1 Overview of methods for linking economics and pest risk assessment

A growing number of economists are evolved in economic evaluations for non-tariff barriers (NTB) to trade. Table 5.1 lists a summary of the primary methods that have been used for modelling and quantifying NTB to trade.[33] Inventory and survey-based

[33] The classifications in Table 5.1 following those established by Beghin and Bureau (2001).

approaches are used to identify the importance and list the problems and obstacles of NTB issues by searching and collecting information on current policies. Even though these two methods generally do not quantitatively provide economic impact, results are a good starting point for an economic evaluation and draw attention to a specific NTB issue. However, collecting information, especially through surveys, can entail some difficulties related to political issues, business secrets, and/or availability of data. Similar to the two methods mentioned above, gravity-based approach is also a method used to indirectly evaluate the economic impact of NTBs. In a gravity model, ready-available proxy variables (like "shared boarder") are used to capture factors that affect trade such as standards, regulations, and cultural characteristics. However, just like other econometric models, a single model might not be realistic enough to explain a complicated situation. Focusing on detailed products and spatial trade flows, prediction is likely to be sensitive to assumptions of the model. However, gravity-based approaches, coupled with the use of proxy variables from survey- or inventory-based methods, are a promising area of research (Beghin and Bureau, 2001).

According to FAO, the potential economic importance of an invasive pest is based on information about probability of spread (FAO/IPPC, 2004). Therefore, the economic analysis of NTB barriers concerned with these issues should include scientific pest risk assessment. The other four methods listed in Table 5.1 could possibly be used to evaluate impacts by linking economics to a pest risk assessment. Price-wedge method is the simplest way which basically expresses some factors in terms of price, like calculating a tariff equivalent. Cost-benefit analysis approach quantitatively compares the cost and benefit to capture the economic effect on a country/region from a policy change. Partial equilibrium model is a more complex version of cost-benefit analysis approach. In a partial equilibrium model, the effect of regulations on supply and demand can be measured by standard estimates of cost or profit functions, as well as by utility or demand functions estimated econometrically (Beghin and Bureau, 2001). General equilibrium models have the widest scope among all the methods. General equilibrium models attempt to describe the entire economic system, capturing not only the direct impact of a policy shock on the relevant market, but also the impact on other areas of the economy and feedback effects from these sectors to the original market (O'Toole and Matthews, 2002). However, there are many difficulties when applying general equilibrium model due to the complexity, therefore, it is rarely used in empirical studies. Compared with general equilibrium, a partial equilibrium model concentrates only on a particular subsection of the economy. It is easier and possible to model a particular commodity or industry for empirical studies and it is commonly used by economists. A recent empirical partial equilibrium model used for analysis of phytosanitary policies is the one developed by Peterson and Orden in 2006. The model has been successfully applied to the case of U.S. imports of Mexican avocados. A more detailed discussion about this model is provided later.

Table 5.1: Summary of methods for modelling and quantifying NTB to trade

Method	Descriptions	Example of existing studies
Inventory-based approaches	*General idea:* Collect data and information on regulations, frequency of detentions, complaints, number of restrictions, frequency ratios, and import coverage ratio. *Main application*: Collect information; used to develop proxy variables for econometric (gravity) models. *Limitations*: Don't provide quantification of the effect of regulations but do provide useful indication on the importance of the problem.	Swann, Temple, and Shurmer, 1996
Survey-based approaches	*General idea:* (compared with inventory-based approaches) Ask practitioners which measures have more impact on their activity, surveys make it possible to narrow the scope of the analysis and to focus on the relevant issues. *Main application:* Surveys, interviews. *Limitations:* Useful when other sources are lacking; able to identify barriers that are diffuse and difficult to measure.	USTR, 2001
Gravity-based approaches	*General idea:* Look at the residuals in economic regressions of trade flows on the various determinants of trade. *Main application:* Gravity model. *Limitations:* Not able to explain correctly all trade flows; would be better if used combined with survey- or inventory-based methods.	Moenius, 1999
Price-wedge method	*General idea*: NTBs can be gauged in terms of their impact on the domestic price in comparison to a reference prices. Can be used in a partial or general equilibrium model. *Main application:* Calculate tariff equivalent. *Limitations:* Data limitation, not working for large-scale studies.	Calvin and Krissoff, 1998

Table 5.1: Summary of methods for modelling and quantifying NTB to trade (continued)

Method	Descriptions	Example of existing studies
Cost-benefit measures	*General idea:* By decomposing the welfare effects, compare the costs of compliance to the gains from the trade. *Main application*: Iso-risk framework, cost-benefit analysis. *Limitations:* Great uncertainty about risk.	Glauber and Narrod, 2001; Bigsby, 2002; Orden and Romano, 1996; Krissoff, Calvin, and Gray, 2004
Partial equilibrium approach	*General idea*: (compared with cost-benefit measures) accounting more sophisticated effects in an analytical representation of producers and consumers; *Main application:* (stylized) Partial equilibrium model. *Limitations:* Requires simplified assumptions; data-intensive; difficult to calibrate demand functions (elasticity).	Paarlberg and Lee, 1998; Wilson and Anton, 2006; Peterson and Orden, 2006
General equilibrium approach	*General idea:* Extend partial equilibrium model to encompass an entire economy, and allow the effects on wages, exchange rates and national welfare to be measured *Main application:* General equilibrium model; *Limitations:* Difficult to collect data.	Wittwer, McKirdy, and Wilson, 2005

Source: Beghin and Bureau, 2001; FAO/IPPC, 2004; Bigsby, 2002.

A static partial equilibrium model

A partial equilibrium model is one of the feasible and useful methods to estimate economic impact of a SPS regulation. Peterson and Orden developed a multi-scenario static partial equilibrium model for the case of U.S. imports of Mexican avocados. The model was successfully used to compare welfare changes under different SA requirements for the avocado case.

According to Peterson/Orden, a phytosanitary policy (ϕ) will be chosen to maximize social welfare and the expected welfare change (EW) can be expressed by:

$$EW = p(\phi)W_D(\phi) + [1 - p(\phi)]W_N(\phi) - C(\phi) - W_0$$

Where $p(\phi)$ is the probability of a pest/disease outbreak and $C(\phi)$ is cost of implementing the systems approach. $W_D(\phi)$ and $W_N(\phi)$ represent welfare if there is a pest/disease outbreak and if there is no outbreak, respectively. W_0 is the original welfare level before implementing the systems approach. For empirical applications expected welfare, sum of producer surplus and consumer surplus, can be calculated. Peterson and Orden's model determines the level of imports and the associated risk of a pest outbreak, as well as the expected welfare. Welfare is then compared between different scenarios, with and without (partial) restriction on imports, which are under the regulation of different systems approach policy.

Table 5.2 shows the general framework of the partial equilibrium model. Three different types of regions are identified: region 1 is an importer, region 2 is an exporter free of pest, and region 3 is an exporter not free of pest with some non-zero probability of transmitting pest(s) to the importer. Demand in the importing region Q_i^{Demand} is derived from a utility function for a representative consumer. The goods from different regions are treated as slightly different goods. Q_i^{Demand} decreases as the its own price P_i^{Retail} increases and increases as cross prices $P_j^{Retail}(j \neq i)$ increase. Total supplies are from domestic production in region 1 (Q_1^{Supply}), imports from region 2 (Q_2^{Import}), and imports from region 3 (Q_3^{Import}). Q_1^{Supply} increases as the level of producer price increases, decreases as either the frequency of pest outbreaks (N) or the costs associated with controlling an outbreak (PC_1) increases. Producer price is calculated as the difference between retail price P_1^{Retail} and a fixed market margin m_1. The frequency of a pest outbreak (N) is an important factor used in the model for incorporating risk assessment results. It is assumed to depend on probability that a pest can be introduced from region 3 into region 1 and the level of imports from region 3 (Q_3^{Import}). In the case of pest outbreak in region 1, the cost of mitigation depends on the frequency of outbreak and level of eradication ($0 \leq \alpha \leq 1$). Control cost in exporting region 3 depends on risk mitigation measures included in the systems approach.

Change in expected welfare for the region 1 is defined as:

$$EW_1 = CS_1(\phi) + PS_1(\phi) - PC_1 - PCP_1$$

where $CS_1(\phi)$ is the expected change in consumer surplus, which is defined as the equivalent variation; $PS_1(\phi)$ is the change in producer surplus in region 1 before and after the change in policy; PC_1 is the cost of control measures for growers/exporters in the importing region; and PCP_1 is the cost of control measures paid by public agencies. Welfare can be computed according to this equation and compared across different scenarios to choose the optimal policy that maximizes expected welfare.

Table 5.2: General framework of a partial equilibrium model

Endogenous Variables		Description
Q_i^{Demand}	Demand for the product from region *i*, *i*=region 1, 2, and 3	A function of retail prices of product in the importing country $Q_i^{\text{Demand}} = D\left(P_1^{\text{Retail}}, P_2^{\text{Retail}}, P_3^{\text{Retail}}\right)$, *i*=region 1, 2, and 3.
Q_1^{Supply}	Supply in the importing region 1 +	A function of the producer price (retail price minus a fixed marketing margin), the frequency of pest outbreaks, and the costs associated with controlling pest outbreak. $Q_1^{\text{Supply}} = S_1\left(P_1^{\text{Retail}} - \text{m}_1, N, PC_1\right)$
Q_2^{Import}	Exporter excess supply from region 2	A function of export (FOB) price of the product in regions 2 (the retail price in region 1 minus a fixed margin). $Q_2^{\text{Import}} = E_2\left(P_2^{\text{Retail}} - m_2\right)$
Q_3^{Import}	Exporter excess supply from region 3	A function of export (FOB) price and the cost of control measures required by the regulatory policy being considered in region 1. $Q_3^{\text{Import}} = E_3\left(P_3^{\text{Retail}} - m_3, PC_3\right)$
P_i^{Retail}	Retail prices of the products from region *i*, *i*=region 1, 2, and 3	
N	Frequency of pest outbreaks	A function of the regulatory policy (ϕ) and the level of imports from region 3. $N = \left(\phi, Q_3^{\text{Import}}\right)$ The regulatory policy decides the magnitude of the probability that the product being exported is infested ($Prob_1$), the probability that the pest survives shipment ($Prob_2$), the probability that the product/pest is transported to a suitable habitat, ($Prob_3$), and the probability that the pest is able to become established ($Prob_4$).

$$N = prob_1 * prob_2 * prob_3 * prob_4 * prob_5 * Q_3^{\text{Import}}$$

Table 5.2: General framework of a partial equilibrium model (continued)

Endogenous Variables		Description
PC_1	Pest-control costs in the importing region 1	A function of the frequency of an outbreak (N), the intensity of an outbreak (Int_1) and the level of eradication (α). $PC_1 = PC_1(N, Int_1, \alpha)$
PC_3	Control costs in the exporting region with pest risk in region 3	Related to the risk mitigation measures specified in the regulatory policy (ϕ) under consideration. $PC_3 = PC_3(\phi)$
PCP_1	Cost of control measures paid by public agencies	A function of the regulatory policy under consideration, the level of exports from region 3, and the intensity of infestations in regions 1 and 3. $PCP_1 = PCP_1(\phi, Q_3^{\text{Import}}, Int_1, Int_3)$
Exogenous Variables		
m_i	Fixed market margin, *i*=region 1, 2, and 3	It is the link between producer and retail (FOB) prices. It includes all trade and transport services needed to get the product from producers to consumers.
Int_1	The intensity of an outbreak in region 1	
α	Level of eradication	Vary between 0 and 1
Market clearing conditions		Equate the demands for the substitutable products in region 1 with the supplies from region 1,2, and 3. $Q_1^{\text{Demand}} = Q_1^{\text{Supply}}$ $Q_2^{\text{Demand}} = Q_2^{\text{Import}}$ $Q_3^{\text{Demand}} = Q_3^{\text{Import}}$

Source: Summarized from Peterson and Orden, 2006.

Note*: Region 1: an importer of a product

Region 2: an exporter free of the pest or pathogen

Region 3: an exporter not free of the pest with some non-zero probability of transmitting the pest to the importer

5.2 Adaptation of partial equilibrium model in the case of Chinese fresh apples

In this section, the partial equilibrium model introduced in last section will be adapted to Chinese fresh apple case. First, a discussion of the potential impact of importing Chinese apples into the U.S. is provided. Then, based on the general framework, key components of the model are described for adaptation to the Chinese fresh apple case. By comparing the methods and logic used by Peterson and Orden in the avocado case, feasibility of the model and potential difficulties to adaption will also be evaluated in this section. At last, some conclusions about the model for apple case are provided.

5.2.1 Potential impact of opening the U.S. market to Chinese fresh apples

The introduction of exotic invasive species could have potential impacts not only on a country's plant, animal, and human health, but also on the environment, consumer interests, and total welfare. It is likely that the U.S. market will open to Chinese fresh apples at some point in the future. Table 5.3 provides a general summary of potential impact from initiation of trade. Since apples are not mainly used as an animal feed, it is not expected to affect animal health. As for human health, it is not clear whether the potential import of apples will influence the Americans without further scientific assessment.[34] However, no vital serious apple disease/pest harmful to human has been found in China, it is not expected that the import of Chinese apples would affect human health in the U.S. It is hard to find evidence to say that invasive species exist which would affect the U.S. environment. However, from economic perspective, it is likely that imports will have effects on the U.S. apple industry and market. On one side, even under regulations, there is still a non-zero

[34] The food safety issue about Chinese fresh apples is sensitive these days. However, it is regulated under other agencies and rules and is not the interests of this study.

probability that the exotic disease/pests could be introduced into the U.S. along with Chinese apples. In that case, a pest outbreak could have negative effect on apple trees and other similar susceptible plants. In addition, the pest outbreak may lead to production loss and increases in pest control cost. The apple market (like price) could also be affected depending on the scope of pest outbreak and total import volume of Chinese apples. On the other side, like any policy adjustment, potential future trade with or without transfer of pests will have impacts on the U.S. China is the world's leading apple production country and Chinese apples are competitive in the global market due to low prices. U.S. consumer and producer surplus would be affected due to the change in wholesale price and producer price. The total impact is indeterminate without further analysis. Thus an assessment of method to evaluate the economic impact linked to the pest risk analysis is important.

Table 5.3: Potential impacts of opening Chinese fresh apples

Types of Impact	Possible Effects
Plant health	Potential impact to plant due to invasive pest outbreak
Animal health	No major impact
Human health	No major impact
Environment	No major impact
Production	Potential production/yield loss, pest control cost increase if there is an invasive pest outbreak
Price and Market	Change in producer and/or consume surplus due to the change in producer and wholesale prices
Food security	No major impact

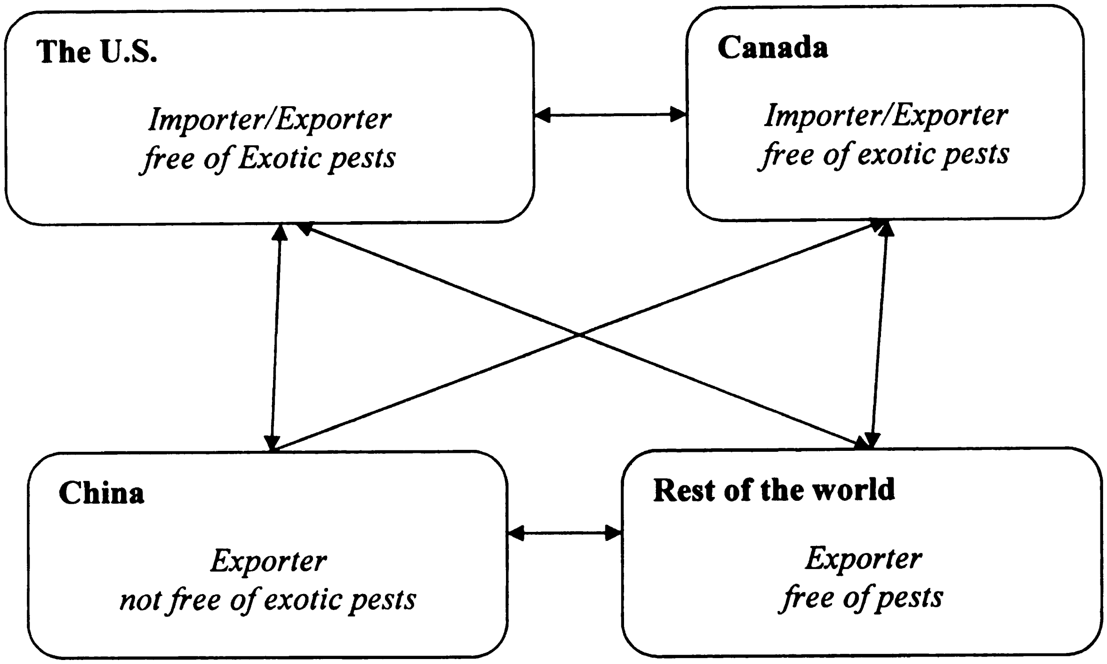
Source: Adapted from Evans, Spreen, and Knapp, 2002.

5.2.2 Adaptation of Peterson/Orden model to Chinese fresh apple case

Based on introduction of the general framework in last section, some key components of the Peterson/Orden model can be described. First, time periods are used to capture differences in policy, like different geographic, seasonal or phytosanitary requirements. Since the import of Chinese apples is still in the early stage of political debate and not yet reality, two different time periods are obvious. The first is during the period when Chinese apple imports are prohibited and the second period is during the period when the hypothetical systems approach will be implemented to regulate imports. For simplicity at this point, year 2004 can be used as the first period and 2005 as the second. Different than the avocado case, there is no seasonal restrictions identified in the hypothetical systems approach. Therefore, two periods are not necessary within one year.

The second model component is geographic regions. Peterson/Orden divided the regions into three different kinds: an importer, an export free of exotic pest, and an export not free from the pest under consideration. Following the same logic, the regions for Chinese apple case are listed in Figure 5.1. The U.S. and Canada---the North American Region are identified as two demand regions. These two fruit markets are quite similar in terms of consumer preference, market structure, seasonal change, etc. The hypothetical U.S. systems approach is projected to be similar to Canadian phytosanitary regulation for Chinese apples. Apples consumed in the U.S. and Canada will be supplied from U.S. and Canadian domestic production, Chinese excess apple supplies available for export, and all other countries in the world (Figure 5.1).

Figure 5.1 Fresh apple trade relationships between supply and demand regions



Before further adapting the model to Chinese fresh apple case, some key assumptions should be made. First, similar to other partial equilibrium models, only the variables determined by the model (defined in Table 5.2) are endogenous to the model system, while other variables or factors not defined by the general framework would all be assumed to be exogenous. Under this assumption, only the variables, like apple demand, apple supply, apple wholesale and producer price, frequency of pest outbreak, costs, are determined by the model, while other factors outside the system, like orange price, GDP rate, and apple price in Japan are all assumed to exogenous variables. Second, apples from different supply regions are assumed to be imperfect substitutes with each other. They are assumed to the same products but slightly different in freshness, appearance, tastes. Third, it is assumed to be small open economy and it will not change the world price. Apples are grown all over the world and it is one of the most common fruits. In this model, only two terminal markets, the U.S. and Canada, are considered. The production of these two countries accounted for only eight percent of the world's total in 2005 (FAO, 2007). Even though China is the world's largest apple producer, import volume to Canada in 2005 accounted for less than one percent of Canadian production and 0.1 percent of U.S. production. Total consumption of fresh apples in these two countries only accounted for 11 percent of the world's total in 2005 (FAO, 2007). It is assumed that this small volume of production and consumption in regions defined by the model is not enough to influence global apple price.

Evaluation of the key model components

The partial equilibrium model has been applied successfully to Mexican avocado case as a feasible and useful method for linking economics to the pest risk assessment. Similar to other partial equilibrium model, the parameters of the production, consumption, and prices are needed. A more detailed discussion and data availability for estimating these parameters are given later in this section. Since scientific pest risk is incorporated into the model, estimates of pest infestation probabilities would be pivotal to the economic analysis for Chinese apple case. The results from a PRA are needed to estimate these probabilities. By implementing SA policy, there are extra compliance costs undertaken by Chinese apple growers. Introducing exotic invasive species will also result in increased cost for pest control and/or production loss for apple growers in the U.S. and Canada. More discussion related to the case under consideration is provided below.

Frequency of pest outbreak

The frequency of pest outbreak is defined as the product of a series of probabilities that a pest/disease can survive during different production periods and the quantity of imports. Five stages of probabilities are needed for each pest/disease under consideration: pest infests fruit pre- or post-harvest, pest not detected during harvest or packing, pest survives shipment, pest not detected during port of entry inspection, and infested fruit is located in suitable habitat leading to outbreak. Peterson and Orden obtained the necessary data from PRA for Mexican avocados; however, there is no direct source currently available for Chinese apple case. Among all the reference policies, even though Canadian, Australian and the U.S. policies provide PRA results for certain pest/disease, they only provide qualitative pest risk results in terms of high, medium or low instead of numerical probability estimates for limited pests/diseases.

Therefore, to adapt the model to Chinese fresh apple case these probabilities must be estimated. The data from avocado case provides a starting reference. Four pests /diseases are considered in avocado case: fruit fly, seed weevil, stem weevil, and seed moth for both before and after the implementation of the Systems Approach. The data for seed moth will be most relevant to peach fruit moth (one of three pests mentioned in Chapter Four for further analysis in apple case) because they belong to the same category "Lepidoptera".[35] As for brown rot and hawthorn spider mite, the other two pests identified in Chapter Four, data from avocado case is not a reliable reference source since these two pests do not

[35] According to Table 9 in final extension of policy for the importation of pears from the Peoples' Republic of China (page 27-28), peach fruit moth and seed moth both belong to Lepidoptera category which includes moths and butterflies. As for other three pests/diseases mentioned by Peterson and Orden's model, fruit fly belongs to diptera, seed weevil and stem weevil belong to coleoptera which normally includes weevils and beetles.

belong to any similar category of pest/disease as those in avocado case. Only the data with SA implementation in the Avocado case can be used as a reference for the apple case because the avocado case assumes free trade when no SA is in place. All probabilities in avocado case have a uniform distribution and are expressed in terms of minimum, mean and maximum values. The range of probabilities varies with the type of probability and the type of pest/disease. For example, based on PRA in avocado case, the probability that Seed Moth survives shipment with SA in place has a mean value of 0.8 while the probability that Fruit Fly infests fruit pre- or post-harvest has a mean of 2.5E-06 (Peterson and Orden, 2006). Table 5.4 gives the estimations of the probabilities for peach fruit moth outbreak with the SA in place.

Table 5.4: Estimated probabilities for peach fruit moth outbreak with SA

	Minimum	Mean	Maximum
Pest infests during pre-or post harvest period	0.000005	0.0000028	0.00005
Pest survives during harvest or packing	0.00008	0.00044	0.0008
Pest survives during shipment	0.7	0.8	0.9
Pest survives during port of entry inspection	0.2	0.325	0.45
Pest outbreak in suitable habitat environment	0.00005	0.000275	0.0005

Source: Peterson and Orden, 2006.

Compliance cost for Chinese growers/exporters

Cost of implementing phytosanitary measures included in a SA is an important variable that links economics to the pest risk assessment. In Chinese apple case, it is the sum of costs of measures needed to be undertaken to implement a SA policy, like bagging the apples, registering orchards and/or packing house, monitoring the orchards, cold treatment, and getting a phytosanitary certificate and an import permit.

In avocado case, there are two types of compliance costs: compliance costs for growers and compliance cost for packers/exporters in the originating country. Compliance costs for growers are grouped into three categories: increased costs of production for approved acreage; fees paid to the local government agency for pest surveys and fruit fly trapping to establish and maintain certification to participate; and loss of fruit sorted out during inspections. Compliance costs for packers/exporters are grouped into four categories: investments to establish fruit fly quarantine conditions at the plant; operating costs of certification and fruit fly protection during picking and processing; costs for inspectors to cut fruit and undertake other quarantine activities; and fees to reimburse APHIS for its inspection cost and for a product promotion program.

However, for apple case, it is quite difficult to find all the data in such a detail since the U.S.-China fresh apple trade has never started, secondary-or even primary-data does not exist. To get a cost estimate, a good option is to refer to the compliance cost for apples exported to Canada. There are currently only a few big companies in China approved to export fresh apples to Canada due to strict phytosanitary requirements.[36] Statistically speaking, such a small sample size can hardly provide accurate and sufficient data. Cost varies according to, for example, the size and capacity of the company, the production area, subsidies from the government ("Guanxi" with the government), inspection ability, and type of pest control program chosen. In addition, since the SA is applied throughout all the periods of production, storage, packing and shipment, cost data for every phytosanitary

[36] Such as Longkou Fook Huat Tong Kee Fruit Co., Ltd in Shandong province, and Huasheng Fruit Co., Ltd in Shaanxi province.

measure is not available directly. The market information system is still under construction in China. Projects or programs like those in avocado case are not available. Chinese government has started setting up a market price system for fruit and vegetables, however, in terms of cost (especially the cost of phytosanitary measures), there is no direct source of information.

Cost of control measures and pest damage in the U.S.

Cost of mitigation measures in the importing country depends on the specific phytosanitary measures included in a systems approach for Chinese fresh apples. Given the probability that an invasive species might be introduced, spread, and established, domestic plants in the importing country might also be infested and certain production losses may occur. The cost for growers in an importing country to prevent production loss from invasive species should be included in the model. Several key parameters are considered: the percentage of total production impacted by infestation, the production loss due to the infestation of particular pest/disease, and the pest control cost due to infestation.

As mentioned in Chapter four, the infestation rate for peach fruit moth in China ranges from 10 percent to 30 percent in middle of Yellow River old river way and Northwest Yellow Plateau area. In Bohai Bay apple production area, which has relatively higher management technology, the infestation rate is as low as three percent. For brown rot, Moore (1950) recorded an average of about nine percent of apple fruit become infected with brown rot. No data has been identified to provide infestation rates for hawthorn spider mite. There is no updated data for the infestation rate for any of these three pests. Similarly, there is little literature related to production loss for the three pests we are interested in. In avocado case, Peterson and Orden estimated the cost of controlling the fruit fly infestation and productivity losses based on an existing regulatory control program. Then they applied this estimated cost to other supply regions in the U.S for Fruit Fly. However, in apple case, there is no similar regulatory control program since trade is still in the early stage of negotiation. In addition, Peach Fruit Moth, as discussed in Chapter four, is mainly spread in Asia and still considered an exotic pest to the U.S. There are limited resources and data regarding to this pest.

Other issues

Some other parameters in the general framework (Table 5.2) are also essential to the model. First is the elasticity. The elasticity of substitution and transformation are applied to the model's demand and supply equations to replicate the baseline quantities, prices, and yield shift parameter values (USDA/APHIS, 2004b). From the demand side, two kinds of elasticity are needed for the model: the aggregate demand elasticity of substitution between fresh apples and all other goods; and the demand elasticity of substitution between apples from different supply regions. The demand for fresh apples in each demand region is derived from a heterogeneous utility function for a representative consumer where consumers are assumed to view fresh apples from different supply regions as slightly different products due to the variance in price, appearance, freshness and taste. Little empirical evidence exists for fresh apple demand elasticity. Table 5.5 lists several kinds of demand elasticity for apples from USDA/ERS online elasticity data set. The apple own price demand elasticity ranges from -0.7 to -0.122 with a mean of -0.35838. In a partial equilibrium model, the change in apple price represents the change in relative prices when holding the prices of all other goods constant. Thus the overall price (index) change can lead to the consumer to change apple consumption (Peterson and Orden, 2006). This price elasticity could be used to generate aggregate demand elasticity for apples from all supply regions according to the U.S. share of total supply. Then this own-price elasticity and aggregate demand elasticity could be used to determine the two values of elasticity mentioned above during the model calibration, elasticity of substitution between apples and all other goods and one between apples from different supply regions.

From the supply side, the elasticity of transformation is also needed for the model to capture the possibility for producers to shift avocado sales between different time periods as relative price changes. Roosen (1999) estimated the total supply response elasticities for fresh apple production were 0.306, 0.346, 0.868 and 0.638 for Northwest, Southwest, Central and East region of the U.S. respectively in a short run. These numbers could be used to determine aggregate supply elasticity for apples from all supply regions based on their share of total supply.

Table 5.5: Demand elasticity of fresh apples in the U.S.

	Minimum	Maximum	Mean	Standard Deviation
Apple own price	-0.7	-0.122	-0.35838	0.22444
Apple income	0.04	0.14	0.09	0.07071
Apple expenditure	-0.206	0.8808	0.161	0.62341
Fruit other cross price	-0.0598	0.0591	-0.0151	0.06471
Food other cross price	-0.3143	0.0766	-0.11885	0.27641
Nonfood cross price	0.1997	0.1997	0.1997	

Source: USDA/ERS, 2007.

A second issue of importance is the apple variety. In avocado case, Hass avocados account for nearly 85 percent of all avocados consumed in the U.S. In contrast, apple is one of the most popular and common fruits and there is no a particular dominant variety in both the U.S. and Canadian market. Most of the Chinese fresh apples for export are Fuji, so it is likely that the major variety of Chinese apples that would enter the U.S. market is Fuji. However, it is not realistic to restrict our target to only one variety compared with the large apple production and demand quantity. Even if no variety in particular was identified in the model, the large number of apple varieties and variance among different varieties presents difficulties in collecting data. For example, computation of apple wholesale price in the U.S. is very data-intensive. In addition, some varieties have an obvious higher price than other varieties in some markets. For instance, wholesale price of Honey Crisp from Michigan is as high as 87.5 cents/lb in Atlanta market on November 19, 2005, while at the same time, the wholesale price of Rome apples from Georgia is as low as 32.5 cents/lb. Aggregating there values may mask important differences and give misleading results.

5.2.3 Limitations to adaptation

Based on the discussion above, the partial equilibrium model would be one approach for evaluating the potential impact of opening the U.S. market to Chinese fresh apples. However, lack of a PRA, the early stage of discussions over this trade issue and data intensive requirements of the model limits its empirical application. The most important limitation is lack of a PRA or no official Systems Approach implemented before the economic evaluation. From the political point or view, the U.S. and Chinese government are still negotiating the issue. Since everything is still not open to the public (and much data does not yet exist), important information is lacking for economic assessment. For example, without the official SA, it is not clear about what kind of phytosanitary measures are being implemented in China to control the risk, which make estimating the compliance cost directly impossible and less accurate. The on-going negotiation between the governments also increases the difficulty. The sensitive political nature of the issue even limits information available through interviewing those government and industry in both the U.S. and China. In addition, from scientific point of view, according to FAO, the pest risk assessment is the basis for economic evaluation. Unlike avocado case, there is no government pest risk assessment available for public in apple case. The PRA for Chinese fresh apples is still undergoing development and review from scientists in both countries. The most important information like the probability of pest infestation has to be assumed according to PRA for other commodity, which greatly restricts the accuracy of model.

Second, similar to the lack of SA policy, import of Chinese apples to the U.S. has never existed, which further restricts economic evaluation. In the general framework, welfare is compared different time periods. For Chinese apple case, all the data in second period related to import are lacking where, by assumption, there was potential imports under the regulation of a SA. Most of the data like import volume and price have to be be assumed. Further information, like where the Chinese apples would go within the U.S. and how the U.S. consumers would like the Chinese apples (demand elasticity between apples from different regions) are also missing.

In addition, apple is a more popular fruit than avocado, which makes this Chinese apple case much more complicated than avocado case. From consumption point of view, apple is one of the most popular fruits among U.S. consumers. In contract, avocado is less popular. There are only a few avocado varieties in the market where Hass avocado accounts for more than 85 percent. In contract, there are nearly 100 varieties of apples are grown commercially in the U.S. and about 7,500 varieties throughout the world (University of Illinois, 2007). Therefore, it is difficult to estimate the demand elasticity and other parameters. From production point of view, avocado production in the U.S. is quite concentrated (mainly in California). However, as for apples, there are as many as 35 states currently growing apples. In the case of pest outbreak, all apple producing states would at least be susceptible to infestation and it is harder to estimate the production loss and corresponding cost.

5.3 Sensitivity analysis for selected types of parameters

Based on the discussion above, it is difficult to fully adapt the partial equilibrium model to Chinese fresh apple case at this point. Some important data and information for analysis are unavailable without an official SA policy and actual trade existing. Data intensiveness and case-to-case difference limit the empirical applications of the model. In this section, instead of fully adapting the partial equilibrium model, a simple sensitivity analysis will be performed to find out how sensitive the model is and how the results will change with some particular parameters. Input data is first provided in this section, which includes the quantity demanded, total supply, wholesale price, producer price and also income, expenditure and population information. Then parameters for sensitivity analysis are described and estimated based on three scenarios identified in Chapter Four. Three types of parameters are considered for the sensitivity analysis: first, the probabilities of introducing pest/disease associated with the Chinese fresh apples; second, the compliance cost undertaken by Chinese apple growers; third, the pest control cost undertaken by U.S. apple growers in the case of pest outbreak. Results of sensitivity analysis and model calibration are provided below.

Input data for sensitivity analysis

To implement the partial equilibrium model, a set of input data including quantity and prices are required to present initial market equilibrium (Table 5.6 (a) and Table 5.6 (b)). Apple quantity demanded (in million lbs) refers to consumption for fresh apples[37] from different supply regions. In period 1, the U.S. import of Chinese apples is banned. In period 2, U.S. import volume is estimated according to the proportion of total U.S. to Canada apple imports (U.S.: Canada=9.81:1). Total (base) supply for each supply regions refers to quantity of production or import in demand regions, the U.S. and Canada.

Wholesale prices are the weekly average data (September to November in 2004 and 2005) at representative terminal markets in the U.S. and Canada. All apple varieties are considered. For simplicity, only data for apples in tray pack cartons are used. In period 2, wholesale price in the U.S. for apples from China is assumed to be the same as the

[37] Only fresh apple consumptions are considered in this model. Sometimes, only aggregate data of fresh apple consumption are available. In this case, consumptions by demand and supply regions are adjusted according to the proportion of domestic production and import quantity/origin. For example, the total U.S. fresh apple consumption in 2004 is 5605.67 million lbs, among of which 5455.24 million lbs (97 percent) are domestically produced. Among other three percent, about 150.43 million lbs of imported apples, only 35.12 are from Canada. Therefore, the others are from the rest of the world, about 115.31 million lbs.

Canadian apples imported from China. According to price data available in Agriculture and Agri-food Canada (AAFC), Chinese apples do not have a price advantage in terminal markets over other apples even though producer price is much lower. In general, wholesale price in Canada (except for domestically produced apples in Canada) is higher than that in U.S. market.

Producer prices for apples from different supply region are slightly different depending on the data source, especially for Chinese apples. In this model, since only the Chinese apples for export purpose are considered, the producer price should be higher than the national average producer price. Based on the estimated production cost for Chinese apples in Shandong province, the producer price is set equal to the production cost for simplicity, which is 15 cents and 16 cents per lb in 2004 and 2005, higher than the cost of production in other (i.e. not export-oriented) regions of China. Even so, costs in Shandong are still lower than that for apples from U.S., Canada, and the rest of the world. Sources for apples from other regions are listed in the table below.

In addition, income and population data are needed. Table 5.6 (b) lists the data and sources. At last, per capita expenditure for apples in each demand region is calculated based on the data of wholesale price, population and base supply (Table 5.6(b)).

Table 5.6(a): Input data in the model

Description	Parameters	Values			
Quantity Demanded[1] (Million lbs)		**U.S.**	**Canada**	**China**	**Rest of the world***
Period 1	$q1_{i,j}$ **				
The U.S.		5455.24	35.12	0.00	115.31
Canada		249.83	530.26	8.19	80.93
Total (base) supply	$yb1_j$	**5705.07**	**565.38**	**8.19**	**196.24**
Period 2	$q2_{i,j}$				
The U.S.		4769.74	74.47	77.76	107.02
Canada		289.32	521.76	7.93	53.46
Total (base) supply	$yb2_j$	**5059.07**	**596.23**	**85.68**	**160.48**
Wholesale prices ($/lb)		**The U.S.**	**Canada**	**China**	**Rest of the world***
Period 1	$pb1_{i,j}$				
The U.S.[2]		0.53	0.66	0.66	0.52
Canada[3]		0.73	0.64	0.69	0.80
Period 2	$pb2_{i,j}$				
The U.S.		0.57	0.70	0.70	0.54
Canada		0.78	0.64	0.59	0.77
Producer prices[4] ($/lb)					
Period 1	$pp1_j$	0.273	0.216	0.15	0.29
Period 2	$pp2_j$	0.217	0.216	0.16	0.33

[1]Source: Author's calculation.

[2]Source: Agricultural marketing services, US Department of Agriculture online dataset (USDA/AMS, 2007). Six markets are chosen as representatives: Atlanta, Boston, Chicago, San Francisco, Detroit, and New York. Weekly data is be used through September to November in 2004 and 2005. Cartons tray pack is considered during the calculation, which has been converted into pounds according to standard conversion (40 pounds per carton tray pack for net weight).

[3]Source: Agriculture and Agri-Food Canada (AAFC, 2008a). Nine terminal markets are chosen: St. John'S, Winnipeg, Regina, Saskatoon, Calgary, Edmonton, Vancouver, Ottawa, and Moncton.

[4]Source: Fruit and tree nut yearbook (USDA, 2006) for the U.S.; Agriculture and Agri-Food Canada (AAFC, 2008b) for Canada; author's calculation for China; FAO online dataset for Rest of the world.

Notes: * For quantity demanded and wholesale prices, the rest of the world refers to all the other countries that export apples to the demand country. For producer price, the rest of the worlds refer to nine world's big apple producing countries including Turkey, France, Poland, Italy, the Russian Federation, Germany, Argentina, Japan, and Chile.

** Subscript *i* denote demand regions, the U.S. and Canada. Subscript *j* denotes supply regions, the U.S., Canada, China, and the rest of the world. For example, $q1_{US,China}$ denotes the per capital demand of apples in the U.S. from China import.

Table 5.6(b): Input data in the model (Continued)

Description	Parameter	Values	
		The U.S.	Canada
Per capital income ($/year)[1]			
Period 1	$inc1b1_i$	33,050	28,310
Period 2	$inc1b2_i$	34,586	32,600
Population[2]			
Period 1	$pop1_i$	293,655,404	31,989,454
Period 2	$pop2_i$	296,410,404	32,299,496
Per capita apple expenditure ($/year)[3]			
Period 1	$exp1_i$	10.13	18.51
Period 2	$exp2_i$	9.73	18.74

[1]Sources: Infoplease online data source (2008); Statistics Canada (2004); World Bank (2008).
[2]Source: Wikipedia.(2008); Factmonster online data source (2008); U.S. Census Bureau (2008).
[3] Source: Author's calculation.

Model assumption and estimation for selected parameters for different scenarios

Based on the discussion in the last Chapter, three scenarios will be considered as part of the sensitivity analysis. Scenario 1 only considers thirteen common measures in the SA that have been mentioned by most of the reference policies (high risk); scenario 2 adds six more measures which are mentioned less frequently (medium risk); and scenario 3 includes all thirty four measures that are mentioned by at least one of the polices (low risk). As discussed in Chapter Four, different scenarios imply different probability of pest infestation, compliance cost for Chinese growers, and pest control cost for growers in the importing country (Table 4.8).

General assumptions about the model discussed earlier (section 5.22) still hold for sensitivity analysis. [38] Variables adjusted for each scenario include probability of infestation and cost of compliance both in U.S. and China (Table 5.7). Probabilities of introducing pest/disease are one of the most important parameters for the model. For the U.S., trade is banned in the first period, so the probability of pest infestation is very low even though there is no SA in place. However, it is still possible that pest (like Peach Fruit Moth) could be introduced indirectly, for instance, along with other fruits. However, the data of this probability is not available.[39] For simplicity, these probabilities are assumed to be the minimum value of probabilities when there is SA. The overall probability after periods of harvest, packaging, storage, shipment to the boarder is 2.8E-15. In the second period, the ban is lifted according to our assumption. Based on the discussion earlier, probability data for Seed Moth in Mexican avocado case is used as corresponding data for Peach Fruit Moth in Chinese fresh apple case. The overall probability now goes to 8.8088E-13 on average.

[38] The assumptions are: first, on the variables determined by the model itself are endogenous to the model system and other variables are assumed to be exogenous; second, apples from different supply regions are assumed to be imperfect substitutes with each other; third, it is assumed to be a small economy and it will not change the world's price.

[39] For Avocado case, the probabilities without a SA are provided. However, they cannot be applied to Chinese apples since trade exists for avocado case even though there is no SA in place.

Table 5.7 Trade situation, cost and risk level between periods and scenarios

	Period 1 (2004)	**Period 2** (2005)
Scenario 1 (High risk)	Base period, no trade, no SA	Trade, high risk, low cost
Scenario 2 (Medium risk)	Base period, no trade, no SA	Trade, medium risk, medium cost
Scenario 1 (Low risk)	Base period, no trade, no SA	Trade, low risk, high cost

Cost related parameters are also important for sensitivity analysis. As discussed in the last section, it is difficult to estimate the compliance cost for a SA undertaken by Chinese growers. Instead, cost is estimated according to the percentage increase in total cost if a SA were to be implemented. Table 5.8 shows the average cost for growing apples in China and in Shandong province in 2004. On average in China, total cost is estimated to be US$2,429 per hectare. The cost in Shandong province is used for the model, which is higher than national average, US$4,422 per hectare. This is because that Shandong is the one of a few provinces in China capable of exporting apples to the EU, Australia and Canada, which have relatively higher requirements for food safety and standards. Among export markets Russia and some other counties in Southeast Asia have less restrictive requirements than Canada and the EU. Therefore, the production cost in Shandong is higher than the national average. Cost consists of three parts: material cost, labor cost and land cost. Among these three parts, only material cost (like pesticide) and labor cost (like bagging the apples) will increase with the implementation of SA policy. The land cost or rent does not vary with crop planted or production measures employed. Therefore, only production cost in Shandong province is used to estimate the compliance cost, which is converted to 16.74

cents per lb in 2005.[40] Since this cost has included the extra cost of compliance for measures needed for producing apples for export purpose, it is assumed that the cost of implementing SA for the U.S. market is another one to five percent higher, adding 0.167 cents to 0.837 cents per lb.

Table 5.8: Apple production cost and SA compliance cost in China in 2004 (US$ per hectare)

Item		Average cost	Shandong
Material cost		1,154	2,414
Labor cost		1,109	1,862
	Family labor	893	1,424
	Hired labor	216	437
Total production cost		**2,263**	**4,276**
Land cost		166	146
	Rent of lease land	11	1
	Rend for own land	155	146
Total cost		2,429	4,422

Source: Author's calculation. NDRC, 2005. Data was converted into U.S. dollars according to the exchange rate 8.2768US$ per RMB in 2004 (RMB guide, www.rmbguide.com).

Pest control cost due to pest infestation in the importing regions also needs to be estimated. Similarly, cost is estimated indirectly based on percentage of total production cost. Table 5.9 provides the basic apple production cost data in Washington State.[41] Cost is divided into two parts, production cost and packing and marketing cost. Production cost for an acre of apples is reported to range from $4,800 to $6,600 per acre in 2002. Greatest expenses are labor for picking, pruning and hand fruit thinning. Packing and marketing costs add an additional $4,410 to $5,250 per acre of production, about half of which is labor costs

[40] Data in 2005 is obtained by adjusting the number in 2004 according to the production price index.
[41] Washington State produced approximately 60 percent of U.S. apples between 2001 and 2005.

(Washington State University, 2002). Adjusted from the data in 2002, it is assumed that the production cost for U.S. growers will range from $5,132 to $7,057 in 2004 and $5,381 to $7,399 in 2005 based on the producer price index in the U.S. It is assumed that the pest control cost will be one to five percentage of production cost in the case of pest outbreak (Table 5.9).[42] As for production loss and infestation rate in case of pest outbreak, estimates range from one to three percent (Table 5.10).

As for other parameters like elasticity, the sensitivity results and estimations of Mexican avocado case are applied or adjusted to Chinese apple case for simplicity. More detailed application of the model (variables, parameters, and demand and supply calibration) is described in Appendix 3.

Table 5.9: Apple production costs and pest control costs in the U.S. (US$ /acre)

Item	Minimum	Average	Maximum
Production cost in 2002	4,800	5,700	6,600
Packing and marketing costs including labor	4,410	4,830	5,250
Total Cost	9,210	10,530	11,850
Adjusted production cost in 2004	5,132	6,094	7,057
Adjusted production cost in 2005	5,381	6,390	7,399

Source: Washington State University, 2002; Glover, *et al.*, 2002; Data in 2002 has been adjusted according to Grower Price Index 2002-2005.

[42] Only the extra cost due to pest outbreak of Peach Fruit Moth is considered.

Table 5.10: Estimated parameters in the sensitivity analysis

Description	Parameter	Values		
Probabilities				
Without SA*, without trade (Period 1)				
Pest infests during pre-or post harvest period	*prob*1	0.000005		
Pest survives during harvest or packing	*prob*2	0.00008		
Pest survives during shipment	*prob*3	0.7		
Pest survives during port of entry inspection	*prob*4	0.2		
Pest outbreak in suitable habitat environment	*prob*5	0.00005		
Probabilities		**Scenario 1**	**Scenario 2**	**Scenario 3**
Trade with SA (Period 2)**				
Pest infests during pre-or post harvest period	*probsa*1	0.00005	0.0000028	0.000005
Pest survives during harvest or packing	*probsa*2	0.0008	0.00044	0.00008
Pest survives during shipment	*probsa*3	0.9	0.8	0.7
Pest survives during port of entry inspection	*probsa*4	0.45	0.325	0.2
Pest outbreak in suitable habitat environment	*probsa*5	0.0005	0.000275	0.00005
Pest control cost in U.S.		**Scenario 1**	**Scenario 2**	**Scenario 3**
Production loss from infestation	*ploss*	3%	2%	1%
Percentage of production affected by infestation	*pctef*	3%	2%	1%
Pest control cost in period 1 (Cents per lb)	*controlc*1	0.819	0.546	0.273
Pest control cost in period 2 (Cents per lb)	*controlc*2	0.651	0.434	0.217
Extra compliance cost (China)		**Scenario 1**	**Scenario 2**	**Scenario 3**
Compliance cost of implementing SA (Cents per lb)	*pcost*	0.837	0.502	0.167

Comparison of market equilibrium and welfare

Sensitivity analysis is performed based on currently available data and above estimations. The purpose of this section is to find out how the market equilibrium quantity, price, and welfare changes due to the change in selected parameters. First, welfare change, including change in producer surplus, consumer surplus and extra pest control cost are compared between period 1 and period 2 for each scenario. Appendix 3 explained in detail how the consumer surplus and producer surplus are calculated. Next, in addition to the comparison within a scenario between two periods, what is interesting is changes between different scenarios with different cost and probabilities applied. This is the main purpose of the sensitivity analysis.

Therefore, two parts (types) of analysis are performed in this section. First, within one scenario, the analysis will focus on how the quantity of supply, demand and corresponding prices change between two periods. Results for only one scenario (for example, scenario 2 with medium risk) are shown in Table 5.11 since the direction and trends in change between periods are consistent among scenarios. Second, between alternative scenarios, the analysis will focus on how simulated equilibrium change with the change in risk of infestation and cost. Net welfare change differs between scenarios and the discussion of whether U.S. consumers and apple producers gain or lose with the change are provided.

Comparison of market equilibrium between two periods (scenario 2)

Table 5.11 provides the market equilibrium results between two periods in scenario 2. At the producer level, there is a decrease in quantity of U.S. apple supply, from almost 5340 million lbs in period 1 to over 4750 million lbs in period 2. This is also reflected by reduced producer price, from 38.1 cents to 30.5 cents per lb. This is consistent with the change in input data where both the quantity of supply and producer price are decreased in period 2. The decrease can also be explained by the increase in risk of pest infestation and potential pest control cost with the market opening for Chinese fresh apples in period 2. Producer's gross yearly revenue decreases by $585.6 million. And change in producer surplus is $-384.838 million. For Chinese growers, producer price increases from 11.5 cents to 17.9 cents per lb. The difference is much higher than the difference in input data (55.7 percent vs. 6.7 percent). It is because of the increase of export volume to U.S. market (under the assumption).[43] It indicates that market opening benefits Chinese growers. The expanded export leads to the producer gross revenue increase by $17.4 million. For growers in Canada and the rest of the world, there is no extra cost and pest infestation considered, the change in equilibrium producer price and supply are also basically consistent with the initial equilibrium.

From the consumer perspective, U.S. consumer demand for domestically produced apples declines by 11.4 percent in period 2, which can be reflected by increased wholesale prices. This is basically consistent with then trend in input data. Due to market opening, U.S. consumer demand for Chinese apples increases to 91.73 million lbs with wholesale price at 72.4 cents per lb. U.S. demand for Canadian apples increases from 41.17 to 79.93 million lbs even though the wholesale price increases by 7 cents. U.S. demand for apples from Canada and the rest of the world are replaced by some shipments from China. In Canadian

[43] Note that the producer price for Chinese growers in period 1 is in the case that no trade exists. In period 2, after market opening, the increase in export volume leads to an larger increase in producer price for Chinese apple growers.

market, the input data shows that the Canadian demand for U.S. apples increases in the second period. However, simulated equilibrium shows this demand decreased by 2.3 percent, which can also be reflected by the wholesale price with 3.3 percent's increase. It can be explained by the decrease in U.S. total supply in the second period and thus the decrease in export quantity to Canada due to market opening. Decreased U.S. supply in Canada is substituted with the apples from domestic production, China and the rest of the world. Demands from these three regions all increase even though, in input data, the demand from these regions all more or less decrease.

Table 5.11: Market equilibrium between two periods (scenario 2 with medium risk)

	Period 1 (No Trade) Input value	Results[1]	Period 2 (With trade) Input value	Results	Change between periods (Period 2 minus period 1) Input value	Results
Quantity of Supply (Million lbs)						
The U.S.	5705.07	5339.914	5059.07	4750.530	-646.0 (-11.3%)	-589.4 (-11.0%)*
Canada	565.38	573.085	596.23	616.674	30.9 (5.5%)	43.6 (7.6%)*
China	8.19	10.281	85.68	103.943	77.5 (946.2%)	93.7 (911.0%)*
Rest of the world	196.24	218.542	160.48	187.410	-35.8 (-18.2%)	-31.1 (-14.2%)*
Producer prices ($/lb)						
The U.S.	0.273	0.381	0.217	0.305	-0.056 (-20.5%)	-0.076 (-19.9%)*
Canada	0.216	0.267	0.216	0.278	0	0.011 (4.2%) *[1]
China	0.15	0.115	0.16	0.179	0.01 (6.7%)	0.064 (55.7%)[2]
Rest of the world	0.29	0.333	0.33	0.417	0.04 (13.8%)	-0.084 (-25.2%)
Quantity of demand (Million lbs)						
The U.S.						
(Origin)The U.S.	5455.24	5119.120	4769.74	4534.843	-685.5 (-12.6%)	-584.3 (-11.4%)*
Canada	35.12	41.173	74.47	79.929	39.4 (112.0%)	38.8 (94.1%)*
China	0	0	77.76	91.730	77.8	91.7*[1]
Rest of the world	115.31	133.731	107.02	101.886	-8.3 (-7.2%)	-31.8 (-23.8%)
Canada						
(Origin)The U.S.	249.83	220.794	289.32	215.687	39.5 (15.8%)	-5.1 (-2.3%)
Canada	530.26	531.912	521.76	536.745	-8.5 (-1.6%)	4.8 (0.9%)
China	8.19	10.281	7.93	12.213	-0.3 (-3.2%)	1.9 (18.8%)
Rest of the world	80.93	84.811	53.46	85.523	-27.5 (-33.9%)	0.7 (0.8%)

Table 5.11: Market equilibrium between two periods (scenario 2 with medium risk) (continued)

	Period 1 (No Trade) Input value	Results	Period 2 (With trade) Input value	Results	Change between periods (Period 2 minus period 1) Input value	Results
Wholesale prices ($/lb)						
The U.S.						
(Origin)The U.S.	0.53	**0.644**	0.57	**0.662**	0.04 (7.5%)	**0.018 (2.8%)***
Canada	0.66	**0.711**	0.7	**0.762**	0.04 (6.1%)	**0.051 (7.2%)***
China	0.66	**0.630**	0.7	**0.724**	0.04 (6.1%)	**0.094 (14.9%)***
Rest of the world	0.52	**0.563**	0.54	**0.627**	0.02 (3.8%)	**0.064 (11.4%)***
Canada						
(Origin)The U.S.	0.73	**0.844**	0.78	**0.872**	0.05 (6.8%)	**0.028 (3.3%) ***
Canada	0.64	**0.691**	0.64	**0.702**	0	**0.011 (1.6%) ***
China	0.69	**0.660**	0.59	**0.614**	-0.1 (-14.5%)	**-0.046 (-7.0%)***
Rest of the world	0.8	**0.843**	0.77	**0.857**	-0.03 (-3.8%)	**0.014 (1.7%)**
Producer gross revenue (Million $)						
The U.S.						
(Origin)The U.S.	1557.484	**2034.507**	1097.818	**1448.912**	-459.7 (-29.5%)	**-585.6 (-28.8%)***
Canada	122.122	**153.014**	128.786	**171.435**	6.7 (5.5%)	**18.4 (12.0%)***
China	1.229	**1.182**	13.709	**18.606**	12.5 (1015.5%)	**17.4 (1474.1%)***
Rest of the world	56.910	**72.774**	52.958	**78.150**	-4.0 (-6.9%)	**5.4 (7.4%)**

Notes: * denotes that the results are basically consistent with the input value. For the results that are not consistent are explained in the text。

1 The results of the model are all from GAMS (General Algebraic Modeling System) software. It is not statistical or econometric software, thus no statistical results like t-stat or p-value are provided. The results are shown in the terms of "minimum","level","maximum" and "marginal". The "min" and "max" value are set in the input to restrict the output within a reasonable range. The "level" is the optimal value and "marginal" shows the distance between the optimal value and the current "level" value. All the results are shown as "." For "marginal", which means zero marginal, thus the value in "level" is an optimal value. This is the same for all the results through Table 5.11to Table 5.13.

Comparison of market equilibrium and welfare between alternative SA (among scenarios)

Market equilibrium price, quantities and welfare change are listed in Table 5.12 and Table 5.13 for all three scenarios. The discussion will compare impacts of SA (along alternative low risk, medium risk, and high risk) after imports from China are allowed (i.e. the second period for each SA) since the change in risk of pest infestation and cost mainly occurs in this period. For completeness, all results are provided, period 1 and 2 in Table 5.12 and difference between periods in Table 5.13.

Compared with scenario 1, U.S. quantity of apple supply increases by 12.789 million lbs (0.27%) in scenario 2 and another 12.69 million lbs (0.27%) in scenario 3.[44] This is mainly in response to increase in the production loss due to pest infestation. Producer price received by U.S. apple growers reduces by 0.2 cents (0.65%) in scenario 2 and another 0.2 cents in scenario 3. U.S. producer gross revenue increase by $1.379 million in scenario 2 and continue to increase by another $1.376 million in scenario 3. Producer surplus is increased by $0.892 million in scenario 2 and another $0.964 million in scenario 3. This indicates that the lower risk has positive effect on U.S. growers. The more measures included in a SA, the small probability of introducing a pest into the U.S., and thus the less production loss. For Chinese growers, increased compliance cost leads the supply to decrease by 2.40 million lbs (2.3%) in scenario 2 and another 2.33 million lbs in scenario 3. Producer price correspondingly increases by 0.25 cents (1.7%) in scenario 2 and another 0.25 cents in scenario 3. Gross revenue declines 0.175 million dollars in scenario 2 and

44 Most of the differences among scenarios are linear because the cost and probability vary in a linear way under our assumption. For example, the production loss from infestation in the U.S. is three percent (scenario 1), 2 percent (scenario 2), and 1 percent (scenario 3).

0.172 million dollars in scenario 3. Increased compliance cost for Chinese growers has negative effects on their revenue and surplus. There is not much difference in quantity of supply and producer price for apples from Canada and the rest of the world since there is no cost or pest risk considered for these two regions.

Quantity of U.S. apple demanded in the U.S. market increase 11.49 million lbs (0.3%) in scenario 2 and another 11.39 million lbs in scenario 3. Corresponding wholesale price decreases by 0.387 cents (0.6%) in scenario 2 and another 0.4 cents in scenario 3. Demand for Chinese apples declines by 2.15 million lbs (2.3%) in scenario 2 (another 2.1 million lbs in scenario 3) and wholesale price increases by 0.6 cents (0.8%) in scenario 2 (another 0.6 cents in scenario 3). For apples from Canada and the rest of the world, there is no change in wholesale price and the changes in quantity of demand are both around 0.7%. Total consumer surplus for U.S. consumers declines by $4.529 million in scenario 2 and another $4.815 million in scenario 3. In Canadian market, there is no big change in wholesale prices and quantity of demand. From scenario 1 to 2, Canadian consumers lose $0.36 million in consumer surplus and another $0.384 million from scenario 2 to scenario 3.

Extra pest control cost is applied to U.S. apple growers in the second period, which should be considered when calculating the net welfare change. Multiplying the simulated quantity by cost per lb, total simulated pest control cost is $10.234 million in scenario 1. The cost increases to $20.522 million in scenario 2 and $30.866 million in scenario 3. The change in producer surplus for U.S. growers increases $0.892 million from scenario 1 (high risk) to scenario 2 (medium risk) and another $0.964 million in scenario 3 (low risk).[45] These results are consistent with our expectation because U.S. growers are better off due to the reduced risk and lower compliance cost. For Chinese growers, the producer surplus decrease $0.142 million in scenario 2 and another $0.137 million in scenario 3. This indicates that Chinese growers are worse off due to the increase number of measures include in a SA, which is also consistent with our expectation. Net welfare change decreases $3.277 million from scenario 1 to scenario 2, which means that the gain in producer surplus is less than the loss in consumer surplus plus extra pest control cost. This also means the change in welfare between two periods in scenario 2 is bigger than in scenario 1. The same situation occurs from scenario 2 to scenario 3.

In general, the simulation results are consistent among three scenarios. The changes are also in accordance with economic theory. Based on the above results, it can be concluded that adjustments in risk probability and cost of compliance between scenarios have an almost linear impact on prices and welfare. For most of the results, the changes in relative value or the trend are more important than the absolute value. For instance, the welfare change in absolute values are all around 500 million dollars for three scenarios, which is not a small number compared with the annual apple import values of $215 million in 2004 (FAO, 2007) and the annual apple export values of $500 million (USDA/ERS, 2008). However, this number is not so meaningful since it is calculated as a difference in welfare between two periods in each scenario where most of the trade data do not exist in reality.

[45] Note that the welfare change (including gross revenue, producer surplus and consumer surplus) is calculated as the difference between welfares in two periods (before and after the trade). So the bigger welfare change means that the welfare increase/decease more than that in another scenario.

What we are really interested in for this sensitivity analysis is to see the change between scenarios. The results show that there is about $3.5 million difference in absolute value between scenarios, which is reasonable compared with the trade value mentioned above. In terms of relative values, the change is about 0.6 percent, which is also reasonable considering the small amount of Chinese apples that are allowed to enter the U.S. by assumption. The change in probabilities, compliance cost and pest control cost leads to changes in market equilibrium and welfare, but the changes are reasonable.

Table 5.12: Market equilibriums simulation results under alternative SA

	Scenario 1: High risk Value	Scenario 2: Medium risk Value	Change	Scenario 3: Low risk Value	Change
Quantity of Supply (Million lbs)					
Period 1 (No Trade, no SA)					
The U.S.	5325.341	5339.914	14.573	5354.603	14.689
Canada	574.622	573.085	-1.537	571.544	-1.541
China	10.505	10.281	-0.224	10.063	-0.218
Rest of the world	219.831	218.542	-1.289	217.258	-1.284
Period 2 (Trade under hypothetical SA)					
The U.S.	4737.741	4750.530	12.789	4763.215	12.685
Canada	618.147	616.674	-1.473	615.214	-1.46
China	106.341	103.943	-2.398	101.613	-2.33
Rest of the world	188.344	187.410	-0.934	186.484	-0.926
Producer prices (cents/lb)					
Period 1 (No Trade, no SA)					
The U.S.	38.322	38.116	-0.206	37.910	-0.206
Canada	26.702	26.666	-0.036	26.630	-0.036
China	11.168	11.519	0.351	11.870	0.351
Rest of the world	33.391	33.316	-0.075	33.240	-0.076
Period 2 (Trade under hypothetical SA)					
The U.S.	30.656	30.488	-0.168	30.322	-0.166
Canada	27.785	27.765	-0.02	27.745	-0.02
China	17.620	17.869	0.249	18.120	0.251
Rest of the world	41.708	41.689	-0.019	41.672	-0.017
Quantity of demand (Million lbs)					
Period 1 (No Trade, no SA)					
The U.S.					
(Origin)The U.S.	5106.185	5119.120	12.935	5132.155	13.035
Canada	41.598	41.173	-0.425	40.749	-0.424
China	0.0	0.0	0	0.0	0
Rest of the world	134.903	133.731	-1.172	132.565	-1.166
Canada					
(Origin)The U.S.	219.156	220.794	1.638	222.448	1.654
Canada	533.024	531.912	-1.112	530.795	-1.117
China	10.505	10.281	-0.224	10.063	-0.218
Rest of the world	84.928	84.811	-0.117	84.693	-0.118

Table 5.12: Market equilibriums simulation results under alternative SA (continued)

	Scenario 1: High risk	Scenario 2: Medium risk		Scenario 3: Low risk	
	Value	**Value**	**Change**	**Value**	**Change**
Period 2 (Trade under hypothetical SA)					
The U.S.					
(Origin)The U.S.	4523.357	4534.843	11.486	4546.229	11.386
Canada	80.551	79.929	-0.622	79.317	-0.612
China	93.884	91.730	-2.154	89.638	-2.092
Rest of the world	102.673	101.886	-0.787	101.108	-0.778
Canada					
(Origin)The U.S.	214.384	215.687	1.303	216.986	1.299
Canada	537.596	536.745	-0.851	535.897	-0.848
China	12.457	12.213	-0.244	11.975	-0.238
Rest of the world	85.671	85.523	-0.148	85.376	-0.147
Wholesale prices (Cents/lb)					
Period 1 (No Trade, no SA)					
The U.S.					
(Origin)The U.S.	64.841	64.362	-0.479	63.883	-0.479
Canada	71.102	71.066	-0.036	71.030	-0.036
China	62.322	62.980	0.658	63.638	0.658
Rest of the world	56.392	56.316	-0.076	56.240	-0.076
Canada					
(Origin)The U.S.	84.841	84.362	-0.479	83.883	-0.479
Canada	69.102	69.066	-0.036	69.030	-0.036
China	65.322	65.980	0.658	66.638	0.658
Rest of the world	84.392	84.316	-0.076	84.240	-0.076
Period 2 (Trade under hypothetical SA)					
The U.S.					
(Origin)The U.S.	66.607	66.220	-0.387	65.839	-0.381
Canada	76.185	76.165	-0.02	76.145	-0.02
China	71.788	72.371	0.583	72.957	0.586
Rest of the world	62.708	62.689	-0.019	62.672	-0.017
Canada					
(Origin)The U.S.	87.607	87.220	-0.387	86.839	-0.381
Canada	70.185	70.165	-0.02	70.145	-0.02
China	60.788	61.371	0.583	61.957	0.586
Rest of the world	85.708	85.689	-0.019	85.672	-0.017

Table 5.13: Welfare comparison for alternative scenarios

	Scenario 1 (High risk)	Scenario 2 (Medium risk)			Scenario 3 (Low risk)		
	Value	Value	Change (unit)	Change (%)	Value	Change (unit)	Change (%)
Change in Gross revenue							
The U.S.	-588.389	-587.01	1.379	-0.23%	-585.634	1.376	-0.23%
Canada	18.321	18.398	0.077	0.42%	18.489	0.091	0.49%
China	17.564	17.389	-0.175	-1.00%	17.217	-0.172	-0.99%
Rest of the world	5.149	5.319	0.17	3.30%	5.495	0.176	3.31%
Change in producer surplus							
The U.S.	-385.730	-384.838	**0.892**	-0.23%	-383.874	**0.964**	-0.25%
Canada	6.464	6.535	0.071	1.10%	6.616	0.081	1.24%
China	3.769	3.627	**-0.142**	-3.77%	3.490	**-0.137**	-3.78%
Rest of the world	16.972	16.995	0.023	0.14%	17.022	0.027	0.16%
Change in consumer surplus							
The U.S.	-100.069	-104.598	-4.529	4.53%	-109.413	-4.815	4.60%
Canada	-12.399	-12.759	-0.36	2.90%	-13.143	-0.384	3.01%
Pest control cost (U.S)	**10.234**	**20.522**	**-0.360**	-3.52%	**30.866**	**-0.384**	-1.87%
Net welfare Change							
The U.S.	-496.033	-509.958	-3.277	0.66%	-524.153	-3.467	0.68%
Canada	-5.935	-6.224	-0.289	4.87%	-6.527	-0.303	4.87%

5.4 Summary

This chapter first evaluates methods for modeling and quantifying non-tariff barriers (NTB) to trade. Several methods currently exit: inventory-based and survey-based approaches are used to identify the importance and list the problems of NTB to trade; gravity models, a simple econometric model, is used to capture the "boarder effect"; price-wedge approach converts the NTB impact into a value by calculating a tariff equivalent; cost-benefit method evaluates impact by comparing the cost and benefit from a NTB to trade; partial and general equilibrium models evaluate the impact by solving utility or demand functions and cost/profit function. The partial equilibrium approach was recently applied to Mexican avocado case by Peterson and Orden.

This chapter provides a more detailed evaluation for a partial equilibrium model as a method to link economics to the pest risk assessment for the Chinese fresh apple case. The lack of an official SA policy and Chinese apple imports limits direct adaptation, which also indicates that the partial equilibrium model is very data-intensive. Following Peterson/Orden's logic and method, information and data for key variables of the model are obtained, which are crucial for estimation. However, pest risk related parameters, like probability of pest infestation and corresponding compliance cost cannot easily be estimated due to data limitations. Even the economic parameters such as demand elasticity and wholesale prices are difficult to estimate because of the complexity of apple production and consumption characteristics. Despite these limitations, this partial equilibrium framework is still a feasible and useful method to link economic evaluation to pest risk assessment as a general approach. Case-to-case difference and data sensitivities may limit feasibility for empirical assessment as a template for evaluation.

At last, a sensitivity analysis for selected parameters is performed. Three parameters of prime interest are selected: probability of pest infestation, compliance cost for Chinese apple growers, and pest control cost for U.S. growers in the case of pest infestation. According to the simulation results, welfare is first compared between two periods, before trade (no SA) and after trade (under SA). Consistent with economic theory, results shows market opening has a negative effect on U.S. growers and a positive effects on Chinese growers. Then differences between scenarios are discussed. From scenario 1 to 3, with the risk and pest control cost being reduced, the loss in producer surplus is also reduced. Lower risk has positive effects on U.S. growers and negative effects on Chinese growers since the compliance cost increases with the increased number of measures required in a SA. Results are consistent among scenarios and it can be concluded that adjustments in risk probability and cost of compliance between scenarios have an almost linear impact on prices and welfare.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

The potential for fresh apple imports from China is very contentious in the U.S. It is likely that any future imports will be governed under the regulation of a Systems Approach (SA) to manage the risk of introducing exotic pest(s) or disease(s). This study consists of three parts: first an overview of the current Chinese fruit market and supply chain organization, which is the basis for the study; second, development of a hypothetical SA policy listing the phytosanitary measures likely to be included to control pest risk; and last, evaluation of methods for modeling and quantifying the SA policy for the Chinese case. This chapter will draw some main conclusions for the study and provide suggestions for future research work.

6.1 Summary

The SPS agreement provides guidelines for WTO members in implementing sanitary and phytosanitary measures to mitigate risk of introducing exotic invasive species associated with traded commodities. Pest Risk Analysis is an important component for trading countries in the implementation of the SPS Agreement. As one type of multi-step SPS regulation, the Systems Approach, which includes at least two mutually independent measures, is recommended by WTO as one of the International Standards for Phytosanitary Measures. The multiple independent mitigation measures in a Systems Approach together increase the probability of preventing pest entry and establishment.

SPS issues, as one of the technical barriers to trade, are determined not only by scientific assessment but also by political constraints. According to FAO/IPPC, conclusions from the Pest Risk Analysis are the basis for implementing sanitary and phytosanitary measures. Within WTO, members are allowed to introduce their own SPS requirements to reach an appropriate level of protection, while not too restrictive to trade. However, in reality, SPS barriers might be used by policy-makers as a shield to protect a country's domestic industry from international competition. Compared with traditional tariff barriers, SPS barriers and other non-tariff barriers might have greater impact on restricting trade, which involves scientific assessment.

As the largest apple producing country in the world, China is asking for consideration to export fresh apples to the U.S. Even though the export market has a limited market share in terms of total production volume in China, there is huge potential for future development with the support of Chinese government and foreign partners. More support is needed for the development of coordinated supply chains in new emerging for both domestic and export markets. Chinese apples that enter currently enter the global horticultural market (for example, to Canada) are mainly supplied by highly coordinated supply chains. For millions of small-scale farmers, which dominate the traditional fruit markets, there are many obstacles to getting involved with these supply chains except through contract farming. From both the government and industry point of view, a well-developed administrative system is needed to further guide the development of horticultural markets.

Since there is currently a ban on fresh apple exports from China to the U.S, no official systems approach exists. Expectations, however, are that the ban will eventually be lifted and replaced with a less restrictive policy to govern invasive species risk. Any economic assessment method for such a policy will first need to determine which steps might be included. By evaluating current like-product existing policies including corresponding pest risk assessment reports, a list of pests of concern associated with potential U.S.-China fresh apple trade is obtained and a hypothetical systems approach for Chinese fresh apples is developed. This study does not attempt to determine the validity of risk reduction or pest exposure probabilities related to individual steps already in use for other like-policies, but rather draw on results-to-date that have been accepted within the political and scientific process.

A hypothetical SA provides a general idea of what kinds of phytosanitary measures might be included to prevent the introduction of exotic pests or diseases once trades begins. Like any policy adjustment, potential future trade, with or without transfer of pests, will have economic impacts on the U.S. and Chinese apple industries and consumers. Relatively little research has been done using quantitative analysis to link economics to pest risk assessment. Among all the methods, partial equilibrium model has proved to be a feasible method and was recently applied to Mexican avocado case by Peterson and Orden. The lack of an official SA policy and Chinese apple imports limits adaptation of this model to Chinese fresh apple case, which also indicates that the partial equilibrium model is very data-intensive. Even the economic parameters such as demand elasticity and wholesale prices are difficult to estimate because of the complexity of apple production and consumption characteristics. Despite these limitations, this partial equilibrium framework is still a feasible and useful method to link economic evaluation to pest risk assessment as a general approach. Case-to-case difference and data sensitivities may limit feasibility for empirical assessment as a template for evaluation. A multi-scenario sensitivity analysis is conducted with different risk probability and cost of compliance applied. The results shows that the adjustments in risk probability and cost of compliance between scenarios have an almost linear impact on prices and welfare.

Even though the phytosanitary problem is a concern for U.S. to import Chinese fresh apples, the pest control capacity of China is improving. Laws and regulations for fruit safety do exits and new laws/regulations are under the construction by Chinese regulators. China is experiencing the transformation from traditional market to new emerging supermarket and export markets and from traditional supply chain to new coordinated supply chain. Establishment of centralized procurement system, tacking facilities, industry associations and certification services are all helping to improve the quality and pest control capacity. The Chinese government is also trying their best to help growers open the international market by providing policy priority and support. In addition, Chinese apples have been accepted by Canada and Australia under certain pest risk management policy, which indicates that China is capable to meet the high standards and phytosanitary requirements in these countries. The potential for U.S. import is still optimistic especially under the regulation of a specific Systems Approach policy.

6.2 Conclusions

A static multi-scenario partial equilibrium model, as an analytical tool for linking economics to pest risk assessment, is data intensive and sensitive to case-to-case differences. By incorporating pest outbreak parameters, scientific pest risk data are crucial for the model. For example, through the case of Chinese fresh apples, many data are related directly or indirectly to pest risk assessment, including the probabilities of a pest being introduced, spread, and established, and compliance cost for U.S. and China apple growers and government agencies. However, most pest risk related data are missing and difficult to collect, which makes the empirical analysis incomplete. In addition, empirical case-to case differences is another factor that limits the feasibility of the model to Chinese apple case. Compared with avocado, apple is a more widely consumed and produced fruit, which makes the estimate of production loss and welfare loss more difficult. Other critical inputs like regions, pests, and relevant government agencies vary across cases. More work is needed to adapt the partial equilibrium model as a general empirical analytical tool.

Economic evaluation of an on-going political trade debate is complicated from both political and scientific points of view. Compared with avocado case, potential import of Chinese fresh apples is still in the early stage of policy making, therefore, there is no trade or official SA policy existing. Lack in data of public policy, pest risk assessment, trade volume and price makes the empirical study difficult. While some of these data have been estimated in this study, more data are unable to obtain or estimated due to the lack of policy and scientific pest risk assessment. The sensitive political nature of the issue even limits information available through interviewing those government and industry in both the U.S. and China.

Data unavailability in China itself makes the empirical analysis more difficult. On one hand, apples are grown in most of provinces (25 of 34) in China. Even focusing on some big producing area, coexistence of different market forms and supply chain organizations makes implementation of phytosanitary measures more difficult. Directly collecting compliance cost of SA measures is difficult. On the other hand, compared with the U.S., China has relatively less developed data resource systems either for academic or for industrial purpose. Chinese government has just started setting up economic data system. Limited research work have been done on market price or cost analysis for apples.

Sensitivity analysis is a good option to apply the model to see how the results will vary with the change in some particular parameters given that fully adapting the model is impossible. Due to data limitation and other difficulties, to fully apply the model to Chinese apple case is really hard at this point. However, by making reasonable assumption and estimations, results of sensitivity are still helpful for analysing and even predicting. The flexibility in data assumption and results makes the sensitivity analysis a good transition to fully adaptation of the model.

The partial equilibrium model is not sensitive to the probability of pest infestation, the compliance cost for Chinese growers and pest control cost for U.S. growers given a small amount of apples import in to the U.S. With increase in the strength of SA regulation, the probability of introducing a pest into the U.S. from China is decreasing. Correspondingly, the compliance cost for Chinese growers are increasing since more phytosanitary measures are required and the pest control cost are decreasing due to the decrease in risk. However, the changes do not have significant effect on the market equilibrium and welfare.

6.3 Recommendations for future research

Economic evaluation of SA policy for Chinese apple case is possible but more work is needed. The partial equilibrium model is a theoretically and conceptually feasible method for linking the economic assessment with scientific pest risk assessment. To adapt this model to Chinese fresh apple case, the focus of the future work would be data collection and estimation to overcome existing empirical limitations. Results and conclusion from the study will provide important information for both U.S. and Chinese policy makers seeking to reduce invasive species risk. The method of static, multi-period partial equilibrium model provide a general framework for linking economics to pest risk assessment for the case of Chinese fresh apple imports into the U.S. The evaluation of a SA provides insight about how economic analysis and pest risk assessment can be linked.

Appendix 1: Comparison of pests of concern from reference policies

Scientific Name	Common Name	U.S. (Pears)	Australia (Pears)	Canada (Pears)	Canada (Apples)	Argentina (Apples and Pears)
Acleris fimbriana	Fruit tree tortrix		✓			
Acrocercops astaurota	Pear bark miner		✓			
Acrobasis pyrivorella	Pear fruit moth		✓			
Adoxophyes orana	Summer fruit tortrix (Fisher)		✓	✓	✓	
Alternaria gaisen(=kikuchiana)	Black Spot (Nagano) of Japanese Pear	✓	✓	✓		
Alternaria spp.	Causative agent of Chocolate spot of Ya pears		✓	✓		
Amphitetranychus viennensis	Hawthorn spider mite (Zacher)				✓	
Anarsia Lineatella	Peach Twig Borer					✓
Bactrocero Dorsalis (Hendel)	Oriental Fruit Fly	✓	✓			✓
Cacopsylla pyrisuga	Pear wood psylla		✓			
Carposina sasakii(=niponensis)	Peach Fruit Moth (Matsumura)	✓	✓	✓	✓	✓
Ceroplastes Japonicum	Japanese Wax Scale					✓
Ceroplastes Ruhens	Ruby Wax Scale					✓
Choristoneura longicellana	Common apple leaf roller		✓			
Conogethes (Dichocrocis) punctiferalis	Yellow Peach Moth (Guenee)	✓		✓	✓	✓
Cydia funebrana (Treitschke)		✓				
Cydia inopinata (Heinrich)	Manchurian codling moth	✓			✓	✓

Appendix 1: Comparison of pests of concern from reference policies (continued)

Scientific Name	Common Name	U.S. (Pears)	Australia (Pears)	Canada (Pears)	Canada (Apples)	Argentina (Apples and Pears)
Diaporthe tanakae	Twig blight (Kobaryashi& Sakuma)			✓	✓	
Diaspidiotus ostreaformis	Pear Oyster Scale					✓
Dolycoris baccarum	Sloe bug		✓			
Ectomyelosis Pyrivorella	Pear Fruit Moth					✓
Euzophera pyriella	Pyralid moth		✓			
Grapholitha inopinata	Manchurian fruit moth		✓			
Grapholita molesta	Oriental Fruit Moth (Busck)			✓	✓	
Gymnosporangium asiaticum	Japanese pear rust	✓	✓			✓
Gymnosporangium sabinae	European pear rust	✓	✓			
Halyomorpha picus	Yellow-brown stink bug		✓			
Holotrichia parallela	Large black chafer		✓			
Holotrichia titanis	Brown chafer		✓			
Hoplocampa pyricola	Pear sawfly		✓			
Leucoptera malifoliella (=scitella)	Pear leaf blister moth (Costa)	✓	✓	✓	✓	

Appendix 1: Comparison of pests of concern from reference policies (continued)

Scientific Name	Common Name	U.S. (Pears)	Australia (Pears)	Canada (Pears)	Canada (Apples)	Argentina (Apples and Pears)
Lopholeucaspis japonica	Pear white scale		✓			
Lymantria dispar	Gypsy moth		✓			
Monilinia fructigena	Brown rot (Honey)	✓	✓	✓	✓	
Monilinia mali	Apple blossom blight				✓	
Lopholeucaspis japonica	Pear white scale		✓			
Mycosphaerella pomacearum (Cord.) Sacc.	Leaf spot	✓				
Numonia(=Myelois) pirivorella	Pear fruit moth (Matsumura)	✓		✓		
	Pear rustry skin viroid	✓				
Pandemis heparana	Apple brown tortrix		✓			
Phomopsis fukushii	Japanese pear canker		✓			
Physalospora piricola	Physalospora canker		✓			
Pseudococcus comstocki	Comstock's mealybug		✓			
Rhynchites coreanus	Pear leaf weevil/curculio		✓			
Rhynchites foveipennis (Fairm)	Korean pear weevil/curculio	✓	✓			

Appendix 1: Comparison of pests of concern from reference policies (continued)

Scientific Name	Common Name	U.S. (Pears)	Australia (Pears)	Canada (Pears)	Canada (Apples)	Argentina (Apples and Pears)
Rhynchites heros (Roel)	Japanese pear weevil	✓	✓			
Spilonota albicana	Eye spotted bud moth		✓			
Spilonota lechriaspis	Tipshoot tortrix		✓			
Spilonota ocellana	Eye spotted bud moth		✓			
Sphanostigma iakusuiense	Powdery pear aphid		✓			
Stephanitis nashi	Pear lace bug		✓			
Tetranychus kanzawai (Kishida)	Kanzawa spider mite	✓				✓
Tetranychus truncatus	A red spider mite (Ehara)			✓		
Tetranychus viennensis	Hawthorn spider mite (Zacher)	✓	✓	✓		✓
Urochela luteovaria	Pear stink bug		✓			
Vespa mandarinia	Paper wasp		✓			
Venturia nashicola	Japanese pear scab	✓	✓			

Source: Policies and regulations listed in Table 4.3.
Notes: The U.S. treats *Gymnosporangium asiaticum and Gymnosporangium sabinae* as the same pests, but they are shown here as two pests. Therefore, there are actually 18 pests of concern in appendix 1 for U.S rather than 17 as mentioned in table 4.4.

Appendix 2.1: Comparison of reference polices: pre-harvest measures

Field certification/management (treatments, bio-control, etc)	
Argentina (Apples and Pears)	From orchards registered by AQSIQ and designated by both SENASA and AQSIQ; Monitoring for *Baclrocera dorsalis* in the Orchard within a surrounding area of 1 km radius
Australia(Pears)	Pear must be from registered orchards by AQSIQ in the designated export areas; Registered growers must implement an orchard control program; Fruit fly monitoring system; the traps must consist of cue lure, trimedlure and methyl eugenol; a minimum of one methyl eugenol trap should be placed in each export orchard and any village present
Canada (Apples)	Approved orchards by AQSIQ in Shaanxi and Shandong provinces in China; Field inspection and/or chemical control for fruit boring moths after the bags have been removed
Canada (Pears)	Approved orchard by AQSIQ from Hebei, Shandong and Xinjiang Province in China; In registered orchards, cultural practices, chemical controls and field inspection (or monitoring) programs are carried out
U.S. (Fragrant Pears)	Pears must have been grown in the Korla region of Xinjiang Province in a production site that is registered with the national plant protection organization of China (AQSIQ); Within 30 days prior to harvest, inspect the registered production site for signs of pest infestation and allow USDA/APHIS to monitor the inspections
U.S. (Ya Pears)	
Protected conditions	
Argentina (Apples and Pears)	The export pear shall be conducted bagging measure until packinghouse; The export apple shall be conducted bagging measure and the bag must not be removed more than 4 weeks prior to harvest
Australia(Pears)	Bags must be placed over Ya pears, Sand pears and Asian Pears grown in Shandong and Shaanxi Provinces when the fruit is no more than 2.5 cm in diameter; Bags must be removed in the packing house away from the packing line; No fallen fruit is to be collected for export
Canada (Apples)	Option a: Apples must be bagged without holes just after flowering, provided fungicide application has occurred during flowering and until more than four weeks prior to harvest
U.S. (Ya Pears)	Bagging the pears on the trees
Vector-and pathogen-free areas, places or sites of production	
Argentina (Apples and Pears)	Apples are from area free of *Baclrocera dorsalis* and from free production site for *Gymnsporangium asiaticurn;* With 1 km from the fruit production place, no transiting host tree
Australia(Pears)	AQSIQ must ensure that telial hosts of Japanese pear and European pear rust occurring within 2km of registered orchards are removed
Canada (Pears)	Certain control program are carried out to ensure freedom from quarantine pests
U.S. (Fragrant Pears)	All propagative material introduced into a registered production site must be certified free of the pests listed.
Testing and subsequent elimination of infected component	
Australia(Pears)	If either Japanese pear rust or European pear rust is found, fruit from the export orchards within 2 km of the infected site will not be accepted into Australia; If brown rot is detected in any designed export area, if the orchards are infected with Japanese pear scab, or if more than 0.5% of fruit are infected with black spot at the time of blossoming, those orchards will be excluded from the export program; the notification of unusual weather conditions occurrence resulting in brown rot, black spot or scab disease

Appendix 2.2: Comparison of reference polices: harvest requirements

Culling, inspection or selection	
Argentina (Apples and Pears)	Field inspection or monitoring and/or chemical control for fruit boring moths after the bags have been removed; Apple should be selected, stored and processed to ensure fruit without insects, mites, rotting fruit, leaves, twigs, roots and soil
Harvest technique and handling	
Australia(Pears)	Bagging the pears (except for Fragrant pear) when the fruit is no more than 2.5 cm in diameter
U.S. (Ya Pears)	Bagging the pears through the harvest and during their movement to the packinghouse

Appendix 2.3: Comparison of reference polices: Post-harvest and handling measures (including storage and packing)

Treatment to kill, sterilize or remove vectors or pathogens (fumigation, irradiation, cold, controlled atmospheres, washing, brushing, waxing, dipping, heat, etc.)	
Argentina (Apples and Pears)	Monitoring for *Baclrocera dorsalis* in the packinghouse within a surrounding area of 1 km radius
Canada (Apples)	Option **b** for un-bagged apples: cold treatment followed by fumigation with methyl bromide; packing facilities are maintained free of pests, soil, plant debris and discarded or infested fruit;
U.S. (Fragrant Pears)	All packing houses must be situated within the area subject to a fruit fly monitoring (trapping) program; Fragrant pears must be held in a cold storage facility while awaiting export
U.S. (Ya Pears)	Cold treatment for *Bactrocera dorsalis*
Inspection and grading	
Argentina (Apples and Pears)	Packing and storage should be subject to quarantine supervision by AQSIQ; 2% sampling
Australia(Pears)	Joint inspection for all consignments by CIQ and AQIS; The AQIS sampling protocol requires inspection of 600 units for quarantine pests, in systematically selected samples per homogeneous consignment or lot
Canada (Apples)	Post-Harvest Inspection at 5% level and graded
U.S. (Fragrant Pears)	After harvest, inspect the pears for signs of pest infestation and allow USDA/APHIS to monitor the inspections
Sanitation, including removal of parts of the host	
Argentina (Apples and Pears)	The apples should be stored separately in the chamber to avoid re-infestation
Australia(Pears)	Pears destined for Australia are not mixed with fruit for other destinations; Culled fruit must be removed from the packing house at the end of each day
Canada (Apples)	Safeguard from contamination from orchards or other crops during packing and loading
Certification of packing facilities	
Argentina (Apples and Pears)	From packinghouses registered by AQSIQ and designated by both SENASA and AQSIQ; Packing box should have marking in English indicating the relative production information; the package of apples should be clean the unused
Australia(Pears)	All packing houses must be registered with AQSIQ; Packing houses must be well-lit, and the storage area must be secure to prevent infestation after packing; Pears must be packed into clean, new cardboard or cartons; No fresh or dried packing material of plant origin is to be used; Only processed or synthetic packing material can be used; Fruit must be packed and directly transferred into a shipping container sealed with a AQSIQ seal and not opened until the container reaches its destination; OR, fruit must be packed into cartons with screened ventilation holes; the screening mesh size must not exceed 1.6mm and not less than 0.16 strand thickness; OR fruit must be packed into cartons and the pallet of cartons must be shrink-wrapped in plastic on all six sides
Canada (Apples)	Apples should be packed and stored in a approved facility only for export to Canada; The facility must be clean Each carton is clearly labeled in Chinese and English or French and marked with the code number of each approved orchard

Appendix 2.3: Comparison of reference polices: Post-harvest and handling measures (including storage and packing) (continued)

Certification of packing facilities	
Canada (Pears)	Clearly labeled in Chinese and English or French; Specify the type of pears and the place of origin; Marked with a number representing the code of each approved orchard; Each carton shall be sealed with a sticker
U.S. (Fragrant Pears)	Must be packed in cartons
U.S. (Ya Pears)	Packing houses are only used for Ya pears in intact bags and in sealed containers from registered growers
Testing with subsequent elimination of infected component	
U.S. (Fragrant Pears)	Upon detection of large pear borer, pear curculio or Japanese apple curculio, USDA/APHIS may reject the lot or consignment

Appendix 2.4: Comparison of reference polices: Shipping and distribution measures

Reference policies	
In-transit or on-arrival treatment or processing	
Argentina (Apples and Pears)	Transportation should be subject to quarantine supervision by AQSIQ; Transportation under the commercial cold treatment
Australia(Pears)	The fruit must remain within intact bags and be covered by a tarpaulin if they are shipped through an unmonitored area
Canada (Apples)	The apples must be appropriately stored and transported free of quarantine pests and free of soil, sand, leaves, and plant debris
Canada (Pears)	Shipment must be free of visible pests and signs and symptoms of pests, soil, leaves and plant debris; Shipment will be subject to inspection and sampling on arrival
U.S. (Fragrant Pears)	Must be shipped in insect-proof containers
Restrictions on end use, distribution and periods, and ports of entry restrictions	
Argentina (Apples and Pears)	The Phytosanitary Certificate issued by AQSIQ with 2% sampling; AQSIQ provide the sample of Phytosanitary Certificate in advance to SENASA
Australia(Pears)	CIQ will issue a Master Phytosanitary Certificate for all pre-export inspected lots
Canada (Apples)	A permit to import issued under the Plant Protection Regulations, is required during the trial importation period; A Phytosanitary Certificate issued by either the Shandong or Shaanxi Entry-Exit Inspection and Quarantine Bureau within 14 days prior to shipment and bear the official stamp of AQSIQ
Canada (Pears)	A permit to import issued under the Plant protection regulation is required for the importation of Asian pears from Shandong and Hebei Province; Not required for the importation of Fragrant pears from Xinjiang Province; A phytosanitary certificate issued within 14 days prior to shipment;
U.S. (Fragrant Pears)	Each shipment of pears must be accompanied by a phytosanitary certificate; Fragrant pears may be imported only under a permit issued by USDA/APHIS;
U.S. (Ya Pears)	Phytosanitary certificate issued by the Chinese Ministry of Agriculture
Inspection and/or testing with subsequent elimination/denial of entry	
Argentina (Apples and Pears)	After the arrival, SENASA will verify the documents, the labeling and the corresponding phytosanitary inspection
Australia(Pears)	If brown rot, black spot, or scab is intercepted on imported fruit, DAFF reserves the right to implement remedial measures as deemed necessary before trade commences next season; On arrival, AQIS will examine the documentation for consignment verification prior to release from quarantine
Canada (Apples)	On arrival, inspection of all shipments during the trial importation; inspection of random sample of 5% (further 5% if necessary) of the contents of the inspected shipment
Canada (Pears)	During Trial Period, 100% of the pear shipment will be inspected; then a random sample of 5% of the contents of the shipment will be examined

Appendix 2.4: Comparison of reference polices: Shipping and distribution measures (continued)

Sanitation (freedom from contamination of carriers)	
Canada (Apples)	Safeguard from contamination from orchards or other crops during the transportation; Shipments free of other visible pests, signs and symptoms of pests, soil, sand, leaves, and plant debris
U.S. (Fragrant Pears)	Safeguard from pest infestation during transport

Appendix 3: Model calibration for sensitivity analysis

This section provides the main calibration for demand and supply for sensitivity analysis. By adapting and adjusting the avocado partial equilibrium model (Table 5.2), the most important model equations are described below. Notations for variables and parameters mentioned earlier are applied here.

Computing frequency of pest outbreak

The frequency of pest outbreak is computed as the products of the probabilities that the pest will in introduced into an importing regions at different periods, the percentage of suspected area in importing country, and the quantity of import. In period 1, it is assumed that there is still small probability that the pest could be introduced along with other fruits. However, the frequency is zero since U.S. import of Chinese apples is banned. Like discussed earlier, the frequency is adjusted since quantity unit used in the model is million lbs. There is about 25,000 cartons tray pack in a million lbs (net weight 40 lbs per cartons tray pack).

(1)

$$freq1_{US,p} = prob1_{US,p} * prob2_{US,p} * prob3_{US,p} * prob4_{US,p} * prob5_{US,p} * suscept_{US,p} * D1_{US,CH} * 25000$$

(2)

$$freq2_{US,p} = probsa1_{US,p} * probsa2_{US,p} * probsa3_{US,p} * probsa4_{US,p} * probsa5_{US,p} * suscept_{i,p} * D2_{i,CH} * 25000$$

Where $freq1_{US,p}$, $freq2_{US,p}$ = *the frequency of pest outbreak for demand region i for particular pest in period 1 and period 2. i refers to demand regions, the U.S. (US) and Canada (CA). p refers to pest "Peach Fruit Moth".*

$prob1_{US,p}$, $prob2_{US,p}$, $prob3_{US,p}$, $prob4_{US,p}$ *and* $prob5_{i,p}$ = *probability of pest infestation during pre-or post harvest period, during* *harvest or packing, during shipment, during port of entry inspection and in suitable habitat environment in the case of without trade and without SA in place;*

$probsa1_{US,p}, probsa2_{US,p}, probsa3_{US,p}, probsa4_{US,p}$ *and* $probsa5_{US,p}$

= *probability of pest infestation during pre-or post harvest period, during harvest or packing, during shipment, during port of entry inspection and in suitable habitat environment in the case of without trade and without SA in place;*

$suscept_{US,p}$ = *Proportion of population in susceptible areas;*

$D1_{US,CH}, D2_{US,CH}$ = *calibrated Chinese apple imports to the U.S.*

Supply calibration:

A constant Elasticity of Transformation (CET) production possibility frontier is used to capture sales between different situations (periods). Total amounts of U.S. apple supplies available in each U.S. region can be calculated as the sum of utilized production of the states included in each region. Supply calibration for each supply regions that are used in the GAMs code is provided below.

CET revenue functions for different supply regions are given as:

$$(3) \qquad \boldsymbol{R}(pp1, pp2, V) = V\left[1-(freq1+freq1)*ploss*pctef\right] * \left\{\delta(pp1-cost)^{\beta}+(1-\delta)(pp2-cost)^{\beta}\right\}^{1/\beta}$$

Where V = *supply of factor endowment;*

$freq1, freq2$ = *frequency of pest outbreak.*

$ploss$ = *production loss from infestation;*

$pctef$ = *percentage of production affected by infestation*

$pp1, pp2$ = *calibrated producer price in period 1 and period 2;*

$cost$ = *compliance cost or pest control cost for supply regions;*

δ = *shift parameters for CET revenue function for each supply region;*

β = *exponent parameter that determines the elasticity of transformation*

By taking the derivative of above revenue equation to the producer price, the conditional supply function for different supply regions are derived as following. In period 1, supply of each supply regions ($S1_j$) can been calculated through the following equations. Forms for each supply region are slightly different since the cost and frequency of pest outbreak are different. For the U.S. and Canada, there exist probabilities of pest outbreak. Therefore, the apple growers suffer the production loss from pest infestation. The frequency of pest outbreak ($freq1_{US,p}$, $freq2_{US,p}$), productivity loss ($ploss_p$) and percentage of pest infestation ($pctef_p$) are considered in the supply equations, which will affect the final quantity of supply. In addition, in the case of pest outbreak, the cost increase due to the increasing pest control cost ($controlc_{US,p}$) for the U.S. For Chinese apple growers, compliance cost of implementation of SA ($pcost_{CH,p}$) is considered. For the rest of the world, according to the assumptions, there is no extra cost considered for this partial equilibrium model. For period 2, same function form can be applied for each supply region and function forms are listed here.

(4)

$$S1_{US}(pp1_{US}, pp2_{US}, V_{US}) = V_{US}\left[1 - \sum_{p}\left[\left(freq1_{US,p} + freq2_{US,p}\right) * ploss_p * pctef_p\right]\right]$$

$$* \left\{\delta_{US}\left(pp1_{US} - \sum_{p} controlc1_{US,p}\right)^{\delta_{US}} + (1-\delta_{US})\left(pp1_{US} - \sum_{p} controlc1_{US,p}\right)^{\delta_{US}}\right\}^{1/\beta_{US} - 1}$$

$$* \delta_{US}\left(pp1_{US} - \sum_{p} controlc1_{US,p}\right)^{\delta_{US}-1}$$

(5)

$$S1_{CA}(pp1_{CA}, pp2_{CA}, V_{CA}) = V_{CA}\left\{\delta_{CA} PP1_{CA}^{\beta_{CA}} + (1-\delta_{CA}) PP2_{CA}^{\beta_{CA}}\right\}^{\beta_{CA}-1}$$

(6)

$$S1_{CH}(pp1_{CH}, pp2_{CH}, V_{CH}) = V_{CH}\left\{\delta_{CH}\left(PP1_{CH} - \sum_{p} pcost_{CH,p}\right)^{\beta_{CH}} + \right.$$

$$\left.(1-\delta_{CH})\left(pp1_{CH} - \sum_{p} pcost_{CH,p}\right)^{\delta_{CH}}\right\}^{1/\beta_{US} - 1} * \delta_{CH}\left(pp1_{CH} - \sum_{p} pcost_{CH,p}\right)^{\delta_{CH} - 1}$$

(7) $$S1_{RW}(pp1_{RW}, pp2_{RW}, V_{RW}) = V_{RW}\left\{\delta_{RW} * PP1_{RW}^{\beta_{RW}} + (1-\delta_{RW}) * PP1_{RW}^{\beta_{RW}}\right\}^{\delta_{CH}-1}$$

$$\delta_{RW} * PP1_{RW}^{\beta_{RW}-1}$$

Notes: *1) Subscript p refers to pest variety. However, for simplicity, the sensitivity analysis only considers the pest "Peach Fruit Moth" at this point. Model can be extended to more than one pest for further analysis;*

2) $freq1_{US,p}=0$ due the zero import in the first period.

Calibration of supply factor endowment for CET revenue functions

The factor endowment for CET revenue function V_j is also calculated through model calibration. Similar to the supply calibration, function form of V_j is slightly different for different supply region due to different cost and frequency application. Intercept c_j abd slope d_j can be computed during the calibration. Starting values are set equal to the quantity of base supply for each supply region.

(8)
$$V_{US} = c_{US} + d_{US} \left\{ \begin{array}{l} \delta_{US} * \left(pp1_{US} - \sum_{p} controlc1_{US,p} \right)^{\beta_{US}} \\ +(1-\delta_{US}) * \left(pp2_{US} - \sum_{p} controlc2_{US,p} \right)_{US}^{\beta_{US}} \end{array} \right\}^{\frac{1}{\beta_{US}}}$$

(9)
$$V_{CA} = c_{CA} + d_{CA} \left\{ \delta_{CA} * pp1_{CA}{}^{\beta_{CA}} + (1-\delta_{CA}) * pp2_{CA}{}^{\beta_{CA}} \right\}^{\frac{1}{\beta_{CA}}}$$

(10)
$$V_{CH} = c_{CH} + d_{CH} \left\{ \begin{array}{l} \delta_{CH} * \left(pp1_{CH} - \sum_{p} pcost_{CH,p} \right)^{\beta_{CH}} \\ +(1-\delta_{CA}) * \left(pp2_{CA} - \sum_{p} pcost_{CH,p} \right)^{\beta_{CH}} \end{array} \right\}^{\frac{1}{\beta_{CH}}}$$

(11)
$$V_{RW} = c_{RW} + d_{RW} \left\{ \delta_{RW} * pp1_{RW}{}^{\beta_{RW}} + (1-\delta_{RW}) * pp2_{RW}{}^{\beta_{RW}} \right\}^{\frac{1}{\beta_{RW}}}$$

Demand calibration

By adapting the avocado model, the demand for apples from different supply regions is derived from a weakly separable utility function for a representative consumer. The demand is defined as a function of wholesale price, apple price index, and total expenditure. As mentioned in the text, two different elasticity of substitution are used in the model. $\sigma 1_i$ represents the elasticity of substitution between fresh apples and all other goods. A relative increase in the apple price will lead the consumers to substitute more all other goods. 0.6 (absolute value) [46] is used in avocado case. In Chinese apple case, this value will be adjusted and then used in Chinese apple case due to the data limitation, Referring to the discussion in the text (Table 5.8), based on available limited literature, price elasticity of demand between apples all other food products ranges from -0.3143 to 0.0766. Price elasticity of demand between apples and all other food is 0.1997. Since apple is a more common fruit variety than avocado, apple should be less elastic than avocado. 0.3 is applied during model calibration for Chinese apples case.

$\sigma 2_i$ represents the elasticity of substitution between fresh apples from different supply regions. A relative increase in the apple price from a supply region will lead the consumers to consume more apples from other supply regions. According to the assumptions, apples produced in different supply regions are assumed to be heterogeneous products, which means the apple from different regions are imperfect substitute. Since there is no available literature about this, same value 1.85 will be applied to apple case. More detailed discussion and demand calibration are provided below.

[46] 0.6 and 1.85 only refers to the absolute values of elasticity. Minus sign is applied during calibration.

Computing demand shift parameters

To replicate the quantities demanded in the initial input data, shift parameters needs to be calculated. The following equations are first used to compute the basic shift parameters ($\gamma 1_{i,j}, \gamma 2_{i,j}$) for different demand regions.

(12)

$$q1_{US,r2} = \frac{\gamma 1_{US,r2} * pb1_{US,r2}^{-\sigma 2_{US}} \, exp1_{US}}{\sum_{r2}\left\{\gamma 1_{US,r2} * pb1_{US,r2}^{1-\sigma 2_{US}}\right\} + \left(1-\sum_{r2}\gamma 1_{US,r2}\right) * pb1_{US,RW}^{1-\sigma 2_{US}}}$$

(13)
$$q2_{US,r1} = \frac{\gamma 2_{US,r1} * pb2_{US,r1}^{-\sigma 2_{US}} \, exp2_{US}}{\sum_{r1}\left\{\gamma 2_{US,r1} * pb2_{US,r1}^{1-\sigma 2_{US}}\right\} + \left(1-\sum_{r1}\gamma 1_{US,r1}\right) * pb2_{US,CH}^{1-\sigma 2_{US}}}$$

(14)
$$q1_{CA,r1} = \frac{\gamma 1_{CA,r1} * pb1_{CA,r1}^{-\sigma 2_{CA}} \, exp1_{CA}}{\sum_{r1}\left\{\gamma 1_{CA,r1} * pb1_{CA,r1}^{1-\sigma 2_{CA}}\right\} + \left(1-\sum_{r1}\gamma 1_{CA,r1}\right) * pb1_{CA,CH}^{1-\sigma 2_{CA}}}$$

(15)
$$q2_{CA,r1} = \frac{\gamma 2_{CA,r1} * pb2_{CA,r1}^{-\sigma 2_{CA}} \, exp2_{CA}}{\sum_{r1}\left\{\gamma 2_{CA,r1} * pb1_{CA,r1}^{1-\sigma 2_{CA}}\right\} + \left(1-\sum_{r1}\gamma 2_{CA,r1}\right) * pb2_{CA,CH}^{1-\sigma 2_{CA}}}$$

Where $\gamma 1_{i,j}, \gamma 2_{i,j}$ *=demand shift parameters for demand and supply regions for both period, which satisfy* $\sum_j \gamma 1_{i,j} = 0, \sum_j \gamma 2_{i,j} = 0, \forall i$ *.And* $\gamma 1_{US,CH}$ *=0 since import is banned for the U.S. in period 1.*

i *= demand regions, the U.S., and Canada*

j *= supply regions, the U.S., Canada, China and the rest of the world.*

r1 =subset of supply regions, the U.S., Canada and the rest of the world;

r2 = subset of supply regions, the U.S. and Canada.

$pb1_{i,j}$, $pb2_{i,j}$ = *wholesale prices (input data) for demand region i and supply region j in period 1 and 2.*

$exp1_i$, $exp2_i$ = *per capita apple expenditure pear year for consumers in demand region.*

Then apple quantity index ($qindex1_i, qindex2_i$) and price index ($pindex1_i, pindex2_i$) are calculated through equation (17) to (19).

(16) $$qindex1_{US} = \left\{ \sum_{r1} \gamma 1_{US,r1}^{1/\delta 2_{US}} * q1_{US,r1}^{\frac{\delta 2_{US}-1}{\delta 2_{US}}} \right\}^{\frac{\delta 2_{US}}{\delta 2_{US}-1}}$$

(17) $$qindex1_{CA} = \left\{ \sum_{j} \gamma 1_{CA,j}^{1/\delta 2_{CA}} * q1_{CA,j}^{\frac{\delta 2_{CA}-1}{\delta 2_{CA}}} \right\}^{\frac{\delta 2_{CA}}{\delta 2_{CA}-1}}$$

(18) $$qindex2_{i} = \left\{ \sum_{r1} \gamma 2_{i,j}^{1/\delta 2_{i}} * q2_{i,j}^{\frac{\delta 2_{i}-1}{\delta 2_{i}}} \right\}^{\frac{\delta 2_{i}}{\delta 2_{i}-1}}$$

(19) $$pindex1_{i} = \left\{ \sum_{j} \gamma 1_{i,j} * pb1_{i,j}^{1-\delta 2_{i}} \right\}^{\frac{1}{1-\delta 2_{i}}}$$

(20) $$pindex2_{i} = \left\{ \sum_{j} \gamma 2_{i,j} * pb2_{i,j}^{1-\delta 2_{i}} \right\}^{\frac{1}{1-\delta 2_{i}}}$$

Based on the price and quantity index calculated above, aggregate shift parameters ($\varphi 1_i, \varphi 2_i$) are computed through the following two equations.

(21) $$qindex1_i = \frac{\varphi 1_i * pqi1_i^{-\delta 1_i} * inc1b_i}{\varphi 1_i * pindex1_i^{1-\delta 1_i} + (1-\varphi 1c_i)}$$

(22) $$qindex2_i = \frac{\varphi 2_i * pqi2_i^{-\delta 1_i} * inc2b_i}{\varphi 2_i * pindex2_i^{1-\delta 1_i} + (1-\varphi 2_i)}$$

where $inc1b_i, inc2b_i$ = *per capital income for a consumer representative in each demand region.*

Demand calibration

As mentioned earlier, the demand can be expressed as a non-linear function in terms of apple wholesale price, price index and income. As shown in equation (24) to (27), $\gamma 1_{i,j}, \gamma 2_{i,j}$ and $\varphi 1_i, \varphi 2_i$ are shift parameter that are calculated above. Quantity demanded ($x1_{i,j}, x2_{i,j}$), wholesale price ($wp1_{i,j}, wp2_{i,j}$), and apple price index ($index1_i, index2_i$) are variables that needs to be calibrated through systems of equations.

(23) $$D1_{i,j} = \frac{pop1_i * \left\{ \varphi 1_i * \gamma 1_{i,j} * wp1_{i,j}^{-\delta 2_i} * index1_i^{(\delta 2_i - \delta 1_i)} * inc1_i \right\}}{\varphi 1_i * index1_i^{(1-\delta 1_i)} + (1-\varphi 1_i)}$$

(24)

$$D2_{i,j} = \frac{pop2_i * \left\{ \varphi 2_i * \gamma 2_{i,j} * wp2_{i,j}^{-\delta 2_i} * index2_i^{(\delta 2_i - \delta 1_i)} * inc2_i \right\}}{\varphi 2_i * index2_i^{(1-\delta 1_i)} + (1-\varphi 2_i)}$$

(25) $$index1_i = \left\{ \sum_j \left(\gamma 1_{i,j} * wp1_{i,j}^{1-\delta 2_i} \right) \right\}^{\frac{1}{1-\delta 2_i}}$$

(26) $$index2_i = \left\{ \sum_j \left(\gamma 2_{i,j} * wp2_{i,j}^{1-\delta 2_i} \right) \right\}^{\frac{1}{1-\delta 2_i}}$$

In addition, the following equations express the relationship between wholesale prices, cost, and producer prices. These equations, as part of the system of equations, are also needed to solve the model. In period 1, the wholesale price for apples from the U.S. ($wp1_{i,US}$) is equal to the producer price ($pp1_{US}$) plus the market margin ($mar1_{i,US}$) and pest control cost ($controlc1_{US,p}$). This is the same for apples from Canada. For apples from China, the pest control cost is replaced by compliance cost of SA ($pcost1_{CH,p}$). No cost is added for apples from the rest of the world. In the second period, same equations are applied.

(27) $$wp1_{i,US} = pp1_{US} + mar1_{i,US} + \sum_p controlc1_{US,p}$$

(28) $$wp1_{i,CA} = pp1_{CA} + mar1_{i,CA}$$

(29) $$wp1_{i,CH} = pp1_{CH} + mar1_{i,CH} + pcost1_{CH,p}$$

(30) $$wp1_{i,RW} = pp1_{RW} + mar1_{i,RW}$$

Marketing clearing conditions:

Market clearing conditions are needed to guarantee the partial equilibrium for demand and supply.

(31) $$y1_j = \sum_i x1_{i,j}$$

(32) $$y2_j = \sum_i x2_{i,j}$$

Welfare calibration

Based on the general framework of the model, welfare is defined as the sum of producer surplus and consumer surplus. Detailed computation is listed below. What needs to be mentioned is the method used in Avocado case is not applied here. In avocado case, welfare change is compared between initial equilibrium (input data) and new calibrated equilibrium (calculated data). However, in apple case, what is more interesting is the welfare difference before and after trade (without and with SA implementation). Therefore, welfare change is calculated as the difference between two time periods for each scenario. In this sensitivity analysis, for simplicity, the consumer surplus is approximately computed using rule of one-half:

(33) $$\Delta PS_j = \frac{1}{2}\left\{pp2_j - pp1_j\right\} * \left(S1_j + S2_j\right)$$

Similarly, for consumer surplus:

(34) $$\Delta CS_i = \frac{1}{2}\sum_j \left\{\left(wp1_{i,j} - wp2_{i,j}\right) * \left(D1_{i,j} + D2_{i,j}\right)\right\}$$

where $pp1_j, pp2_j$ = simulated producer price from model calibration;

$wp1$, $wp2$ = simulated wholesale price from model calibration;

$D1_{i,j}, D2_{i,j}$ =simulated quantity of demand from model calibration;

$S1_j, S2_j$ = simulated quantity of supply from model calibration;

Appendix 4: GAMs code for sensitivity analysis (scenario 2 with medium risk)

```
$Title Economic Evaluation for Chinese Fresh Apples-New version

$offsymxref
$offsymlist
option limrow=0,limcol=0,decimals=8,solprint=on;
option iterlim=999999;
option reslim=999999;


* Two time period: academic year 2004 (t1) and 2005 (t2)
* Demand regions:  U.S.(Region U) and Canada (Region C)
* Supply regions:The U.S.- Region US
*          China-Region CH
*          Canada-CA
*          The rest of the world-RW
* Only one pest is considered: "PFM"-Peach Fruit Month
* ---------------------------------------------------
SETS i     set of demand regions / US,CA /
     j     set of supply regions / US,CA,CH,RW /
     r1(j) subset of supply regions / US,CA,RW /
     r2(j) subset of supply regions  / US,CA /
     s1(j) subset of supply regions  /CH/
     s2(j) subset of supply regions /RW/
     s3(j) subset of supply regions /US/
     s4(j) subset of supply regions /CA/
     d1(i) subset of demand regions /US/
     d2(i) subset of demand regions /CA/
     p     set of pests / PFM/

ALIAS(r1,k1);
ALIAS(r2,k2);
ALIAS(m,i);
ALIAS(n,j);
ALIAS(z,p);

PARAMETERS
  sig1(i)   Elasticity of substitution between apples and all other goods
            / US 0.3, CA 0.3 / ,
  sig2(i)   Elasticity of substitution between apples
            / US 1.85, CA 1.85 /,
  exp1(i)   percapita apple expenditure in t1
            / US 10.12894918, CA 18.51085274  /,
  exp2(i)   percapita apple expenditure in t2
            / US  9.72674412, CA 18.74481219  /,
  inc1b(i)  base percapita income in t1
```

```
              / US 33050, CA 28310/,
   inc2b(i)   base percapita income in t2
              / US 34586, CA 32600 /,
   a1c(i,j)   calibrated bottom-level demand shift parameters for t1,
   a2c(i,j)   calibrated top-level demand shift parameters for t1,
   b1(i)      top-level demand shift parameters for t1,
   b2(i)      top-level demand shift parameters for t2;

TABLE pb1(i,j) Wholesale prices by demand and supply region in t1
        US      CA      CH      RW
US      0.53    0.66    0.66    0.52
CA      0.73    0.64    0.69    0.80 ;

TABLE pb2(i,j) Wholesale prices by demand and supply region in t2
        US      CA      CH      RW
US      0.57    0.70    0.70    0.54
CA      0.78    0.64    0.59    0.77 ;

TABLE q1(i,j) Percapita quantity demand in t1 in lbs
        US            CA            CH            RW
US      18.57702164   0.119606569   0.0           0.392668026
CA      7.810016553   16.5763013    0.256153996   2.529951957;

TABLE q2(i,j) Percapita quantity demand in t2 in lbs
        US            CA            CH            RW
US      16.09171134   0.251243516   0.262330539   0.36104966
CA      8.957701799   16.15395734   0.24540512    1.655172816;

VARIABLES  a11(r2)    US shift parameters for apples at second level in t1,
           a12(r1)    US shift parameters for apples at second level in t2,
           a21(r1)    CA shift parameter at second level in t1,
           a22(r1)    CA shift parameter at second level in t2;

 a11.LO(r2) = 0;
 a11.UP(r2) = 1.0;

 a12.LO(r1) = 0;
 a12.UP(r1) = 1.0;

 a21.LO(r1) = 0;
 a21.UP(r1) = 1.0;

 a22.LO(r1) = 0;
 a22.UP(r1) = 1.0;

EQUATIONS  z11(r2)    equations for US region in t1,
```

```
                    z12(r1)      equations for US region in t2,
                    z21(r1)      equation for CA region in t1,
                    z22(r1)      equation for CA region in t2;

z11(r2)..   q1("US",r2) =E= (a11(r2)*pb1("US",r2)**(-sig2("US"))*exp1("US"))/
                (sum(k2,a11(k2)*pb1("US",k2)**(1-sig2("US"))) +
                (1-sum(k2, a11(k2)))*pb1("US","RW")**(1-sig2("US")));

z12(r1)..   q2("US",r1) =E= (a12(r1)*pb2("US",r1)**(-sig2("US"))*exp2("US"))/
                (sum(k1,a12(k1)*pb2("US",k1)**(1-sig2("US"))) +
                (1-sum(k1, a12(k1)))*pb2("US","CH")**(1-sig2("US")));

z21(r1)..   q1("CA",r1) =E= (a21(r1)*pb1("CA",r1)**(-sig2("CA"))*exp1("CA"))/
                (sum(k1,a21(k1)*pb1("CA",k1)**(1-sig2("CA"))) +
                (1-sum(k1, a21(k1)))*pb1("CA","CH")**(1-sig2("CA")));

z22(r1)..   q2("CA",r1) =E= (a22(r1)*pb2("CA",r1)**(-sig2("CA"))*exp2("CA"))/
                (sum(k1,a22(k1)*pb2("CA",k1)**(1-sig2("CA"))) +
                (1-sum(k1, a22(k1)))*pb2("CA","CH")**(1-sig2("CA")));

MODEL r11 / z11 /;
MODEL r12 / z12 /;
MODEL r21 / z21 /;
MODEL r22 / z22 /;


SOLVE r11 using CNS;
a1c("US", r2)  = a11.L(r2);
a1c("US", "RW")  = 1-sum(r2,a11.L(r2));
a1c("US", "CH")  = 0;

SOLVE r12 using CNS;
a2c("US",r1) = a12.L(r1);
a2c("US","CH") = 1 - sum(r1, a12.L(r1))

SOLVE r21 using CNS;
a1c("CA",r1) = a21.L(r1);
a1c("CA","CH") = 1 - sum(r1, a21.L(r1))

SOLVE r22 using CNS;
a2c("CA",r1) = a22.L(r1);
a2c("CA","CH") = 1 - sum(r1, a22.L(r1));

Display a11.l, a12.l, a21.l, a22.l;
```

```
PARAMETERS aqi1(i)   apple quantity index in t1,
           aqi2(i)   apple quantity index in t2,
           pqi1(i)   apple price index in t1,
           pqi2(i)   apple price index in t2;

aqi1("US") = (sum(r1, a1c("US",r1)**(1/sig2("US"))*q1("US",r1)**
        ((sig2("US")-1)/sig2("US"))))**(sig2("US")/(sig2("US")-1));

aqi1("CA") = (sum(j,  a1c("CA", j)**(1/sig2("CA"))*q1("CA",j)**
        ((sig2("CA")-1)/sig2("CA"))))**(sig2("CA")/(sig2("CA")-1));

aqi2(i) =(sum(j, a2c(i,j)**(1/sig2(i))*q2(i,j)**
        ((sig2(i)-1)/sig2(i))))**(sig2(i)/(sig2(i)-1));

pqi1(i) = (sum(j, a1c(i,j)*pb1(i,j)**(1-sig2(i))))**(1/(1-sig2(i)));

pqi2(i) = (sum(j, a2c(i,j)*pb2(i,j)**(1-sig2(i))))**(1/(1-sig2(i)));

DISPLAY a1c, a2c, aqi1, aqi2, pqi1, pqi2 ;

VARIABLES  b1c(i)  shift parameter for aggregate level of apples in t1,
           b2c(i)  shift parameter for aggregate level of apples in t2;

b1c.LO(i) = 0;
b1c.UP(i) = 1.0;

b2c.LO(i) = 0;
b2c.UP(i) = 1.0;

EQUATIONS  zb1(i)  equation for calibration of b1->aggregate shift parameter,
           zb2(i)  equation for calibration of b2->aggregate shift parameter;

zb1(i).. aqi1(i) =E= (b1c(i)*pqi1(i)**(-sig1(i))*inc1b(i))/(b1c(i)*pqi1(i)**
            (1-sig1(i)) + (1-b1c(i)));

zb2(i).. aqi2(i) =E= (b2c(i)*pqi2(i)**(-sig1(i))*inc2b(i))/(b2c(i)*pqi2(i)**
            (1-sig1(i)) + (1-b2c(i)));

MODEL top1 / zb1 /;
MODEL top2 / zb2 /;

SOLVE top1 using CNS;
b1(i) = b1c.L(i);

SOLVE top2 using CNS;
```

```
b2(i) = b2c.L(i);

display b1c.l, b2c.l;

PARAMETERS  xq1(i,j),
            xq2(i,j);

xq1(i,j) = (b1(i)*a1c(i,j)*pb1(i,j)**(-sig2(i))*pqi1(i)**(sig2(i) - sig1(i))*
        inc1b(i))/(b1(i)*pqi1(i)**(1-sig1(i)) + (1-b1(i))) - q1(i,j);

xq2(i,j) = (b2(i)*a2c(i,j)*pb2(i,j)**(-sig2(i))*pqi2(i)**(sig2(i) - sig1(i))*
        inc2b(i))/(b2(i)*pqi2(i)**(1-sig1(i)) + (1-b2(i))) - q2(i,j);

DISPLAY xq1, xq2;

PARAMETERS
   pp1(j)    Producer price of apples $ per lb in t1
          /US 0.273 , CA 0.216, CH 0.15, RW 0.29 /,
   pp2(j)    Producer price of apples $lbs in t2
          /US 0.217, CA 0.216, CH 0.16, RW 0.33 /,
   yb1(j)    Base supply in time period 1 (million lbs)
          / US 5705.069908, CA 565.3823691, CH 8.19, RW 196.2395623/,
   yb2(j)    Base supply in time period 2 (million lbs)
          / US 5059.068969, CA 596.2277587, CH 85.68, RW 160.4791564/,
   vb(j)    Base endowment,
   c(j)     Intercept for supply functions ,
   d(j)     Slope for supply functions ,
   AS(j)    Aggregate supply elasticities ,
   e(j)     Shift parameter for CET revenue function ,
   f(j)     Exponent for CET revenue function
          / US 1.5,  CA  1.5 , CH  1.5,  RW  1.5 / ;
VARIABLES
   ec(j)   CET shift parameter for each region,
   vc(j)   Apple factor endowment;

vc.L("US") = 10764.14;
vc.L("CA") = 1161.61;
vc.L("CH") = 93.88;
vc.L("RW") = 356.72;

EQUATIONS
  sup1(j) Supply time period 1,
  sup2(j) Supply time period 2;

ec.LO(j) = 0.01;
ec.UP(j) = 0.99;
```

```
sup1(j).. yb1(j) =e= ec(j)*pp1(j)**(f(j)-1)*(ec(j)*pp1(j)**f(j) + (1-ec(j))*
              pp2(j)**f(j))**((1/f(j))-1)*vc(j);

sup2(j).. yb2(j) =e= (1-ec(j))*pp2(j)**(f(j)-1)*(ec(j)*pp1(j)**f(j) +
              (1-ec(j))*pp2(j)**f(j))**((1/f(j))-1)*vc(j);

MODEL calib / sup1, sup2 /;

SOLVE calib using CNS;

e(j) = ec.L(j);
vb(j) = vc.L(j);

Parameters  checks1(j) Check on first period supply,
            checks2(j) Check on second period supply,
            ppi(j)     apple price index;

ppi(j) = (e(j)*pp1(j)**f(j) + (1-e(j))*pp2(j)**f(j))**(1/f(j));

checks1(j) = e(j)*pp1(j)**(f(j)-1)*(e(j)*pp1(j)**f(j) + (1-e(j))*pp2(j)**f(j))
        **((1/f(j))-1)*vb(j) - yb1(j);

checks2(j) = (1-e(j))*pp2(j)**(f(j)-1)*(e(j)*pp1(j)**f(j) + (1-e(j))*pp2(j)**f(j))
        **((1/f(j))-1)*vb(j) - yb2(j);

AS("US") = 1.5;
AS("CA") = 3;
AS("RW") = 6;
AS("CH") = 8;

d(j) = AS(j)*vb(j)/ppi(j);

c(j) = vb(j) - d(j)*ppi(j);

display ppi, AS, c, d, yb1, yb2, checks1, checks2;


PARAMETERS
   a1(i,j)  Bottom-level demand shift parameters for t1,
   a2(i,j)  Bottom-level demand shift parameters for t2,
   pop1(i)   Population in demand regions for t1
        / US 293.655, CA 31.989 / ,
   pop2(i)   Population in demand regions for t2
        / US 296.41, CA 32.299 / ,
```

```
   inc1(i)  percapita income in t1
          / US 33050,   CA 28310/,
   inc2(i)  percapita total income in t2
          /US 34586,   CA 32600/,
   pcost1(s1) Compliance cost in China in t1 ($ per lb)
          / CH 0.004610175/,
   pcost2(s1) Compliance cost in China in t2 ($ per lb)
          / CH 0.005022098/,
   pcteff(p) Percent of crop in importing region affected by infestation
          /PFM 0.02/ ,
   ploss(p)  percent productivity loss from infestation in importing region
          /PFM 0.02/;

a1("US",r2) = a1c("US",r2);
a1("US","CH") =0;
a1("US", "RW") = 1- sum(r2,a1("US",r2));

a1("CA",r1) = a1c("CA",r1);
a1("CA", "CH") = 1- sum(r1,a1("CA",r1));

a2("US",r1) = a2c("US",r1);
a2("US", "CH") = 1- sum(r1,a2("US",r1));

a2("CA",r1) = a1c("CA",r1);
a2("CA", "CH") = 1- sum(r1,a1("CA",r1));

display a1, a2;

Table prob1(i,p) Probability that pest infects fruit during the harvest for US&CA Without
SA
       PFM
US   0.000005
CA   0.000005;

Table prob2(i,p) Probability the pest is not detected during packing Without SA
       PFM
US   0.00008
CA   0.00008;

Table prob3(i,p) Probability that pest survives shipment Without SA
       PFM
US   0.7
CA   0.7;

Table prob4(i,p) Probability that pest is not detectd at port-of-entry Without SA
       PFM
```

```
US    0.2
CA    0.2;

Table prob5(i,p) Probability that pest is able to become established Without SA
       PFM
US    0.00005
CA    0.00005;

Table probsa1(i,p) Probability that pest infects fruit during the harvest for US&CA
       PFM
US    0.0000028
CA    0.0000028;

Table probsa2(i,p) Probability the pest is not detected during packing
       PFM
US   0.00044
CA   0.00044;

Table probsa3(i,p) Probability that pest survives shipment
       PFM
US    0.8
CA    0.8;

Table probsa4(i,p) Probability that pest is not detectd at port-of-entry
       PFM
US    0.325
CA    0.325;

Table probsa5(i,p) Probability that pest is able to become established

     PFM
US    0.000275
CA    0.000275;

TABLE m1(i,j) Fixed wholesale margins for t1
      US        CA         CH        RW
US     0.257     0.444      0.51      0.23
CA     0.457     0.424      0.54      0.51 ;


Table m2(i,j) Fixed wholesale margins for t2
      US        CA         CH        RW
US     0.353     0.484      0.54      0.21
CA     0.563     0.424      0.43      0.44 ;

Table suscept(i,p) Proportion of population in susceptible areas
```

```
      PFM
US     0.90
CA     0.90;

Table  controlc1(i,p) Fixed control cost of pest in dollors in t1
      PFM
US    0.00546
CA    0.00432;



Table  controlc2(i,p) Fixed control cost of pest in dollors in t2
      PFM
US    0.00432
CA    0.00332;


POSITIVE VARIABLES
      freq1(i,p) frequency of pest outbreak in t1,
      freq2(i,p) frequency of pest outbreak in t2,
      x1(i,j)   Demand for apples in t1,
      x2(i,j)   Demand for apples in t2,
      y1(j)     supply of apples in t1,
      y2(j)     Supply of apples in t2,
      p1(j)     Producer price of apples in t1,
      p2(j)     Producer price of apples in t2,
      V(j)      Endowment for CET revenue function,
      api1(i)   Apple price index in t1,
      api2(i)   Apple price index in t2,
      wp1(i,j)  wholesale price for apples in t1,
      wp2(i,j)  wholesale price for apples in t2;

EQUATIONS
      outbreak11(d1,p) Equation for frequency of pest outbreak in t1,
      outbreak12(d2,p) Equation for frequency of pest outbreak in t1,
      outbreak2(i,p) Equation for frequency of pest outbreak in t2,
      xd1(i,j)   Demand equations for apples in t1,
      xd2(i,j)   Demand equations for apples in t2,
      ys11(s1)   Supply equations for China in t1,
      ys12(s2)   Supply equations for RW in t1,
      ys13(s3)   Supply equations for US in t1,
      ys14(s4)   Supply equations for CA in t1,
      ys21(s1)   Supply equations for China in t2,
      ys22(s2)   Supply equations for RW in t2,
      ys23(s3)   Supply equations for US in t2,
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```
     ys24(s4)   Supply equations for CA in t2,
     mc1(j)     Market clearing conditions in t1,
     mc2(j)     Market clearing conditions in t2,
     ends1(s1)  Supply of factor endowment for CET revenue functions for China,
     ends2(s2)  Supply of factor endowment for CET revenue functions for RW,
     ends3(s3)  Supply of factor endowment for CET revenue functions for US,
     ends4(s4)  Supply of factor endowment for CET revenue functions for CA,
     pind1(i)   Equations for apple price index in t1,
     pind2(i)   Equations for apple price index in t2,
     wholep11(i,s1)  wholesale price for apples from China in t1,
     wholep12(i,s2)  wholesale pricefor apples from RW in t1,
     wholep13(i,s3)  wholesale pricefor apples from U.S in t1,
     wholep14(i,s4)  wholesale price for apples from Canada in t1,
     wholep21(i,s1)  wholesale price for apples from China in t2,
     wholep22(i,s2)  wholesale pricefor apples from RW in t2,
     wholep23(i,s3)  wholesale price for apples from U.S in t2,
     wholep24(i,s4)  wholesale price for apples from Canada in t2;


wp1.LO(i,j) =0.01;
wp2.UP(i,j) =3;

wp2.LO(i,j) =0.01;
wp2.UP(i,j) =3;

p1.LO(j) = 0.05;
p1.UP(j) = 2;

p2.LO(j) = 0.01;
p2.UP(j) = 2;

api1.LO(i) = 0.5;
api2.LO(i) = 0.5;

y1.LO(s1)=1;
y2.LO(s1)=10;

y1.LO(s2)=100;
y2.LO(s2)=100;

y1.LO(s3)=4000;
y2.LO(s3)=4000;

y1.LO(s4)=500;
y2.LO(s4)=500;
```

```
outbreak11(d1,p).. freq1(d1,p) =e= prob1(d1,p)*prob2(d1,p)*prob3(d1,p)*prob4(d1,p)
                    *prob5(d1,p)* suscept(d1,p)*(x1(d1,"CH"))*25000;

outbreak12(d2,p).. freq1(d2,p) =e=
probsa1(d2,p)*probsa2(d2,p)*probsa3(d2,p)*probsa4(d2;p)
                    *probsa5(d2,p)* suscept(d2,p)*(x1(d2,"CH"))*25000;

outbreak2(i,p).. freq2(i,p) =e= probsa1(i,p)*probsa2(i,p)*probsa3(i,p)*probsa4(i,p)
                    *probsa5(i,p)*suscept(i,p)*(x2(i,"CH"))*25000;

xd1(i,j).. x1(i,j) =e= pop1(i)*(b1(i)*a1(i,j)*wp1(i,j)**(-sig2(i))*
              api1(i)**(sig2(i) - sig1(i))*inc1(i))/
              (b1(i)*api1(i)**(1-sig1(i)) + (1-b1(i)));

xd2(i,j).. x2(i,j) =e= pop2(i)*(b2(i)*a2(i,j)* wp2(i,j)**(-sig2(i))*
              api2(i)**(sig2(i) - sig1(i))*inc2(i))/
              (b2(i)*api2(i)**(1-sig1(i)) + (1-b2(i)));

ys11(s1)..   y1(s1) =e= e(s1)*(p1(s1)-pcost1(s1))**(f(s1)-1)*V(s1)*
              (e(s1)*(p1(s1)-pcost1(s1))**f(s1)+
              (1-e(s1))*(p2(s1)-pcost2(s1)))**f(s1)**((1/f(s1))-1);

ys12(s2)..   y1(s2) =e= e(s2)*p1(s2)**(f(s2)-1)*V(s2)*
              (e(s2)*p1(s2)**f(s2)+(1-e(s2)))*p2(s2)**f(s2)**((1/f(s2)-1));


ys13(s3)..   y1(s3)
=e=(1-sum(p,(freq1("US",p)+freq2("US",p))*pcteff(p)*ploss(p)))*e(s3)*
              (p1(s3)-sum(p,controlc1("US",p)))**(f(s3)-1)*V(s3)*
              (e(s3)*(p1(s3)-sum(p,controlc1("US",p)))**f(s3)+
              (1-e(s3))*(p2(s3)-sum(p,controlc2("US",p)))**f(s3)**
              ((1/f(s3))-1));

ys14(s4)..   y1(s4) =e= e(s4)*p1(s4)**(f(s4)-1)*V(s4)*
              (e(s4)*p1(s4)**f(s4)+(1-e(s4)))*p2(s4)**f(s4)**((1/f(s4)-1));

ys21(s1)..   y2(s1) =e= (1-e(s1))*(p1(s1)-pcost2(s1))**(f(s1)-1)*V(s1)*
              (e(s1)*(p1(s1)-pcost1(s1))**f(s1)+
              (1-e(s1))*(p2(s1)-pcost2(s1)))**f(s1)**((1/f(s1))-1);

ys22(s2)..   y2(s2) =e= (1-e(s2))*p2(s2)**(f(s2)-1)*V(s2)*
              (e(s2)*p1(s2)**f(s2)+(1-e(s2)))*p2(s2)**f(s2)**((1/f(s2)-1));
```

```
ys23(s3)..   y2(s3) =e=
(1-e(s3))*(1-sum(p,(freq1("US",p)+freq2("US",p))*pcteff(p)*ploss(p)))*
                 (p2(s3)-sum(p,controlc2("US",p)))**(f(s3)-1)*V(s3)*
                 (e(s3)*(p1(s3)-sum(p,controlc1("US",p)))**f(s3)+
                 (1-e(s3))*(p2(s3)-sum(p,controlc2("US",p)))**f(s3)**
                  ((1/f(s3))-1));

ys24(s4)..   y2(s4) =e= (1-e(s4))*p2(s4)**(f(s4)-1)*V(s4)*
                (e(s4)*p1(s4)**f(s4)+(1-e(s4)))*p2(s4)**f(s4)**((1/f(s4)-1));


mc1(j)..   y1(j) =g= sum(i, x1(i,j));

mc2(j)..   y2(j) =g= sum(i, x2(i,j));

ends1(s1)..  V(s1) =e= c(s1)+ d(s1)*(e(s1)*(p1(s1)-pcost1(s1))**f(s1)+
                 (1-e(s1))*(p2(s1)-pcost2(s1))**f(s1))**(1/f(s1));

ends2(s2)..  V(s2) =e= c(s2) + d(s2)*(e(s2)*p1(s2)**f(s2)+
                 (1-e(s2))*p2(s2)**f(s2))**(1/f(s2));

ends3(s3)..  V(s3) =e= c(s3)+ d(s3)*(e(s3)*(p1(s3)-sum(p,controlc1("US",p)))**
                 f(s3) +(1-e(s3))*(p2(s3)-sum(p,controlc2("US",p)))**
                 f(s3))**(1/f(s3));

ends4(s4)..  V(s4) =e= c(s4) + d(s4)*(e(s4)*p1(s4)**f(s4)+
                 (1-e(s4))*p2(s4)**f(s4))**(1/f(s4));

pind1(i)..  api1(i) =e= (sum(j, a1(i,j)*wp1(i,j)**(1-sig2(i))))**
               (1/(1-sig2(i)));

pind2(i)..  api2(i) =e= (sum(j, a2(i,j)*wp2(i,j)**(1-sig2(i))))**
               (1/(1-sig2(i)));

wholep11(i,s1)..  wp1(i,s1) =e= p1(s1)+ m1(i,s1)+ pcost1(s1);
wholep12(i,s2)..  wp1(i,s2) =e= p1(s2)+ m1(i,s2);
wholep13(i,s3)..  wp1(i,s3)  =e= p1(s3)+ m1(i,s3)+sum(p,controlc1("US",p));
wholep14(i,s4)..  wp1(i,s4)  =e= p1(s4)+ m1(i,s4);

wholep21(i,s1)..  wp2(i,s1) =e= p2(s1)+ m2(i,s1)+ pcost2(s1);
wholep22(i,s2)..  wp2(i,s2) =e= p2(s2)+ m2(i,s2);
wholep23(i,s3)..  wp2(i,s3) =e= p2(s3)+ m2(i,s3)+ sum(p,controlc2("US",p));
wholep24(i,s4)..  wp2(i,s4) =e= p2(s4)+ m2(i,s4);

MODEL aphis  / outbreak11.freq1,outbreak12.freq1, outbreak2.freq2, xd1.x1, xd2.x2,
                  ys11.y1, ys12.y1, ys13.y1, ys14.y1, ys21.y2, ys22.y2, ys23.y2, ys24.y2,
```

```
                    mc1.p1, mc2.p2, ends1.v,ends2.v, ends3.v, ends4.v,pind1.api1,
                    pind2.api2, wholep11.wp1, holep12.wp1,wholep13.wp1,wholep14.wp1,
                    wholep21.wp2,  wholep22.wp2,wholep23.wp2,wholep24.wp2/;

SOLVE aphis using MCP;

display wp1.l, wp2.l, p1.l, p2.l;

Parameters  ga(j)  gross avenue change,
            ppd(j)  producer price inference,
            ps(j)  half rule;
ppd(j)=p1.l(j)-p2.l(j);

ga(j) = p2.l(j)*y2.l(j)-p1.l(j)*y1.l(j);

ps(j)=-ppd(j)*(y1.l(j) + y2.l(j))/2;


display ga, ps;


parameters  pd(i,j) price different for U.S,
            cs(i,j) consumer surplus for US from US,
            css(i)  consumer surplus sum;

pd(i,j)=wp1.l(i,j)-wp2.l(i,j);

cs(i,j)= pd(i,j)*(x1.l(i,j)+x2.l(i,j))/2;
css(i)= sum(j,cs(i,j));

display cs,css;

$ontext

FILE OUT1 /E:lili's ipod\RA\GAMS\RESULT.TXT/ ;

PUT out1;

LOOP (j, PUT 'x1 ='; PUT x1.L("A",j):>10:5; PUT /);
LOOP (j, PUT 'x1 ='; PUT x1.L("B",j):>10:5; PUT /);
LOOP (j, PUT 'x1 ='; PUT x1.L("C",j):>10:5; PUT /);
LOOP (j, PUT 'x1 ='; PUT x1.L("D",j):>10:5; PUT /);
LOOP (j, PUT 'x2 ='; PUT x2.L("A",j):>10:5; PUT /);
LOOP (j, PUT 'x2 ='; PUT x2.L("B",j):>10:5; PUT /);
LOOP (j, PUT 'x2 ='; PUT x2.L("C",j):>10:5; PUT /);
LOOP (j, PUT 'x2 ='; PUT x2.L("D",j):>10:5; PUT /);
```

```
LOOP (j, PUT 'y1 ='; PUT y1.L(j):>10:5; PUT /);
LOOP (j, PUT 'y2 ='; PUT y2.L(j):>10:5; PUT /);
LOOP (j, PUT 'p1 ='; PUT p1.L(j):>10:5; PUT /);
LOOP (j, PUT 'p2 ='; PUT p2.L(j):>10:5; PUT /);
LOOP (i, PUT 'api1 ='; PUT api1.L(i):>10:5; PUT /);
LOOP (i, PUT 'api2 ='; PUT api2.L(i):>10:5; PUT /);
LOOP (i, PUT 'aqn1 ='; PUT aqn1(i):>10:5; PUT /);
LOOP (i, PUT 'aqn2 ='; PUT aqn2(i):>10:5; PUT /);
LOOP (r, PUT 'v ='; PUT v.L(r):>10:5; PUT /);
LOOP (i, PUT 'ev1 ='; PUT ev1(i):>15:8; PUT /);
LOOP (i, PUT 'ev2 ='; PUT ev2(i):>15:8; PUT /);
LOOP (j, PUT 'psur ='; PUT psur(j):>15:8; PUT /);
PUT 'totev ='; PUT totev:>15:8; PUT /;
PUT 'uswelfare ='; PUT uswelfare:>15:8; PUT /;
PUT 'gwelfare ='; PUT gwelfare:>15:8; PUT /;
LOOP (j, PUT 'sub1 ='; PUT sub1("A",j):>10:5; PUT /);
LOOP (j, PUT 'sub1 ='; PUT sub1("B",j):>10:5; PUT /);
LOOP (j, PUT 'sub1 ='; PUT sub1("C",j):>10:5; PUT /);
LOOP (j, PUT 'sub1 ='; PUT sub1("D",j):>10:5; PUT /);
LOOP (j, PUT 'sub2 ='; PUT sub2("A",j):>10:5; PUT /);
LOOP (j, PUT 'sub2 ='; PUT sub2("B",j):>10:5; PUT /);
LOOP (j, PUT 'sub2 ='; PUT sub2("C",j):>10:5; PUT /);
LOOP (j, PUT 'sub2 ='; PUT sub2("D",j):>10:5; PUT /);
LOOP (j, PUT 'ex1 ='; PUT ex1("A",j):>10:5; PUT /);
LOOP (j, PUT 'ex1 ='; PUT ex1("B",j):>10:5; PUT /);
LOOP (j, PUT 'ex1 ='; PUT ex1("C",j):>10:5; PUT /);
LOOP (j, PUT 'ex1 ='; PUT ex1("D",j):>10:5; PUT /);
LOOP (j, PUT 'ex2 ='; PUT ex2("A",j):>10:5; PUT /);
LOOP (j, PUT 'ex2 ='; PUT ex2("B",j):>10:5; PUT /);
LOOP (j, PUT 'ex2 ='; PUT ex2("C",j):>10:5; PUT /);
LOOP (j, PUT 'ex2 ='; PUT ex2("D",j):>10:5; PUT /);

$offtext
```

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