CONSUMERS ACCEPTANCE OF GENETICALLY MODIFIED FOOD PRODUCTS IN CHILE AND ECONOMIC IMPLICATIONS OF INVAISVE SPECIES IN INTERNATIONAL TRADE

By

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To the faculty of Washington State University:

The members of the Committee appointed to examine the thesis of Ricardo Diaz Carcamo find it satisfactory and recommend that it be accepted.

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Chair

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CONSUMERS ACCEPTANCE OF GENETICALLY MODIFIED FOOD PRODUCTS IN CHILE AND ECONOMIC IMPLICATIONS OF INVAISVE SPECIES IN INTERNATIONAL TRADE

General Abstract

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Public acceptance of genetically modified (GM) food appears to be highly affected by cultural issues. Most of the research regarding consumers' willingness to pay (WTP) has focused on first-generation GM products, which have little or no direct benefit to consumers. It is believed that consumers will be more accepting of second-generation GM products that offer direct benefits to consumers (e.g., improved nutritional characteristics). Misinformation and/or lack of information are commonly reported to be the main reasons for low consumer's acceptance of GM food products. Different interest groups, such as biotech companies and environmental groups disseminate information that endorses their own particular interests creating great levels of uncertainty for consumers.

This thesis examines consumers acceptance and consumers' willingness to pay (WTP) for second-generation GM food products in Chile. The data used in this study were collected through in-person surveys conducted in Santiago, Chile, in June of 2004. A standard double-bounded logit model was used to examine the outcomes of the survey. The questioning sequence isolates the range in which the respondents' true WTP lays.

Results suggest respondents are environmental conscious and concerned with food safety. The majority of those surveyed had knowledge about biotechnology and felt very positive about the use of biotechnology in food. However, most of them associated a level of risk to consuming biotech products. Respondents reported to be “willing to buy” first and second generation GM food products. However, Chilean consumers would need a discount in order to buy GM apples over the non-GM product. On the other hand, the information provided to the respondents significantly affects their WTP.

The thesis also studied the economic effects of invasive species in international trade with a special emphasis en the U.S.-Chile fruit trade. It is concluded that trade liberalizing policies have multiple benefits including increase of the countries' population welfare. However, introductions of new IS can harm both producers and consumers, counteracting these benefits. A simulation model is proposed to analyze the impacts of the new IS and alternative quarantine measures.

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INTRODUCTION

Introduction:

Consumer response to genetically modified (GM) food seems to be largely affected by cultural issues. In general, consumers from European countries are usually reported to be less accepting of GM food products when compared to those in the U.S. While there is much less information about consumer's acceptance in low-income countries, it is possible that there may be greater benefits to these consumers.

Most of the GM products ready available contain small modifications (one or more genes) that confer one or more specific characteristics that the original variety does not have. This way, the genetic modification can induce resistance to herbicides, tolerance to insects, virus and fungi, etc. Among these products, the more widely known (and currently used) are Monsanto's Roundup Ready® corn, soybean, and cotton, BT corn, etc. These types of GM products, commonly referred to as first-generation, were developed to improve their agronomic performance. Second-generation GM products have been genetically modified to improve their nutritional value and could offer direct benefits to the consumers. Golden Rice, which by genetic modification produces beta-carotene, a precursor to vitamin A, is one of the emblematic cases of second-generation GM products. Even though second-generation genetically modified organisms (GMO) are not currently available for consumers, because research is still being done, given the high consumers' demand for other non-GM functional food products they are expected to be soon available in the market.

This study follows the approach previously used in China, Japan, Norway, and in the U.S. to determine peoples' willingness to pay (WTP) for food products containing GM ingredients in Chile.

Research Objectives:

The major objective of this research was to study consumers' acceptance for genetically modified (GM) food products in Chile. Consumers' response to GM food seems to be largely affected by cultural issues. A number of studies have been conducted regarding consumers' acceptance to food products containing GM ingredients in several countries; with special importance given to consumers' attitude in developed countries. In general, consumers from European countries are reported to be less accepting of GM food products when compared to those in the U.S. There is much less information about consumer acceptance in low-income countries although it is possible that there may be greater benefits to consumers. The data used in this study was collected through in-person surveys conducted in Santiago, Chile, in June 2004. The survey contained contingent valuation questions regarding the respondents' willingness to pay a premium or accept a discount to buy GM apples and bread made with GM wheat

This study is part of a larger scale research effort trying to understand how several individual characteristics influence consumers' willingness to pay a premium or willingness to accept a discount for GM food products in several countries.

There is an additional chapter that includes an analysis of the economic effects of invasive species, another food safety issue of great importance in international marketing and trade.

Thesis Format:

There are two independent but related articles in this thesis. The first article focuses on consumers' acceptance of GM food products in Chile. It has been accepted for presentation at the Western Agricultural Economics Association Meetings later this year. The article in the third chapter investigates the economic implications of invasive species in international trade, with a special emphasis on the Chile-U.S. fresh fruit market. This article was presented in the Asia Pacific Economic Cooperation (APEC) Study Centers Consortium Meeting in Chile in May 2004.

The relationship between the two chapters seems to be difficult to visualize. As the introduction of non-native organisms to a new ecosystem, the release of a GM organism to the environment, underlines similar uncertainties with regards to long term effects. Only few introduced organisms become "invasive", yet the main issue for government agencies dealing with invasive species is how to differentiate those organisms from "safer" ones. In the case of GM organisms, an important issue for regulatory agencies is to be able to identify the modifications that may enhance invasive characteristics of a given organism. Genetic modifications, both traditionally or through engineering, can potentially enhance organisms' ability to become an invasive species (Wolfenbarger and Phifer, 2000). In Chapter Three we propose a simulation model that evaluates the risk of a given invasive species, as well as the costs and benefits of taking a particular quarantine measure; a bio-economic fruit model based both on invasive species characteristics and the economic implications for both consumers and producers. Based on the similarities between invasive species and GM organisms, a similar modeling approach could be used to analyze the economic effects of the introduction of GM organisms to the environment as well as the introduction of an invasive species under the current international sanitary and phytosanitary regulations.

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CHAPTER 2

CONSUMERS ACCEPTANCE OF SECOND-GENERATION GENETICALLY MODIFIED APPLES IN CHILE

Introduction

Consumer responses to genetically modified (GM) foods seem to be largely affected by cultural issues. Studies of Europe and Japan provide evidence that consumers are only willing to take on the unknown risks of consuming genetically modified foods if these products are offered at significant cost savings over non-genetically modified foods. Grimsrud et al. (2004) conclude that consumers in their Norwegian sample are willing, on average, to purchase bread made with GM wheat only if it were offered at a 49.5% discount over non-GM bread. Burton et al. (2001) conclude that male British shoppers are willing to pay an extra 26% to avoid animal and plant genetically modified technology, while female British shoppers are willing to pay an extra 49.3%. McCluskey et al. (2003) find that Japanese consumers in their sample, on average, require a discount of greater than 50% for noodles made with GM wheat relative to GM-free noodles.

Studies in the United States and Canada find consumers to be more accepting of genetically modified foods compared with consumers in Europe and Japan. For example, Lusk et al. (2001) finds that 70% of their respondents are not willing to pay a premium for non-genetically modified corn chips. A Canadian (ICAST 1995) study finds that consumers are willing to purchase genetically modified potatoes if offered at equal or slightly discounted prices.

Little is known about the consumer response in South America. Pachico and Wolf (2002) find that 66% of the survey respondents in Columbia are willing to try genetically modified foods, and the willingness to purchase genetically modified foods is high among those who feel they do not have adequate or high quality foods available at home. The current study analyzes consumer preferences for a GM food in Chile.

Most available GM products contain first-generation of genetic modifications, which address production conditions and have “input traits;” thus they are producer friendly rather than consumer friendly. As second-generation GM products, which will include “quality traits” such as nutritional benefits enter the market, consumers may be more accepting of biotechnology in food. With benefits directly accruing to consumers, those “consumer-friendly” GM products could be accepted without discounts or even receive a premium. Golden Rice, which by genetic modification produces beta-carotene, a precursor to vitamin A, is one of the emblematic cases of second-generation GM products. In fact, Li et al. (2003) conclude that Chinese consumers in their sample, on average, are willing to pay a 38% premium for Golden Rice. Further, Boccaletti and Moro (2000) report a decrease in the percentage of consumers’ who refuse to buy GM food products from 17% to 12%, when confronted with products that directly affect them, instead of generic GM food products in Italy. They find that consumers are more willing to accept GM products with increased nutritional and organoleptic characteristics, and longer shelf life. The same tendency is reported in Colombia, where the willingness to buy significantly increased when GM products contained a characteristic desired by consumers, such as enhanced nutrition and taste (Pachico and Wolf 2002). West et al.

(2002) report that respondents were willing to pay higher prices for functional food products such as anti-cancer tomatoes, heart-healthy potatoes and chicken in Canada. Maynard and Franklin (2003) report a similar tendency with "cancer-fighting" dairy products.

Although second-generation genetically modified organisms (GMO) are not yet readily available for consumers, a great deal of research is being made and given the high consumers' demand for other non-GM functional food products, they are expected to be soon available in the market. To our knowledge, there is only one second-generation GM product available in the U.S. market. Cigarettes made with genetically modified tobacco plants with reduced nicotine levels, currently sold under the brand name Quest^{tm} (Questcigs 2004).

Apples and other fruits have been genetically modified in order to introduce genes for insects and diseases resistance (James et al. 1993). Fruit produced by the GM trees show higher levels of resistance to Fire Blight (*Erwinia amylovora*), an important apple disease; however fruit appearance is maintained being indistinguishable from non-GM fruit (Aldwinckle et al. 2000). Even though none of these GM fruit crops have been released to the market, large amount of research is being conducted. Potential consumers' benefits of GM fruits could speed the deregulation process, and they could reach the market sooner than later. Prevention of tooth decay by consuming GM apples and strawberries is an example of potential consumers' benefits (Briggs 2000).

It is likely that second-generation GM food products will be offered to consumers at higher prices. In fact, traditional non-GM functional foods currently available (food products enriched to improve their nutritional characteristics that may provide health benefits beyond basic nutrition, such as high fiber cereals and calcium-enriched orange juice) are usually more expensive than regular non-enriched food products. Further, labeling and traceability issues would *per se* increase the cost of the second-generation GM food products, thus it is very realistic to assume that GM functional products will be more expensive than traditional ones.

This article examines the attitudes of consumers in Chile towards GM foods and their willingness to pay for second-generation GM apples. The contribution of this study is that in the information given to the respondents we presented our consumers with a product that combines the characteristics of a first-generation GM product with the consumer's direct benefits associated with second-generation GM food products: GM apples with increased levels of vitamins and nutrients as well as reducing the use of pesticides were presented. This way, respondents could realize direct benefits and to the environment as well.

Data

The data used in this study was collected through in-person surveys conducted in Santiago, Chile, in June of 2004. Santiago is the capital of Chile, a major urban area, with a population of six million people, more than one-third of the country's total population. The survey was performed in four different areas of the city. These locations were chosen in order to guarantee the randomness of the sample and to ensure that a cross section of the city's population was surveyed. Respondents were randomly selected and solicited to fill out the questionnaire, as they were either approaching or leaving a grocery store. By interviewing people at grocery stores, we aimed to acquire the data where their decision regarding food purchases were in fact being made. Every respondent was given a bottled soft drink (worth approximately $0.53 in Chilean Pesos). A Spanish version of the survey was developed and pre-tested with Chilean students in the United States.

The vast majority (84%) of the 600 respondents were the main food shoppers for their households. Females compromised 52% of the respondents, which is comparable to the 50.7% female population of the country. Fifty-four percent of the respondents reported they purchase groceries at least twice a week. The majority of people interviewed were between 31 and 50 years old. Even though the majority of the Chilean population is younger than 20 years old, we excluded young people (18 and younger) from the surveying process to ensure that respondents were the ones in fact making decisions regarding food purchases. Sixty-nine percent of all respondents had children under the age of 18 years living in their household, and the average household size was 4.5 people. Most of the respondents were employed either full time (39%), part time (12%) or self-employed (25%). Fifty-four percent of the people interviewed reported annual income between 1,200,000 and 6,000,000 Chilean *Pesos* (US$2,000- US$9,000). The average annual income of the sampled populations was US$4,800, which is comparable to the US$4,390 gross national income per capita reported by the World Bank (2003). A big percentage (47%) of the 600 respondents reported to have finished high school, and 21% of the respondents had a college degree. Summary statistics of the demographic variables and the country demographic statistics are presented in Table 1.

The survey also asked for information about respondents' attitudes concerning the environment and food safety. This information was acquired by asking respondents to place themselves in a theoretical scale where economic growth at all costs was one and saving the environment at all costs was ten. The responses were distributed with a mean of 7.21, which reflects an environmentally conscious community. A similar approach was taken in order to obtain information regarding respondents' attitude about food safety. The mean of the responses was 4.32, where lower food safety risk was one and lower cost food was ten. Eliciting environmental and food safety attitudes from trade-off scenarios was an effective way of ensuring that survey information was informative as well as useful in an empirical modeling context.

Seventy-seven percent of respondents reported to be either very or somewhat knowledgeable about biotechnology and GM foods. Even though the majority of Chilean respondents (54%) felt either "very positive" or "somewhat positive" about the use of biotechnology in food, 65% of them associated some risk (35% high risk, and 30% low risk) with the use of biotechnology in food. Health concerns, long-term effects, and lack of information are among the sources of risk that were commonly reported by respondents. The vast majority (88%) of the Chilean respondents gave a very high importance to the labeling of GM food products. More than 70% of the respondent preferred domestic to imported food products. A summary of the statistics for consumer information and perception variables is presented in Table 2. [Table 2 here]

Empirical Analysis

The contingent-valuation method (CVM) is a technique primarily developed to estimate the willingness to pay (WTP) for a given policy, service or product for which market data is unavailable. The CVM is the standard method to elicit willingness-to-pay using a dichotomous choice model. Individual WTP can be obtained by market-type questions (Kanninen 1993). This survey contained contingent valuation questions regarding the respondents' willingness to pay a premium or accept a discount to buy GM apples. Apples are a popular product in Chile. Out of the 600 respondents, 80% indicated that they eat apples at least once a week, making them an appropriate product to assess consumers' willingness to pay in this study. Respondents were first asked if they were willing to pay the same price for GM apples as they would for an identical non-GM products. If the respondent's answer to this question was "no," a follow-up question was asked where the respondent was offered a percentage discount on the GM apples relative to the non-GM apples. If the respondent's answer to the first question was "yes," a follow-up question was asked where the respondent was offered a percentage premium on the GM apples relative to the non-GM apples. The discount levels were randomly assigned and included the following values: 5%, 10%, 25%, 50%, and 90%. The premium levels included: 5%, 10%, 20%, 30%, and 50%. Each level of discount or premium was used for one-fifth of the surveys.

Of the 600 respondents, only 36% said that they would be willing to purchase the GM apples at the same price as non-GM apples. Further, 19% of consumers in the sample stated that they would be willing to purchase the GM apples at a premium over the price of the non-GM ones (the "yes, yes" group), while 16% of all respondents said they would not be willing to pay a premium (the "yes, no" group). Only 10.6% of the respondents were not willing to purchase GM apples at the same price as non-GM ones but were willing to purchase GM apples if a discount was given from the non-GM apples' price (the "no, yes" group). The majority of the respondents (53%) were not willing to purchase the GM apples even with the discount (the "no, no" group). For additional statistics on the distribution of responses over various discounts and premiums, see Tables 3 and 4. [Table 3 here] [Table 4 here]

There are typically two types of bidding procedures used in the CVM: the single-bounded and double-bounded dichotomous choice (Kanninen 1993). The single-bounded model approach recovers the bid amount as a threshold by asking only one dichotomous choice question (Hanemann, Loomis, and Kanninen 1991). The statistical efficiency of this approach can be improved by use of the double-bounded model, which engages in two bids. The standard double-bounded logit model was used to examine the outcomes of the survey. A study on the statistical analysis of discrete response contingent valuation data pointed out that there is some bias with the double-bounded model, caused mainly by inconsistencies, which may be present between the consumers' first and second bid (Hanemann and Kanninen 1999). The same authors continued suggesting that this bias is greatly "out-weighed" by the gains in efficiency.

Econometric Model

The double-bounded model applied to our data partitions consumers' willingness to pay for GM products into four different outcomes: (1) the respondent was neither willing to buy GM product at the same price as the non-GM product, nor was he willing to buy it at a discounted price, (i.e., "no" for both bids); (2) the respondent was not willing to buy the GM product at the same price as the non-GM product, but when offered the random discount, the respondent expressed his or her willingness to buy it at that price (i.e., "no" followed by "yes"); (3) the respondent was willing to buy the GM product at the same price as the non-GM product but not at a higher price (i.e., "yes" followed by "no"); and (4) the consumer was willing to buy the GM product at the same price and he or she was also be willing to pay the random premium offered compared to the non-GM product (i.e., "yes" followed by "yes").

The questioning sequence is able to isolate the range in which the respondents' true WTP lays, placing it into one of the following four intervals: $(-\infty, B_L)$, $[B_L, B_I)$, $[B_I, B_H)$, or $[B_H, +\infty)$. The second bid, in conjunction with the response to the initial preference decision, allows for both an upper and lower bound to be placed on the respondent's unobservable true WTP. In particular, when the second decision is in the same direction as the first ("yes, yes"; "no, no"), it raises the lower bound or lowers the upper bound, respectively. Therefore, the following discrete outcomes of the bidding process are observable:

(1) $$D = \begin{cases} 1 & WTP < B_L \\ 2 & B_L \leq WTP < B_I \\ 3 & B_I \leq WTP < B_H \\ 4 & B_H \leq WTP, \end{cases}$$

where *WTP* denotes the individual's WTP (or bid function) for second-generation GM apples. The WTP function is represented as:

(2) $$WTP = \alpha - \rho B + \lambda' z + \varepsilon$$

where B is the ultimate bid amount each consumer faces, z is a column vector of observable characteristics of the individual, ε is a random variable accounting for unobservable characteristics, and α, ρ, and λ' are unknown parameters to be estimated. Assuming linearity in z[1] and letting $\varepsilon \sim G(0, \sigma^2)$, where $G(0, \sigma^2)$ denotes a cumulative distribution function with mean zero and variance σ^2, the choice probabilities can be characterized as:

$$(3) \quad prob(D = j) = \begin{Bmatrix} G(\tilde{\alpha} - \tilde{\rho}B_L + \tilde{\lambda}'z) \\ G(\tilde{\alpha} - \tilde{\rho}B_I + \tilde{\lambda}'z) - G(\tilde{\alpha} - \tilde{\rho}B_L + \tilde{\lambda}'z) \\ G(\tilde{\alpha} - \tilde{\rho}B_H + \tilde{\lambda}'z) - G(\tilde{\alpha} - \tilde{\rho}B_I + \tilde{\lambda}'z) \\ 1 - G(\tilde{\alpha} - \tilde{\rho}B_H + \tilde{\lambda}'z) \end{Bmatrix} \text{ for } j = \begin{Bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{Bmatrix}.$$

Thus, the log likelihood function becomes:

(4)

$$L = \sum_i \begin{Bmatrix} I_{D_i=1} \ln G(\tilde{\alpha} - \tilde{\rho}B_{Li} + \tilde{\lambda}'z_i) + I_{D_i=2} \ln[G(\tilde{\alpha} - \tilde{\rho}B_{Ii} + \tilde{\lambda}'z_i) - G(\tilde{\alpha} - \tilde{\rho}B_{Li} + \tilde{\lambda}'z_i)] + \\ I_{D_i=3} \ln[G(\tilde{\alpha} - \tilde{\rho}B_{Hi} + \tilde{\lambda}'z_i) - G(\tilde{\alpha} - \tilde{\rho}B_{Ii} + \lambda'z_i)] + I_{D_i=4} \ln[1 - G(\tilde{\alpha} - \tilde{\rho}B_{Hi} + \tilde{\lambda}'z_i)] \end{Bmatrix}$$

where I_K is an indicator function for the event K, $D_i = j$ denotes that the j^{th} alternative occurred, and i denotes individual i. In the empirical implementation of the model, we

[1] The condition of linearity on z is a simplifying assumption widely used in RUM (random utility models).

This assumption implies that consumer's willingness to pay of c dollars is generally represented as:

$$U(0, x_0, m) \le U(1, x_1, m - c) \quad \Pr\{WTP \ge c\} = \Pr\{V_0 + \varepsilon_0 \le V_1 + \varepsilon_1\} = \Pr\{\varepsilon_0 - \varepsilon_1 \le V_1 - V_0\},$$

where $V_1 - V_0 = \alpha + \beta c$.

define $G(.)$ to be the standard logistic distribution with mean zero and standard deviation $\sigma = \pi / \sqrt{3}$. The empirical representation of equation (2) is formulated as:

$$WTP_i = \alpha - \rho B_i + \lambda_1 Gender_i + \lambda_2 age_i + \lambda_3 Family\ Size_i + \lambda_4 Income_i + \lambda_5 Employment_i + \lambda_6 FoodSafety_i + \lambda_7 Prefer\ Domestic\ foods_i + \varepsilon_i \quad (5)$$

where B_i represents the random bid offered to each consumer, $Gender_i$ is an indicator variable representing female, age_i is the respondent's age in years, $Familysize_i$ represents the respondent's family size, $Income_i$ is the respondent's income, $Employment_i$ is an indicator variable representing the respondents employment status of the respondent, $Foodsafety_i$ represents the relative importance given by the respondent to food safety versus food price, and $PreferDomesticFood_i$ is an indicator variable representing the respondents reported preferences for domestic over imported food products.

Analysis of Willingness to Pay

Estimation results of equation 2 are presented in Table 5, and marginal effects of the estimated parameters are presented in Table 6. Family size and strong attitudes about food safety have a negative and significant effect on willingness to pay for GM apples. Being employed full-time had a significantly positive effect on willingness to pay for GM apples. Other than the bid, all other variables, including age, gender, and income were not statistically significant at conventional levels. [Table 5 here] [Table 6 here]

One would expect family size to have a negative effect on WTP for two reasons. First, people with larger families may want to avoid the perceived risk associated with GM foods, especially if children are present in the home. Second, shoppers with large families are more likely to have a purchasing mindset of looking for low-cost items to economize on their food budgets. It is not surprising that respondents with strong food safety preferences are less willing to pay for GM apples. It is likely that the food safety-conscious consumer segment is skeptical of the safety of biotechnology. The positive effect of full-time employment on WTP for GM apples may be caused by an income effect.

One would expect for the size of the bid offered to have a negative effect on WTP, which was not the case in our analysis. If consumers are responsive to price, one would expect for the number of consumers accepting the discount to increase and the size of the discount to increase. However, as presented in Table 3, even with a 90% discount, only a small percentage of the consumers surveyed who would not purchase GM apples at an equal price, would now choose them. There is likely a consumer segment that views GM foods as risky and will not purchase them, even if they are deeply discounted.

Almost 64% of consumers surveyed would not buy GM apples at the same price as conventional apples. Approximately 53% of respondents would not choose GM apples at the discounted price. These results are similar to those found in previous studies, particularly those conducted in Europe and Japan. However, they disagree with the results reported on studies conducted in other developing countries, such as China and Colombia.

Conclusions

The results of this research indicate respondents to our consumer survey in Santiago, Chile were concerned with food safety, had knowledge about biotechnology, and felt positive about the use of biotechnology in food. However, most of them associated a level of risk to consuming biotech products. Health concerns, long-term effects, and lack of information were among the most commonly mentioned risk sources. The majority of the respondents agreed GM food products should be labeled.

Family size and strong attitudes about food safety had a negative and significant effect on WTP for GM apples. Being employed full-time had a significantly positive effect on WTP for GM apples. Finally, and unexpectedly, the size of the bid offered had a positive effect on WTP. All other variables, including age, gender, and income, did not have a statistically significant effect on willingness to pay for the GM apples.

A majority of the respondents would not choose GM apples even when deeply discounted. There is likely a consumer segment that views GM foods as risky and are not responsive to price reductions. For those firms who want to market GM products in Chile, there is work to be done. Chilean consumers need to be convinced of the safety of GM foods and told about the benefits associated second-generation biotechnology for firms to successfully market their GM foods in Chile.

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Apendix 1:

Table 1. Summary statistics for demographic variables both from the survey

Variable	*Description*	**Distribution of survey responses** (%)
Gender	Male	48
	Female	52
Age	Younger than 20	3
	20-30	19
	31-40	28
	41-50	27
	Older than 50	23
Education	Compulsory education	9
	High school	48
	Unfinished college	16
	Finished 4-year university	21
	Advanced degree	6
Family Size	1	3
	2-4	53
	5-6	33
	More than 7	11
Children under 18	Yes	69
	No	
		31
Household size	Number of people in the Household	Mean 4.50 St. Dev. 1.19
Annual Income	Less than 1,200,000 pesos	15
	1,200,000-3,000,000 pesos	30
	3,000,000- 6,000,000 pesos	24
	6,000,000-12,000,000 pesos	15
	12,000,000- 30,000,000 pesos	11
	More than 30,000,000	5
Employment Status	Full time employed	39
	Part time employed	12
	Independent worker	25
	Unemployed	4
	Homemaker	13
	Retired	4
	Refuse	3

Table 2. Summary of statistics for consumer information and perception variables

Variable	Description of the coding	Distribution of surveys responses
Environment	Importance of economic growth vs. saving the environment (scale from 1 to 10 where 1 is economic growth at all costs and 10 is saving the environment at all costs)	Mean = 7.21 SD = 2.72
Food Safety	Importance of food safety vs. food price (scale from 1 to 10 where 1 is food safety is all important and 10 is food price is all important)	Mean = 4.32 SD = 3.31
Knowledge about biotechnology	Self-reported knowledge about biotechnology (1 if high knowledge or little knowledge; 0 if no knowledge)	
	Very knowledge	17.6%
	Somewhat knowledge	59.0%
	No Informed	23.4%
Risk	Risk associated with GM foods	
	High risk	34.9%
	Low risk	30.2%
	No risk	10.1%
	Do not know	24.8%
Opinion	Opinion about use of biotechnology in food	
	Very Positive	27.7%
	Somewhat positive	25.7%
	Neutral	14.4%
	Somewhat negative	9.6%
	Very negative	4.5%
	Do not know	18.1%
Label	Importance of labeling of GM foods	
	Very important	88.1 %
	Somewhat important	6.9%
	Not very important	5.0%
Domestic products	Preference for domestic over imported food product	
	Prefers domestic to imported foods	73.0%
	Otherwise	27.0%

Table 3. *Range and distribution of response rates to the randomly assigned discount.*

	Yes to discount					No with discount	Total
% Discount	5%	10%	25%	50%	90%		
	1.5%	2.7%	1.8%	2.5%	2.4%	53.2%	63.8%

Table 4. Range and distribution of response rates to the randomly assigned premium.

	Yes to premium					No with premium	Total
% Premium	5%	10%	20%	30%	50%		
	3.9%	7.7%	3.1%	2.4%	2.7%	16.4%	36.2%

Table 5. *Parameter estimates for willingness to pay model (GM Apples).*

Parameter	Variable description	Estimate	Standard error	*z*-test	*p*-value
α	*Intercept****[2]	1.2503	0.3425	3.6497	0.0002
ρ	*Bid****	0.0183	0.0013	14.0260	1.0794e-044
λ_1	*Gender*	0.1139	0.1698	0.6712	0.5020
λ_2	*Age*	0.1278	0.1683	0.7592	0.4477
λ_3	*Family Size****	-0.2706	0.0853	-3.1722	0.0015
λ_4	*Income*	0.0795	0.2003	0.3972	0.6911
λ_5	*Employment***	0.3706	0.1759	2.1076	0.0351
λ_6	*Food Safety**	-0.0442	0.0257	-1.7146	0.0864
λ_7	*Prefer Domestic food*	0.31216	0.1932	1.6161	0.1061

Table 6. *Marginal effects of estimated parameters for willingness to pay for GM apples*

Parameter	Variable description	Marginal Effect
ρ	*Bid*	*0.0014*
λ_1	*Gender*	*0.0088*
λ_2	*Age*	*0.0099*
λ_3	*Family Size*	*-0.0210*
λ_4	*Income*	*0.0062*
λ_5	*Employment*	*0.0882*
λ_6	*Food Safety*	*-0.0034*
λ_7	*Prefer Domestic food*	*0.0242*

[2] Single (*), double(**) and triple asterisks (***) denote significance at the 10%, 5% and 1% levels, respectively.

CHAPTER 3

The Economic Implications of Invasive Species in International trade: the Chile-US fresh fruit market

I. Introduction:

Invasive species (IS) is the common name associated with “non-indigenous organisms” that pose a threat to the natural environment, agriculture or human health. In terms of natural resources, IS are considered second only to habitat loss as a risk to species extinction (www.biodiv.org). For agriculture, IS are typically associated with crop loss, poultry and livestock diseases and pests, etc. There are several examples of the devastating effects of invasive species. Grape Phylloxera (*Daktulosphaira vitifoliae*) is an aphid native to North America that caused the destruction of a large portion of the wine grape industry in Europe between 1865 and 1875. The damage caused by this insect completely changed growing techniques and wine grape distribution around the world. The case also has a historical importance, bringing several European countries together for the first international agreement on the spread of plant pests; the “International Convention on Measures to be taken against *Phylloxera vastatrix*” which was signed in 1878 (Ebbel, 2003).

Other more recent examples of important IS are mad cow disease (bovine spongiform encephalopathy or BSE) and the Mediterranean fruit fly or Medfly (*Ceratitis capitata*) which is considered one of the world’s most destructive agricultural pests.

The Medfly, which originated in Africa, can attack and destroy more than 200 species of fruit crops, including citrus, cherries, apples, pears, peaches etc. Impacts of IS have also been reported among the forestry, fishery, water use, and utility sectors (OTA, 1993).

Increased trade between countries and the high diversity of environments among trading countries, added to advances in transportation technologies, which allows for fast transoceanic delivery, have all contributed to the risk of introduction of an invasive species. Imports of goods such as fresh produce, animals, and timber and its derivates (such as solid wood packaging materials) represent important pathways for the introduction of IS. Over the last 40 years, increases in the rate of population growth and movement of people, as well as changes in the environment, have been associated with an increase in the rate of introductions and risk associated with “biotic invaders” (Pimentel et al, 2000). However, an extensively cited report by the United States Office of Technology Assessment (OTA) found no evidence that the rates of introduction of non-indigenous species (NIS) to the U.S. have increased in the last 50 years in any of the categories analyzed (terrestrial vertebrates, fish, mollusks, and plant pathogens) (OTA, 1993).

Despite the enormous benefits of most NIS, several cause great harm to countries’ economies. Even though only 16% of the NIS insects are considered to have a high impact as pests (OTA, 1993), countries spend large amounts of resources attempting to stop invasive species before they enter their borders. For example, in 1999, the U.S. spent an estimated $590 million to prevent and control IS, and in 2000 the United Kingdom spent approximately $111 million on animal and plant health (Mumford, 2002).

Extensive information about NIS is available, but it has been described as “widely scattered, sometimes obscure, and highly variable in quality and scientific rigor” (OTA, 1993). Rough assessments of the economic losses due to invasive species in the U.S. range from tens to hundreds of billions of dollars per year. Pimentel et al. (2000), estimated that NIS in the U.S. cause significant environmental damage and economic losses of approximately $137 billion per year. Specifically for agricultural crops, estimates of the potential losses associated with non-indigenous insects and mite pests reach US$16 billion each year in the U.S.; US$17 billion in India; US$8.5 billion in Brazil; US$1 billion in South Africa; US$960 million in the United Kingdom; and US$ 936 million in Australia (Pimentel et al., 2001).

Government agencies concerned with IS usually have two approaches to managing them: A) decisions are taken to stop potential invasive species before they enter the country (*ex-ante*) or B) decisions are made as to how to control invasive species after they have arrived (*ex-post*) (Maguire, 2001). In both of these scenarios, decisions are made with great uncertainty about the biological behavior of the pest and the potential economic loss to local agriculture and environment.

Ecosystems, as well as the biological characteristics of the organisms, will influence whether the NIS can be established and whether they can cause environmental and economic loss. Economic circumstances will also influence the probability of acquiring an organism by modifying both the pathways of introduction (passenger travel, import of goods, etc.) and the level and type of quarantine measures applied for a given species (Leung *et al*, 2002).

The World Trade Organization's Sanitary and Phytosanitary agreement sets a series of procedures to analyze the risks of introduction of IS associated with internationally traded commodities. It also requires that quarantine systems consider both benefits and risks associated with international trade.

In order to accurately evaluate the economic implication of the introduction of a given IS, the expected value of changes in the producers' surplus, given in part by an increase in the production costs associated with the IS, need to be assessed. The costs associated with the compliance of export and import protocols should be addressed as well in order to estimate the total welfare effect that an IS has in international trade of fresh fruit. In this paper we propose a framework to evaluate the economic implications of a given IS in fruit production with a particular emphasis on the U.S.-Chile fresh fruit trade.

II. International Sanitary and Phytosanitary Measures:

Sanitary and Phytosanitary Measures are imposed by countries in order to ensure that food is safe for consumers and to prevent the spread of pests and diseases among animals and plants. Under the World Trade Organization's Sanitary and Phytosanitary (SPS) Agreement, countries are required to use a common set of procedures for evaluating risks of contamination in internationally traded commodities. SPS also requires quarantine systems to reflect the expected benefits from risky trade and the level of risk that is acceptable for society. The SPS Agreement's main points are Basic Rights and Obligations; Harmonization of SPS Measures and Practices; Equivalence; Assessment of Risk and Appropriate Level of Protection; Regionalization; Transparency; and Consultation and Dispute Resolution (http://www.wto.org).

First, the SPS Agreement recognizes the fundamental right of countries to protect the health and life of people, animals, and plants against pests, diseases, and other threats to health. However, SPS measures should not be applied in a manner that would represent a disguised restriction on international trade. The SPS Agreement encourages countries to harmonize their SPS measures on as widely as possible, by supporting their quarantine measures on relevant international standards. The international bodies mentioned in the agreement include the Codex Alimentarius Commission, the International Plant Protection Convention (IPPC), and the Office International des Epizooties (OIE) for food safety, plant health, and animal health standards respectively. Nevertheless, a country may choose not to use the existing international standard, if there is a scientific justification. Under the SPS Agreement, countries are required to accept the other countries' SPS measures as equivalent, even if these measures differ from their own, when the exporting country demonstrates that its measures achieve the importing country's desired level of quarantine security. The SPS Agreement continues to describe some basic terms related to risk analysis, including risk assessment, and its factors, as well as the economic consequences of the potential damage in terms of loss of production or sales in the event of the entry, establishment or spread of a pest or disease. The costs of control or eradication in the territory of the importing country, and the relative cost-effectiveness of alternative quarantine measures are also defined in the agreement. Under the SPS Agreement, countries are required to adopt import requirements based on the health conditions of the specific area or region where a plant or animal commodity originates. This introduces the concept of pest or disease free areas recognizing that pest and disease conditions may vary across a country and are dependent upon geographic and ecological differences as well as the effectiveness of sanitary or phytosanitary controls. The transparency rule is intended to give concerned countries an opportunity to provide relevant information in order to anticipate any changes in the SPS measures or regulatory actions that may affect trade. Finally, the SPS Agreement sets the procedures for dispute settlement, which begin with bilateral consultations and failing that, a complaining party may request intervention of a panel, which may seek recommendations and technical advice from relevant international organizations.

III. U.S. and Chile fresh fruit trade:

In the last five years the main U. S. exports to Chile were computer accessories, excavating machinery and telecommunication equipment. Exports of agricultural products including fresh fruit represent only 4% of the $3 billion a year average in total exported products in the same period. This small percentage proves that U.S. exports of fresh fruit to Chile are not of economic importance. Figure 1 shows the evolution of the U.S.-Chile exports, imports and trade balance.

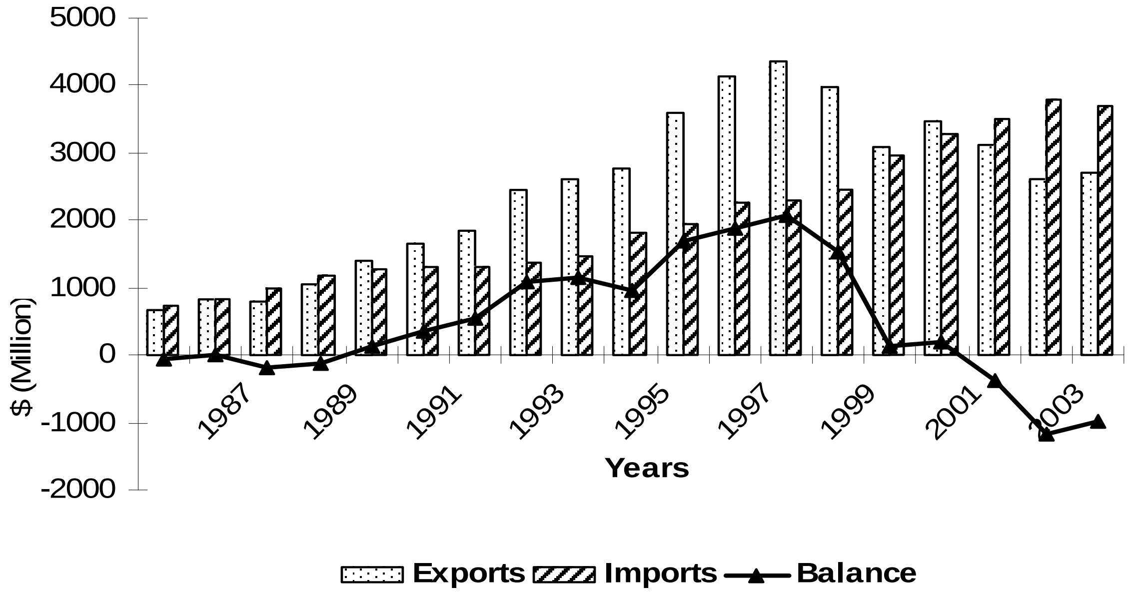

Figure 1: Evolution of the value of the U.S. exports and imports to and from Chile and the Trade Balance (U.S. Bureau of the Census trade data).

Chile is one of the leading fresh fruit exporters in the Southern Hemisphere. For example in 1997, in comparison to all southern hemisphere exports, Chile exported 87% of the peaches, 76% of the table grapes, 35% of the apples, and 30% of the pears to the world market (Torres et al, 2001). Chile is also one of the main suppliers of fresh fruit for the U.S. market supplying more than 20 different types of fresh fruits. Table grapes, apples, nectarines, and avocados are among the most important. In the last five years, U.S. imports from Chile represented an average value of $3.4 billion a year with agricultural products corresponding to 30% of the total value of imported products. Chilean fruit production is mainly oriented toward the export market. U.S. fresh fruit imports represent 60% of the agricultural products and almost 20% of the total value imported from the country (U.S. Bureau of the Census). Figure 2 shows the evolution of U.S. imports of fresh fruit from Chile.

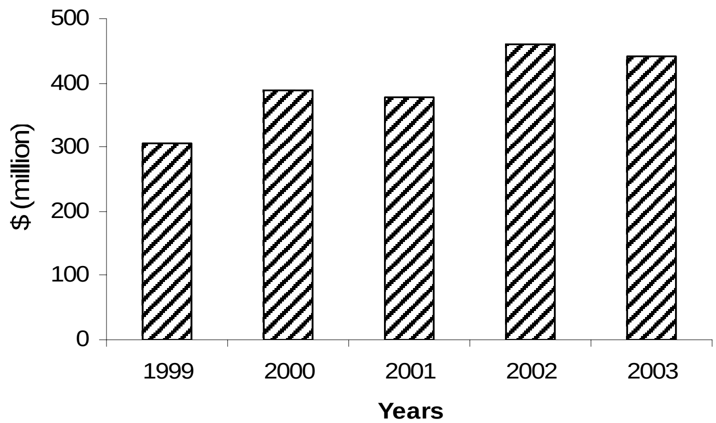

Figure 2. Evolution of the value of the U.S. imports of Chilean Fresh Fruit. Source: U.S. Bureau of the Census trade data.

Diversification of export markets have contributed to Chile's success as a leading fresh fruit exporter. The main export markets targeted by Chile are Western Europe, North America, Latin America, and the Middle and Far East (Torres et al, 2001). However, The North America Free Trade Area (NAFTA) represents the main market for agricultural products, accounting for more than 65% of the total Chilean agricultural exports (Odepa, 2004).

IV. Implications of IS on U.S. and Chile fresh fruit trade

Import of commodities such as agricultural produce, nursery stock, cut flowers and timber, unintentionally contaminated with insects and plant pathogens, is one of the main pathways for the introduction of new IS to the U.S (OTA, 1993). Given the high diversity of the commodities Chile provides to the U.S market, there is potential for the introduction of new IS.

Even though Chile is generally recognized as a country of “exceptional endemism” because of the high number of species exclusive to the territory (Kalin, 2004), many agricultural pests have been introduced with the unintended movement of plants and animals by humans. Chile’s geographical characteristics have allowed the country to remain somewhat free of many destructive agricultural pests. The Andes Mountain to the east, the Pacific Ocean to the west, and the Atacama Desert to the north, have all provided natural barriers to the introduction of many agricultural pests (Gonzalez, 1989). The fact that Chile in one of the few countries where the grape Phylloxera (*Daktulosphaira vitifoliae*) is not present represents an example of the benefits of these geographical barriers. This aphid, native to North America, caused the massive destruction of a large portion of the wine grape industry in Europe in the late 1800s and changed the way wine grapes are grown today. Despite these natural barriers, the increase in trade between countries has enlarged the unintentional introduction of new non-indigenous species and invasive species have increased.

Most of the pests of “primary importance” for agriculture in Chile (Gonzalez, 1989) are not part of the regulated plant pest list of the U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service Aphis (APHIS). This list, published by APHIS, compiles pests frequently intercepted from imported commodities at U.S. ports of entry, and other pests identified by either APHIS or stakeholders as having the potential to cause serious economic or environmental damage in the U.S. In fact, most of the “primary pests” or pests with primary importance for fruit production in Chile are considered “cosmopolitan pests” (Gonzalez, 1989). A notable example is codling moth (*Cydia pomonella*), a native pest of Eurasia that today is a key pest affecting apple, European and Asian pear, Persian walnut, and Japanese plum production not only in Chile but also in the U.S. and other fruit producing countries in the world (Barnes et al. 1992). Even though codling moth is no longer included in the APHIS regulated plant pest list, it is the pest with the highest economic impact for apple production in the western United States and if not controlled, could destroy the entire industry. The cost of controlling codling moth was reported to be in the order of \$150 acre^{-1} year^{-1} (\$330 hectare^{-1} year^{-1}) under conventional production practices, assuming there were five cover applications (Glover et al, 2002).

The APHIS regulated plant pest list includes several insect and mite species that are native to Chile. Most of these are not considered to be of primary importance for agriculture in Chile (Gonzalez, 1989). Out of the insects and mites native to Chile present in this list (*Leptoglossus chilensis*, *Megalometis chilensis*, and *Brevipalpus chilensis*), only the *Brevipalpus chilensis,* also known as Chilean false red mite, has an economic impact on Chilean fruit production and is subject to permanent control measures. Nevertheless, and given that the Chilean fresh fruit industry is mainly oriented to the export market, management practices need to be taken to ensure the fruit to be pest free, no matter the nature or origin of the pests.

Some authors believe that introduction of a new invasive species would have a greater chance of success when goods unintentionally contaminated with IS are traded among countries across latitude rather than south-north trade (Lattin and Oman, 1983). Sailer (1983) in his study about exotic pests in North American agriculture reported that South America accounted for only 1.7% of the exotic agricultural pests introduced to the U.S. This can be explained by the counter seasonality of both hemispheres, implying that neither environmental conditions nor hosts would be readily available at the time of import. This would put Chile and other south hemisphere fruit producer countries in a very low risk category. However, advances in storage technologies allow for gaps between harvest time in the southern hemisphere and arrival time into the northern hemisphere importing country. Some fruit species, such as apples (*Malus domestica* Borkh.) and pears (*Pyrus communis* L.), can be stored for long periods of time, reaching the market when the environmental conditions may be appropriate for a successful adaptation of the pest. On the other hand, for other fruit species like raspberries (*Rubus spp.*) and cherries (*Prunus avium* L.), which have a considerably shorter storage period, this argument could make more sense. Import protocols need to take this consideration into account when defining quarantine measures for each particular fruit species.

The introduction of a new invasive species can affect fruit producers in three major ways; increasing production costs, decreasing yields, and reducing export returns to the grower. Production costs will be increased because the grower will need to undertake new measures to control the presence of the pest in the orchard. The occurrence of a given pest could also reduce the yields, because damaged fruit has to be eliminated. Finally, the detection of an IS in the importing country could cause the closure of this market, thus reducing the returns to the grower.

On the other hand allowing imports of fruit from a “risky” country will increase domestic fruit supply with the consequent benefits of lower prices for consumers (Roberts, 2000). Countries can use quarantine measures in order to reduce the risk of new IS introduction and to ensure that food is safe for consumers. Quarantine measures can be taken either before the fruit gets out of the exporting country (i.e., prevention and pre-clearance practices) or once it enters the importing country (i.e., border control, eradication, and management).

No single quarantine measure can completely eliminate the risk of introduction of a new IS. An economically feasible quarantine measure is one that reduces the expected possibility of successful invasion rather than the certainty of avoiding it (Mumford, 2002). Different quarantine measures have important economic and distribution effects for fruit growers, consumers and government agencies dealing with IS. The U.S. quarantine on Mexican avocados (1990-1997) is a good example of the trade implications and distribution of the benefits from different quarantine measures (open and partial trade, and complete ban to the imports). It was estimated that partial trade (that was subsequently applied) produced a net gain of $2.5 billion per year compared to a complete ban on imports. Conversely, open trade would have had a net welfare of $32 billion without pest introduction and $13 billion with a theoretical pest introduction (Mumford, 2002).

Another important consideration in regards to the impacts of IS in international trade is the increasing importance of pests present in solid packaging wood materials (SPWM) (www.aphis.gov). Packaging materials have generally been considered externalities in most economic analyses of international trade. Evidence indicates that wooden shipping pallets and other types of packaging served as the introduction pathway for the Asian longhorn beetle (*Anoplophora glabripennis*) to the U.S. and Western Europe from China. This pest may not be present in Chile but given the high volume of goods being imported from Asia, government agencies should consider the risk and potential implications of a successful introduction of the Asian longhorn beetle and the consequences for fresh fruit exports to U.S. and other important markets.

V. Conceptual Framework to analyze impacts of IS:

The introduction of a new IS into a country could have serious effects not only in production but also in consumption and exports of the affected commodity. As with any other agricultural process, fruit production depends crucially on the biological features of the productive inventory. These biological features, such as yield and final quality, are highly susceptible to the impacts of an environmental change. The domestic and foreign demands for the final products could also be altered significantly when the quality of the final products changes. To fully analyze the impacts of an IS, we use a general equilibrium simulation model where the consumers maximize their utility and the producer maximizes profit with appropriate biological constraints. The conceptual modeling framework is designed to be general enough to accommodate most agricultural products. Figure 3 shows the diagrammatic representation of the bioeconomic model of production and trade of fruit.

The process of agricultural production consists of a productive population that evolves according to its biological features and the producer's decision to adjust the population. Thus, we specify our model in five parts: A) population mechanics, B) production functions, C) inventory updating, D) consumption decisions, and E) market clearing conditions. Rather than using one simulation for each fruit species, we group similar fruits together and simulate them simultaneously. We do this for two reasons—first, it is more likely that similar fruits would be susceptible to the impact of the same IS (pome fruit, citrus, etc.); second, we need to take into account the substitution effects to evaluate the impacts on consumer welfare.

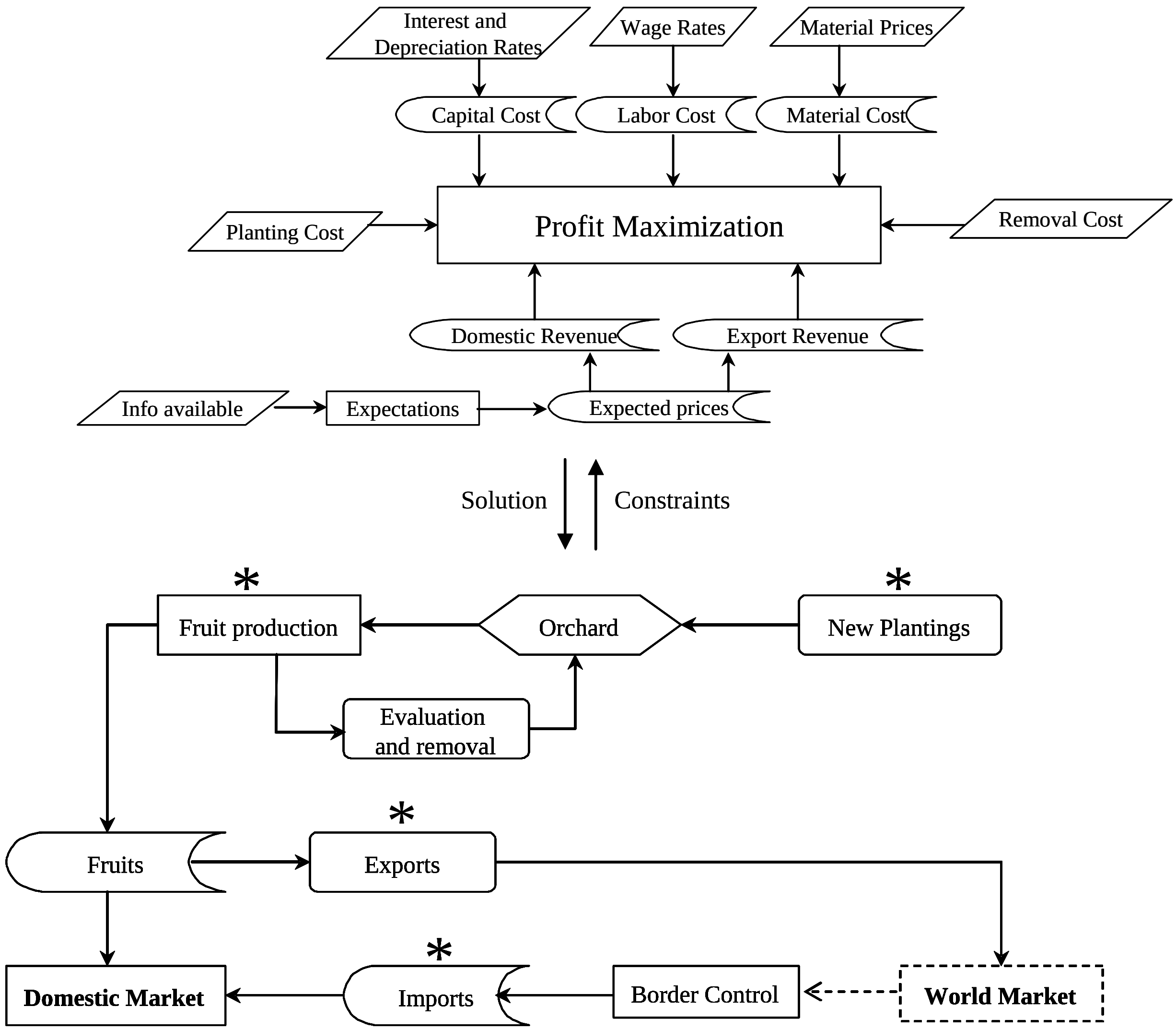

Figure 3. Diagrammatic representation of the bioeconomic model of production and trade of fresh fruit. Legend : ▱ exogenous variables ⊂⊐ Endogenous variables ▭ Processes ▢ Choice variables ⬡ Inventory (stock variable) * indicates processes or variables where invasive species have influence.

Modeling Strategy:

For our analysis we assume that the fruit grower has one single objective: to maximize the total present value of all future profits. Under the grower's control are the addition to and subtraction from the productive stock of trees (orchard); effective management of production inputs, such as tree density at establishment of the orchard, fertilizer, pesticides, etc; and the selective administration of labor for the different orchard operations such as pruning, fruit thinning and harvest. We also assume that the grower's only source of revenue is from fruit sales. This is an important point because in fruit production there is a long lag between investment decisions and revenue generation due to the time required for a tree (or group of trees) to reach its productive stage. Most fruit species will require a few years before they start efficiently producing fruit. This time period will vary depending on several factors such as species, rootstocks, density, climate condition, etc. Thus, a long planning horizon and biological life cycle of the orchard is essential to the modeling framework.

Population Mechanics:

Orchards are usually divided into blocks of trees of the same age. Thus the stock of productive planting area is differentiated by tree ages. Each age group evolves according to the following equations:

(1.a) $K_{t+1}^{j+1} = (1-\alpha_t^j)K_t^j$

(1.b) $K_{t+1}^{0} = NP_{t+1}$

where K_t^j is the total area of age *j* trees at time *t*, α_t^j is the percentage to be removed from the stock of age *j* trees at time *t*, and NP_t is the area of newly planted trees. Any planting area that is not chosen to be removed during the current period progresses into the stock of the next age group.

Fruit Production and Supply:

We assume that fruit is the only product of the industry. Each year's fruit production is given by

(2) $$FP_t = \sum_{j=m}^{u} y^j K_t^j$$

where y^j is the yield per hectare of age *j* trees. While we, for now, treat the yields as exogenously given, they could vary depending on the history of productive inputs and their interaction with other external events such as climate. The events and the stream of inputs, varying in nature, could alter the time required to reach the productive stage, permanently damage the trees, or simply modify the final yield and quality of the fruit harvested for one or more periods.

The total production supplies are for both export and domestic markets. Since fruit production in Chile is mainly directed to the export market, the relative importance of the export market for this case will be higher. The domestic supply is then given by:

(3) $$SD_t = FP_t - E_t + M_t$$

where E_t and M_t are exports and imports respectively. Notice that E_t is a control variable but M_t is not.

Market Clearing Prices:

The Almost Ideal Demand System (AIDS) model is employed to define the fruit domestic demand because of its capability to generate exact welfare measures (compensated variation *CV* and equivalent variation *EV*). The system includes all fruits (assuming weak separability for the group "fruit"). With n commodities, the system can be thought of as a system of n equations in 2n+1 unknowns, including n prices, n demand quantities, and the group expenditure. When we hold the prices of all other fruits and the group expenditure as exogenously given, the number of unknowns is then reduced to n+1. With n equations, the domestic market-clearing price for the fruit under investigation and the demand for all other fruits can be solved in terms of the domestic supply of the fruit of interest. Thus, the domestic market-clearing price is given by

(4) $$Pd_t = f(SD_t)\,.$$

If $EDf()$ denote a single equation export demand for the fruit, then exports are given by

(5) $$E_t = EDf(Pd_t)\,.$$

Finally, if $FSf()$ denotes a single equation foreign supply of the fruit, imports are given by

(6) $$M_t = FSf(Pd_t + Tff_t)$$

where Tff_t is tariff or tariff equivalent trade barriers.

The Producer's Problem:

The producer's total profit equals the total revenue minus total cost. There are two sources of revenue; domestic sales and exports. If we assume that they are sold at the same price, the total revenue is just $Pd_t * FP_t$. Total cost consists of capital cost, labor cost, material cost, planting cost, and removal cost. Capital cost (KC), labor cost (LC), and material cost (MC) can be defined as the following

(7) $$KC_t = (r+d) * KR * \sum_{j=0}^{u} K_t^j$$

(8) $$LC_t = w_t * LR * \sum_{j=0}^{u} K_t^j$$

(9) $$MC_t = \left(\sum_{i=1}^{n} PM_t^i * MR^i \right) * \sum_{j=0}^{u} K_t^j$$

where KR, LR, and MR^i are the capital requirement, labor requirement, and i^{th} material requirement per hectare. r, d, and w_t are interest rate, depreciation rate, and wage rate respectively. Furthermore, let PC_t and RC_t denote the planting cost and removal cost respectively. Then the total cost is given by

(10) $$TC_t = KC_t + LC_t + MC_t + PC_t * NP_t + RC_t * \sum_{j=0}^{u} \alpha_t^j K_t^j \,.$$

Total profit at t is

(11) $$\pi_t = Pd_t * FP_t - TC_t \,.$$

The producer chooses the number of new plantings and the removal rates to maximize the total present value of all expected future profits subject to the constraint of the biological process.

(12) $$Max\left(E_0\left[\sum_{t=1}^{\infty} \beta^t \pi_t \right]\right) \text{ s.t. Biological Constraints}$$

With a certain set of starting values for the stock variable and the solution from this problem, all future production and prices can be uniquely determined by the biological process.

Price Expectations:

The theoretical model could accommodate different expectation schemes, including naive expectations, rational expectations, bounded rational expectations, and adaptive expectations. Each has advantages and disadvantages. Naive expectation is the simplest to implement, but tends to generate a corner solution. As a result production fluctuates dramatically. Rational expectations is relatively easy to implement and can stabilize supply, but the rational expectation assumptions are seldom supported by empirical work, especially in the case where significant delay is present between planning and actual revenue inflow. Adaptive expectations performs reasonably well in terms of mimicking the dynamics of market equilibrium and tends to have stable solution. Bounded rationality is another choice where market equilibrium can be mimicked reasonably well. The choice of the expectations scheme often depends on the particular characteristic of the production process under investigation and the actual behavior indicated by data and practice. In modeling fruit production, adaptive expectations is usually a good choice because of the long delay between planning and harvesting and the uncertainty about market price and production environment.

VI. Using the model to analyze the impacts of IS and benefits of alternative IS management policies:

An IS outbreak can change the production process as well as the market. On the production side, one or more of the exogenous costs of production can be increased dramatically, such as increased chemical use and/or increased requirements for other inputs. The outbreak will certainly change the yield. If we have the information as to how various input levels could affect yield, making some of the costs endogenous could help determine the optimal input level with the presence of the IS. On the market side, depending on the importing countries' policies, the outbreak could mean a complete or partial shutdown of exports. It could also mean an increase in export cost, in which case the exports also decrease due to increased foreign price. Lastly, if fruit quality is affected, it could mean that the higher end of the market is lost.

To complete the analysis, the speed of propagation and the scale of the outbreak need to be established. Several authors have recognized the uncertainties inherent in the bio-ecological nature in the estimation of a particular IS becoming successful in a new environment (Mack et al, 2000; Kareira, 1996; Maguire, 2001). These uncertainties can be reduced through the use of new technologies that are able to analyze bio-ecological data in order to assess the suitability of a habitat for the establishment and spread of a potential IS. Genetic Algorithm for Rule-set Prediction (GARP) (currently in beta version) is an artificial-intelligence application that translates the geographic locations of ecological features into a model of suitable and unsuitable habitats in ecological dimensions. The estimations and data generated using this modeling program can then be projected onto landscapes to identify areas that are suitable for a particular species to establish, succeed and spread (http://www.epa.gov/ord/htm/article3.htm). With all of these pieces specified, the market equilibrium solution will generate the producer's surplus and the consumer's compensated variation and equivalent variation. The net impact of the IS can be measured by the change in the total social welfare caused by the outbreak.

The IS risk management policies include quarantine measures such as prevention (*ex-ante*) and controlling after establishment (*ex-post*) of a given IS. The benefit of controlling is straightforward. To model controlling after establishment, selected parameters in the model are systematically altered, which results in a new equilibrium welfare level. The prevention measures, without going into details of the methods, are designed to reduce the risk of an IS establishment. The benefit of prevention is the reduction in the expected welfare loss under the implementation of the controlling policy due to the reduction in the probability of the IS establishment. Thus, an IS management scheme could be mapped into a social welfare value. The optimal scheme is the one that generates the highest welfare level.

VII. Concluding Remarks:

Invasive species cause great harm not only to agriculture but also the natural environment and human health. Countries spend a large amount of resources attempting to stop IS before they enter their borders and controlling them after they have arrived. In either scenario the decisions are made with large biologic and economic uncertainties. WTO's sanitary and phytosanitary agreement set the common procedures for countries to analyze the risk of contamination in internationally traded commodities. In the case of plant pests, countries are encouraged to harmonize their quarantine measures based on international standards of the International Plant Protection Convention. Nevertheless, countries are allowed to use different standards if there is scientific justification.

Chile is one of the major suppliers of fresh fruit to the U.S. market as well as to other Asia-Pacific Economic Cooperation (APEC) members. Imports of unintentionally contaminated fresh fruit are important pathways for the introduction of new IS. The wide variety of fruits supplied by Chile to the world market, and the diversity of environment among these countries, represent potential risks for the introduction of new IS. Most of Chile's native insects and mites that are considered a quarantine concern for the U.S. are not pests of major importance for the country's agriculture. Nevertheless, the presence in the country of "cosmopolitan pests" such as codling moth, and the high pressure for pest introduction from neighbor countries, increases the risk of introduction of new IS to Chile's fresh fruit importing countries.

Trade liberalizing policies have multiple benefits including increase of the countries' population welfare. However, introductions of new IS can harm both producers and consumers, counteracting these benefits. Increase of production costs, decreases in yield, quality, and export returns for the fruit produced are the major ways producers are affected. On the other hand, allowing imports from a "risky country" increases consumers' surplus by the reduction of the world price. Different quarantine measures have important economic and distributional effects.

The conceptual framework for the analysis of the impacts of IS is a general equilibrium model where consumers maximize utility and the producers maximize profit with appropriate biological constraints. The use of new technologies such as Generic Algorithm for Rule-set Prediction would reduce the uncertainties associated with the bio-ecological nature of the estimation of IS introduction, establishment and spread. Using the model proposed, the market equilibrium solution could generate producer's and consumers' surplus, and the impact of the new IS can be measured by expected changes in the total social welfare produced by alternative quarantine measures adopted by country. This information could be used by countries to evaluate and eventually change their current quarantine measures in order to meet their desired level of security, using the scientific approach required by the WTO SPS agreement.

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