The Economics Of Quarantine - A Consumer Perspective

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Declaration

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution. Furthermore, to the best of my knowledge and belief it contains no material previously published or written by another person except where due reference has been given in the text.

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David Charles Cook

September, 2002

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List Of Abreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AFFA	Agriculture, Fisheries and Forestry Australia
ALOP	Appropriate Level Of Protection
AQIS	Australian Quarantine and Inspection Service
ATC	Average Total Cost
AVC	Average Variable Cost
BCA	Benefit Cost Analysis
BSE	Bovine Spongiform Encephalopathy
DAWA	Department of Agriculture Western Australia
DPIE	Department of Primary Industries and Energy
DSB	Dispute Settlement Body
ED	Expected Damage
ERM	European Red Mite
GATT	General Agreement on Tariffs and Trade
IA	Impact Assessment
IHN	Infectious Haematopoietic Necrosis
IRA	Import Risk Assessment
MC	Marginal Cost
PHA	Plant Health Australia
Q-fly	Queensland Fruit Fly
TDS	Threat Data Sheet
TC	Total Cost
SPS	Sanitary and PhytoSanitary
WA	Western Australia
WAQIS	Western Australian Quarantine and Inspection Service
WTO	World Trade Organisation

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Abstract

Australia's membership of the World Trade Organisation has generated a need for analytical techniques demonstrating that the behaviour of its internal markets and regulatory authorities for food and food-related products conform with the provisions of the Agreement on Sanitary and Phytosanitary Measures (SPS Agreement). However, since quarantine has long been considered a scientific issue, it is as yet unclear what role economic models have to play in this process. Traditionally economic analyses have been limited to the estimation of damage to domestic host industries resulting from the introduction and establishment of specific pests. They have therefore been biased towards a production perspective and do not represent net social welfare changes that can result from quarantine policies designed to avoid pest incursions.

This thesis demonstrates how consumer welfare effects can be integrated with the traditional producer welfare effects in quantitative analytical models using the examples of the mango and tomato industries in Western Australia, both of which enjoy quarantine protection from interstate growers. It derives an expected level of damage that corresponds to the recognised import risk standard governing the importation of horticultural goods, the ambiguous *appropriate level of protection*. These measures of the amount of protection afforded the mango and tomato industries reveal some inconsistency in the imposition of quarantine standards. Although the case studies presented relate to interstate quarantine issues, the analytical techniques demonstrated are equally applicable to international issues. Incorporating them into the import risk assessment process may facilitate a clear and objective means of assessing market access requests, and lead to quarantine policies that better reflect social preferences.

1. An Introduction To The Economics Of Quarantine

1.1 Introduction

In the modern age of the global economy and market liberalisation, many changes are taking place that are altering the way trading entities strategically interact with one another. With the decline of tariffs and quotas as instruments of trade protection quarantine is shaping into an effective and highly complex substitute. This presents a new challenge to the way in which policy analysts represent the relative merits of pursuing one course of quarantine action over another. Analytical methods must not only utilise the skills of scientists with a knowledge of exotic pest biology, but also those of risk analysts and economists to provide decision-makers with sufficient information on which to form a judgement. This process has been made all the more involved by the evolution of the World Trade Organisation (WTO) whose rules and regulations concerning international trade extend to artificial trade barriers. So, not only should policies be designed around the idea of potential damage minimisation, they must also be WTO-consistent if costly retaliatory actions are to be avoided.

It would seem however that satisfying international obligations could lead to a conflict of interest. The fact that all community members are affected by the quarantine regulations protecting their borders against invasive organisms should be reflected in policy-making processes if regulatory authorities are to produce net welfare gains for their society. Yet, the relevant factors to be taken into consideration to achieve WTO-consistency when imposing quarantine restrictions only include selected groups of primary producers. Consumers, whose welfare is affected by restrictions on the range of goods and services made available to them, are excluded. To date, the use of economics in quarantine policy analysis in Australia has taken a back·seat to other disciplines, preventing a more balanced view of social welfare from being adopted. Generally, the information on which policies are based has come in the form of production damage estimates to be expected in the event of unwanted organisms entering a region and becoming established. It is the aim of this investigation to explore means of supplementing this type of information with assessments of consumer welfare changes resulting from quarantine protocols.

1.2 The Issues

On an evolutionary scale humans are relative newcomers to farming, having made the transition from a hunter-gatherer society about ten thousand years ago. All of the crops cultivated and all of the animals farmed and domesticated have evolved from naturally occurring species. Coexisting with man are organisms that have achieved comparable levels of success over far longer periods. For instance, some species of ants whose behavioural patterns include the cultivation of crops (e.g. *Acromyrmex* and *Attini* ants, or leaf-cutter ants) and tending of livestock (e.g. *Iridomyrmex* ants) are estimated to have evolved over 80 million years ago (Holldobler and Wilson, 1990; Schultz and

Meier, 1995)[1]. Many vertebrates, weeds, invertebrates, fungi, viruses and diseases have evolved and formed intimate relationships with the plant and animal species now grown by human communities around the world. Others have been introduced to new areas and have adapted over time to environmental changes. In sharing the planet with organisms like this, clashes between human farmers and the natural world are inevitable, and have continually occurred throughout recorded history.

In the modern world, many communities employ an extensive array of protocols people and produce must satisfy in order to enter their geographic region of influence. Through these requirements, henceforth generally referred to as *quarantine*, they are able to reduce the likelihood of an exotic organism gaining entry to the region, multiplying and causing members of the populace a loss of welfare. Such losses may take the form of crop damage, injury or irritation to livestock, man or native organisms, or reduced fertility of land. The term *pest* is used in the following discussion to describe any organism possessing the capacity to behave in such a way when introduced to new environments, be it an animal, plant or pathogen.

Traditionally, quarantine has been considered the subject of science, and species of quarantine significance have generally been classified as such on the basis of habitat suitability and the abundance of suitable hosts. As a result, quarantine policies designed to keep these pests out of defined areas have been formulated on the basis of consequences to domestic producers of host products from allowing pests to enter. This

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[1] South American leaf-cutter ants forage on a variety of plants they use for the cultivation of fungi in the family *Lepiotaceae*, their dominant food source. Colonies of these ants consist of several different castes, each with a specific task related to the farming process. The butterfly species *Amaryllis Azure* found in Australia lays its eggs on mistletoe growing on trees colonised by ants of the tribe *Papyrius* (formerly *Iridomyrmex*). The emerging butterfly larvae are provided with shelter and protection by the ants which nest at the base of the tree or under the bark. When night falls, the ants shepherd the caterpillars to a clump of mistletoe to feed, and lead them back to shelter before dawn. In return, the ants milk the caterpillars as a source of food (Holldobler and Wilson, 1990).

exclusive consideration of a group within society may have implications for the welfare of all members of the community since quarantine is an example of a *public good*. Public goods are characterised by consumption indivisibilities (or non-rivalry in consumption) and non-excludable benefits, and include such goods as radio transmissions, national defence and biological diversity. Each member of society, be they a primary producer or not, has their choice of goods and services on which to spend their earnings dictated by quarantine. In the absence of border restrictions, products from all over the world would be made available to citizens prepared to pay a sufficient price to cover the costs of production, transportation and marketing. In forming quarantine policies that restrict this product's availability on the basis of potential damage to agricultural producers, this is not recognised by regulatory authorities.

Analyses of the impacts of quarantine policies based on the estimation of pest damage are highly complex and involve a great deal of speculation. Predicting the behaviour of biological organisms in environments they have not been observed in is a difficult task requiring the imposition of strict assumptions. The formulation of these assumptions governing, amongst other things, likely spread scenarios, involves the subjective judgement of individual analysts. Although these can be qualified through the citation of similar historical cases, the margin for error is still sizeable. To overcome problems of this nature, risk analysis techniques can be employed to take account of the range of possible parameters determining the overall pest impact. Rather than focus on the formation of a point estimate, these techniques allow a range of possibilities to be specified, and the pest to be ranked according to this expected damage cost.

In adopting this managed approach to import risk, there remains a means by which the effects on broader society can be considered alongside those felt by producers alone. Quarantine policies effectively alter the extent to which a market is exposed to competition by inflating prices above a level they would be made available at under an 'unrestricted trade' regime. They therefore affect consumers of the product concerned, not just producers[2]. A quarantine protocol may be expected to yield considerable damage abatement to an industry, but if it does so at a higher cost in terms of consumer welfare, a question of its validity on economic grounds is raised. To exclude these factors from an economic analysis is to present a biased view of quarantine-induced welfare effects.

The purpose of this investigation is to provide an analytical framework that will overcome this problem and lead to a more balanced view. This does not involve a radical departure from accepted methodologies, but simply adopts a different point of focus. Rather than embark on a complicated exercise to measure the possible production impacts of specific exotic pest threats, emphasis is placed on calculating the consumer welfare effects brought about by changes in quarantine policy. This can be done using price and quantity data that is readily available and a simple static, partial equilibrium trade model. By estimating the consumer effects, it becomes possible for decision-makers to speculate as to the likelihood that abated production damage (resulting from quarantine procedures succeeding in excluding a pest) will exceed this value. If so, then the policy can be said to produce a socially optimal outcome. If not, it is important to discover why.

The methodology developed should not be used in isolation, but rather in conjunction with other techniques such as traditional pest impact assessments. This is most important since it can not account for several pieces of information. For instance, if a pest is capable of inflicting severe damage to natural ecosystems, this might explain why quarantine measures are maintained which appear to be excessive. While economic models can provide a great deal of important information in a clear and concise form, it must always be remembered that pest-related issues are seldom simple,

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[2] A *good, product* or *commodity* refers to a specific product and country/pathway combination (Bigsby and Whyte, 1999; Bigsby, 2001).

and there are will frequently be omitted factors which should be taken into account in the decision making process. The chapters that follow merely seek to develop a means of providing additional information of economic significance that is not typically taken into consideration in quarantine policy formulations.

For reasons concerning the practical application of the techniques developed in subsequent sections, the central theme of this investigation revolves around quarantine issues of an interstate nature. The sponsorship of the project by the Department of Agriculture Western Australia (DAWA) is motivated chiefly by the need to evaluate the impact of interstate quarantine on agricultural industries in Western Australia (WA), but also by interest in effects felt by broader society. It is to be noted that the techniques used to examine these '*intra*national' trade effects are directly applicable to issues of international significance. It is for this reason that frequent reference is made to national quarantine in developing the theoretical models.

1.3 Thesis Structure

The emergence of the WTO has produced extensive changes in the way quarantine policies are developed and maintained by national and State government authorities. Chapter two discusses why this is the case and outlines the obligations Australia has as a WTO Member. Also included is a brief historical overview of Australian quarantine and the many reviews to which it has been subjected. The most comprehensive of these, the Nairn Review of 1996 (Nairn *et al*, 1996), aimed to modernise the national quarantine system in terms of adopting a conscious 'risk management' approach, and is discussed at length. Having introduced the desirable elements of a quarantine policy analysis as is consistent with international rules and regulations, several examples of past analyses are critically evaluated, before a more appropriate methodology is outlined. This was largely developed by James and Anderson (1998).

Chapter three discusses the practical application of the James and Anderson (1998) model to provide aggregate industry information on the effects of quarantine decisions on consumer and producer welfare. Two case studies are presented both of which deal with commodities traded across State borders. These are mangoes and tomatoes. To guard against the introduction of specific pests, growers of these products in WA enjoy quarantine protection from interstate competition. By measuring the negative impact of resultant price inflation on WA consumers, an estimate of the expected damage cost saved by excluding these pests is provided. Given the size characteristics of the mango (small) and tomato (large) industries, the implications of industry size for the model results are then examined.

In chapter four, an extension of this aggregate model is developed. By looking at the spatial aspects of an industry's structure, a more detailed set of findings relating to the effects of quarantine policies can be calculated. In a State as large as WA, industries are often comprised of a series of component growing regions each with a different set of environmental conditions in which to grow their crops. This in turn effects the production costs faced in each region, in turn determining their capacity to absorb different levels of quarantine-induced competition. Using a spatial approach, the mango and tomato case studies are revisited, and the results compared to those gained through these of the aggregate model. In doing so, an insight into the appropriateness of each model given industry circumstances is provided, and conclusions presented as to which is able to provide policy-makers with the most pertinent information in different cases.

By using partial equilibrium models in the manner described in chapters three and four, a decision-maker is empowered with the ability to comment on the level of protection being afforded domestic industries by maintaining quarantine restrictions. Typically, this issue is avoided due (at least in part) to the political hazards involved in defining a socially optimal level of import risk. To do so is to imply that a certain amount of damage to domestic agricultural industries, communities and the environment caused by trade with other regions is deemed 'acceptable'. Through *ex post* examinations of quarantine policies however, the unavoidable risks involved in agricultural trade may be expressed in a less provocative form.

As a first step towards achieving this aim, chapter five introduces the concepts of *isorisk* curves and the *Appropriate Level of Protection* (ALOP), and uses these to express the relative merits of specific quarantine policies. By calculating the expected level of damage which must be prevented by quarantine policies to exactly offset the effects of price increments and assuming quarantine policies reflect the prevailing ALOP, it is possible to comment on the appropriateness of policies. This methodology is then applied to the two case studies in chapter six to provide some interesting findings with regard to the consistency of quarantine policies. Using the calculated impacts on consumer welfare of raising prices with quarantine protocols, a comment is made on the likelihood of these losses being offset by prevented losses in producer welfare.

In recognition of shortfalls of the techniques developed in previous chapters, chapter seven outlines some shortcomings that must be recognised in the approach used. Specifically, these relate to three areas. Firstly, no account is taken of possible *flow-on* effects from pests should they enter. This should be recognised when forming a judgement as to the likelihood that expected damage prevented by quarantine measures are sufficient to warrant losses of a certain size to consumers of the product concerned. Agricultural industries in WA have been shown in Islam and Johnson (1997) to have considerable flow-on effects, and this constitutes information that must accompany the findings of chapter six. Secondly, possible environmental and socio-economic effects are not accounted for due to the difficulties involved in extracting values for these non-market goods. Finally, the models used are static, and take no account of the dynamics of pest spread or strategic behaviour on behalf of growers and down-stream processors, or consumers. Although dynamic modelling techniques have been outlined in Hinchy and Fisher (1991), they are complex and data intensive, making them impractical for large scale use in policy analysis where time is a limiting factor.

In concluding the findings of previous chapters, chapter eight provides an overview of the issues developed. A brief discussion of the practicalities of using these techniques in policy analysis on a regular basis is presented, and the problems identified in chapter seven placed into context. These problems may serve to motivate further research concerning economic analysis and social welfare.

1.4 Conclusion

Given that decisions regarding quarantine affect all members of society, directing policy towards the welfare maximisation of a select group may lead to socially undesirable outcomes. Typically, the interests of consumers have been largely ignored in economic analyses of quarantine strategies, while those of primary producers have received the bulk of attention. This study aims to rectify this situation by developing a method of measuring consumer welfare effects that can be used to supplement traditional assessments of potential pest impacts on production. By quantifying consumer effects, expected producer losses can be put into perspective, and hopefully improve the ability of decision-makers to design quarantine policies that closely reflect social preferences. Chapter two presents a host of background material to quarantine issues and policy-formulation in Australia, and makes mention of its international obligations with regard to trade protection. It also explores the methodologies used in a number of past economic analyses on national quarantine threats before suggesting a more appropriate approach.

2. Quarantine And Trade

2.1 Introduction

In the modern age of the global economy in which vast quantities of food and food products are moving across State and international borders, quarantine regulations are becoming increasingly important. To understanding the role played by quarantine systems, it is important to recognise that while each member of the world-wide trading network is predominantly motivated by self interest, legitimate means of erecting artificial trade barriers between themselves and competitors are limited. Gone are the days of constructing tariff walls to protect domestic markets from the perils of competition, for international agreements now require countries to undertake trade without unnecessary restriction. The consequences of not abiding by these rules are greater than the gains to be made from a *protectionist* philosophy. However, rent-seeking behaviour has manifested itself in other forms, of which quarantine is a favoured option. By forcing quarantine restrictions on produce from other centres flowing into the domestic economy, a country can successfully protect its domestic industries from competition by ostensibly defending them from exotic pests and diseases.

This behaviour has caused a change in the way policies are evaluated, placing greater emphasis on openness and transparency in policy-making than ever before. But, the role that economic analysis can play in this process has yet to become clear. Quarantine issues have long been the subjects of science, and as such there has been a tendency to evaluate policy options based on the potential damaging effects of pests on domestic industries. There is no doubt that this comprises a main part of the benefits of quarantine regulations, but as members of a society whose welfare is affected by such policies, consumers must also be considered. A failure to recognize consumer effects may lead to levels of protection that do not reflect societal import risk preferences.

Section 2.2 of this chapter provides a brief history of Australian quarantine at both a national and a State level. Section 2.3 then introduces international agreements that affect the way quarantine systems are designed in the modern economy. Sections 2.4 and 2.5 examine some 'traditional' methods of quarantine policy analysis, and demonstrate their omissions using economic techniques to measure social welfare. Section 2.6 explains why a multi-disciplinary approach to risk and economic assessments are needed. Section 2.7 then draws some conclusions.

2.2 Australian Quarantine

2.2.1 A Brief History of National Quarantine in Australia

Australia is fortunate in that it has largely avoided the economic, environmental and social trauma associated with the entry and establishment of 'major' exotic pests and diseases. Unlike other prominent agricultural centres, Australia's settlement history and geographic circumstances have prevented significant numbers of non-indigenous pest incursions. From the early days of colonisation right up to the 1940s the majority of the populace and imported commodities originated from Britain, which up until recent times has enjoyed a long history of relatively high standards of human and animal health. In addition, Australia's remote location served to limit the physical capacity of pests to enter and become established without assistance from man, while the lengthy duration of sea travel from major international trading outlets meant an enforced period of quarantine on passengers and cargo (Senate, 1979).

In the latter half of the 20th century, the situation changed dramatically. With massive improvements in ocean and air transport, the volume and speed of people and cargo moving in and out of Australia has increased significantly. Tourism and immigration policies have resulted in a greater ethnic mix of passengers and groups than ever before, and the growth of mediums like the Internet are making mail orders increasingly accessible to more and more people. Nevertheless, the nation is still in a favourable state of human, animal and plant health, and it is the role of the quarantine system to ensure it remains that way whilst, at the same time, facilitating trade and tourism.

The dynamic history of Australia's quarantine system has reflected the changing climate for trade in which it has found itself. The states had sanctioned uniform quarantine policies known as "Federal Quarantine Acts" in the years preceding 1908 in recognition of the need for a national strategy for dealing with persons, animals and produce infected with pathogens. In July 1909, the Commonwealth Quarantine Act (henceforth referred to as the *Quarantine Act 1908*) was put in place, which essentially mimicked the principles involved in the pre-existing State legislation (Nairn, 1996). The Department of Trade and Customs initially presided over the Act until the emergence of the Commonwealth Department of Health in 1921. There Australian quarantine administration remained until 1984, during which time it was placed low on the Department's list of priorities (DPIE, 1988). Responsibility was then moved to the Department of Primary Industries, which subsequently became the Department of Primary Industries and Energy (DPIE). The Australian Quarantine and Inspection Service (AQIS) was officially formed in 1986 as a separate operational group within the DPIE. The policy arm of AQIS, now called *Biosecurity Australia*, delivers both export inspection and import quarantine service and manages the associated technical and operational support systems (Nairn, 1996).

2.2.2 *Quarantine at a State Level*

While national quarantine services have steadily become more centralised, the same can not be said of quarantine at a State level over the past century. Each State and Territory currently has its own arrangements for the delivery of operational quarantine services. In the Australian Capital Territory, New South Wales, Queensland, South Australia and Victoria service delivery is under direct Commonwealth control. Quarantine services are carried out under the federal *Quarantine Act 1908.* Under formal agency arrangements with the Commonwealth, State government agencies are charged with the responsibility of providing quarantine services. In WA, the Northern Territory and Tasmania operational services are self-provided. The West Australian Quarantine and Inspection Service (WAQIS) actively enforces quarantine regulations under six separate acts: *The Plant Disease Act; Enzootic Disease Regulations*; *Agriculture and Related Resources Protection Act*; *Beekeepers Act*; *Wildlife Conservation Act*; and *Seeds Act.*

2.2.3 *Formal Quarantine Reviews*

As an important community service, quarantine has been the subject of numerous national reviews over the past 20 years, some of which have been more widely cited than others. These include:

1977 Department of Prime Minister and Cabinet: *Review of Australian Quarantine Arrangements* (DPMC, 1977).

1979 Senate Standing Committee on National Resources: *The Adequacy of Quarantine* (Senate, 1979).

1984 Touch Ross Pty Ltd: *Examination of Financial Arrangements Between the Commonwealth and State Governments for the Provision of Quarantine Services.*

1985 Auditor-General's Efficiency Audit: *Reports of the Auditor General on Efficiency Audits: Administration of Quarantine Services* (Auditor-General, 1985).

1986 Joint Parliamentary Committee of Public Accounts: *Administration of Quarantine* (JPCMA, 1986).

1987 Australian National University: *The Adequacy of Exotic Animal Disease Legislation* (ANU, 1987).

1988 Lindsay Review: *Australian Quarantine Requirements for the Future: Report of the Quarantine Review Committee* (DPIE, 1988).

1992 Auditor General's Efficiency Audit: *Efficiency Audit: Australian Quarantine and Inspection Service, Quarantine Division 1991-92* (Auditor-General, 1992).

1996 Senate Review: *Australian Quarantine and Inspection Service: Report of the Senate Rural and Regional Affairs and Transport Legislation Committee* (Senate, 1996).

1997 1996 Department of Primary Industries and Energy: *Australian Quarantine – A Shared Responsibility*, commonly referred to as the 'Nairn Report' (Nairn *et al*, 1996)[3].

Collectively, these reports have made over 270 recommendations. But, prior to the Nairn report the *Quarantine Act 1908*, that provides the legislative backing for an increasingly broad range of activities, has remained largely unchanged since its proclamation. The *Quarantine Amendment Act 1999*, which commenced in June/July 2000, is the first major revision to the *Quarantine Act* to implement, *inter alia*, changes recommended in the Nairn Report (AFFA, 2001). Moreover, a general lack of co-ordination between quarantine activities in each State and Territory has persisted up until the present day, and is only now recognised as a weakness of the national system.

With the push towards trade globalisation, Australia can no longer afford to maintain a segregated quarantine system, for to do so may lead to the violation of global trading rules. Regulatory decisions that affect goods traded within its borders are now subject to more conditions than ever before. If the nation is to grow and prosper under these new conditions of trade, a fair and transparent quarantine system will play a vital role in facilitating progress in this regard.

[3] Discussed at length below.

2.3 *Inter-* and *Intra-*national Trade and Sanitary and Phytosanitary Measures

2.3.1 The World Trade Organisation Agreement

The Uruguay Round of multilateral trade negotiations which led to the transformation of the General Agreement on Tariffs and Trade (GATT) Secretariat into the World Trade Organisation (WTO) Agreement on the 1st January 1995 has had an extensive impact on the quarantine policies of Member nations in subsequent years. As a signatory of the WTO Agreement, the federal government of Australia has an obligation to ensure the nation's internal markets for agricultural products closely resemble those of international markets with respect to technical barriers to trade. During the Uruguay Round concerns that the trend towards free trade may be offset by the use of alternative protection techniques began to surface. Whilst tariffs and quotas constituted the primary trade weapons of the protectionism of the late 1970s and the 1980s, the key instrument of what can perhaps best be termed *neo-protectionism* is quarantine. In response to the concerns about its use as a trade barrier an agreement on Sanitary and Phytosanitary (SPS) measures was negotiated to ensure that future SPS trade restrictions were based on scientific information (James and Anderson, 1998). In this agreement, henceforth refereed to as the *SPS Agreement*, is contained Commonwealth and State obligations and responsibilities relating to "...all sanitary and phytosanitary measures which may, directly or indirectly, affect international trade" (Article 1).

Annex A1 of the SPS Agreement (GATT, 1994) specifically defines SPS measures as any measure applied:

(a) to protect animal or plant life or health within the territory of a Member from risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms;

(b) to protect human or animal life or health within the territory of a member from risks arising from additives, contaminants, toxins, or disease-causing organisms in foods, beverages or foodstuffs;

(c) to protect human life or health within the territory of a Member from risks arising from diseases carried by animals, plants or products thereof, or from the entry, establishment or spread of pests; or

(d) to prevent or limit other damage within the territory of a Member from the entry, establishment or spread of pests

Any such measure taken against one Member by another that directly or indirectly affects international trade may be challenged by another Member through the WTO Dispute settlement procedures.

2.3.2 Dispute Settlement

In the absence of a global government, one of the key contributions of the GATT, the WTO precursor, has been the provision of an avenue for the diplomatic resolution of trade disputes. This important role has been strengthened by the WTO Agreement whereby signatories are committed not to take unilateral action against trading partners but rather to seek recourse through the Dispute Settlement Body (DSB) (Anderson, 1999). It is the roll of the DSB to settle trade disputes in which the parties involved fail to agree on a mutually acceptable solution. It operates by establishing a panel of relevant trade experts (of which there are usually three) within forty-five days to consider a case in their individual capacities, not as representatives. The findings of the panel are handed down within six months, which can then either be accepted or rejected by the DSB[4]. The Appellate Body is a permanent fixture of the WTO made up of seven judges who rule on the legalities of individual cases, of which three are chosen to consider a case. The Appellate Body issues its recommendations within sixty days, which are then either accepted or rejected by the DSB. If accepted, the findings of the panel and/or Appellate Body are legally binding, and an offending Member nation has thirty days in which to demonstrate intended compliance with the DSB ruling (Stanton, 2001). If the panel/Appellate Body finds a Member's actions are in breach of the WTO Agreement, it will usually recommend that the Member bring its measures into line with its obligations within a reasonable period of time (AQIS, 2000).

As of October 2000, over 200 disputes had been formally raised under the WTO's dispute settlement system, 18 of which were alleged violations of the SPS Agreement. Australia has been involved in two of these 18 cases where a panel has been assembled, both concerning restrictions of imports of fresh, chilled or frozen salmon (Stanton, 2001)[5].

The complaint by Canada against Australia's import restrictions on salmon imports in 1997 was widely publicised, providing an example of the possible consequences of WTO Agreement violations. In 1994 Australia agreed to undertake an Import Risk Analysis (IRA) to address the technical quarantine issues raised by a request from Canada for market access through the then GATT dispute settlement process. In May 1995, AQIS published a draft risk analysis which concluded that if certification conditions were met, the risk posed by imported salmon was negligible to

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[4] Panel rulings are automatically adopted by the WTO unless there is a consensus among Members against the ruling. If they are not rejected, the findings of the panel formally become those of the DSB within sixty days.

[5] This is discussed further in section 2.6.

Australian salmon producers (AQIS, 1995). However, a final draft of this assessment published in December 1996 reported that as many as 20 exotic diseases could be introduced through imports, the economic consequences of which could be large (Stanton, 2001). On the basis of this final draft report, Australia's ban on imported salmon was maintained.

Canada's response was to launch a formal complaint through the WTO dispute settlement process, requesting that a panel be formed to examine the legitimacy of Australia's actions. The panel established to look into the issue in April 1997 observed that Australia had conducted an IRA and assumed that it was compliant with the provisions of the SPS Agreement. However, it had failed to demonstrate a rational relationship between the risk assessment and the import ban. The Appellate Body supported this view, finding that the IRA had not evaluated the likelihood of disease entry and establishment either with or without possible quarantine treatments. It therefore represented a breach of Article 5 of the SPS Agreement, which deals with the assessment of risk and the determination of the appropriate level of SPS protection (GATT, 1994). The panel also suggested that there were less trade restrictive measures available to Australia than an import ban, but recognised the fact that the risk abating properties of these measures were difficult to determine.

Although the time limit specified for Australia to comply with the DSB findings was eight months after the adoption of the panel and Appellate Body reports, Australia failed to meet this deadline until two weeks later (July, 1999). By this time, AQIS had completed yet another IRA, this time asserting that the importation of salmon meat from Canada 'under certain conditions' did not pose excessive risk to Australian fisheries (AQIS, 1999). This drew a hostile response from Canada, who requested WTO permission to take retaliatory action against Australia. This action was delayed while the DSB considered the issue of Australia's compliance or non-compliance by way of the original panel established in 1997[6]. It subsequently ruled that this new risk assessment was compliant with the terms of the SPS Agreement, but that the suggested import conditions placed on imported salmon, whereby products were processed to a "consumer-ready" form, were unnecessarily trade restrictive. This panel report was formally adopted in March 2000 without appeal (Stanton, 2001).

This lengthy and turbulent chapter in Australia's trading history graphically demonstrates the repercussions of not acting in accordance with the rules established under the WTO. Although retaliatory action was avoided 'at the eleventh hour', the failure of Australia to mount a clear and concise defence of its actions could potentially have had ramifications with industries completely unconnected with salmonid (trout and salmon) importation. Hence, quarantine policy-makers have an obligation to all exporters to avoid such potentially damaging confrontations with other trading nations.

2.3.3 State and Territory Arrangements and the WTO Agreement

Since the food safety and animal and plant health regulations relating to interstate trade within Australia are often set by State and local government authorities, decisions made at all levels of government have the potential to be challenged by WTO Members. This is recognised in Article 13 of the SPS Agreement, which requires the central government (as the signatory) to formulate and implement positive measures and mechanisms in support of the observance of the international provisions by all tiers of government (GATT, 1994; Miller, 1999). Accordingly, a Memorandum of

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[6] It is noteworthy that by this time the same panel was in the process of examining a complaint by the United States against Australia on the same issue (Stanton, 2001).

Understanding between the Commonwealth of Australia and all states and Territories (henceforth referred to simply as "the Memorandum") was signed on the 21st of December 1995 in which parties agreed to act in accordance with relevant obligations under the SPS agreement (Commonwealth of Australia, 1995). Article 11 of the Memorandum stipulates:

> States and Territories shall not apply any relevant sanitary and phytosanitary measures within their jurisdictions which would not conform with the provisions of the SPS Agreement.

The "provisions" referred to are specified in Article 5 of the SPS Agreement (GATT, 1994), paragraph 1 of which begins:

> Members shall ensure that their sanitary and phytosanitary measures are based on an assessment, as appropriate to the circumstances, of the risks to human, animal or plant life or health, taking into account risk assessment techniques developed by the relevant international organisations.

In a general sense then, any measure applied to imported products by any level of government to protect human, animal or plant health must be based on scientific principles, and not maintained without sufficient scientific evidence. The only exception is where existing evidence is insufficient to prove or disprove an unacceptable level of pest importation risk, in which case a Member may adopt provisional measures to protect itself (Miller, 1999).

2.3.4 The Nairn Review

The need to bring the collective Australian quarantine system in line with these international provisions was one of a number of factors providing motivation for the review of Australia's quarantine system initiated by the Hon. Bob Collins, Minister for Primary Industries and Energy, in December 1995. Through the course of the 1990s concerns began to surface about the effectiveness of Australia's quarantine control after the consequences of pest outbreaks were amply demonstrated by the European Bovine Spongiform Encephalopathy (or BSE) outbreak in Great Britain, which resulted in a "selective cull" of cattle deemed a contamination risk, and significant disruptions to trade. Several exotic pest incursions in Australia served to heighten public concern over trade safety issues, applying added pressure to AQIS to demonstrate competence in the protection of Australian consumers. Specifically, incidences of Western Flower Thrips, Papaya Fruit Fly, Siam Weed, Chalkbrood, Northern Pacific Starfish and Japanese Encephalitis being imported from abroad received a considerable amount of media attention (Nairn *et al*, 1996).

A number of other factors also contributed to the need to formally demonstrate that appropriate exotic pest protection mechanisms were in place in Australia, including:

- The voicing of concerns over the processes and science behind AQIS import protocols following their endeavours to finalise import conditions for goods, as in the salmon case mentioned previously;
- The increasing use of environmentally-friendly, or 'clean and green' approach to food marketing to gain access to certain markets, reflecting consumer concerns over the environment;

- Increased volumes of produce on the world market, and the greatly enhanced movement of people between international destinations brought about by advances in air and sea transport technology; and
- Scientific advances in the study and identification of plant and animal pests and diseases.

(Nairn *et al*, 1996; Tanner, 1997).

The committee appointed to carry out the review was chaired by Emeritus Professor Malcolm Nairn, which presented its findings to the Minister in November 1996 in the form of a report titled *Australian Quarantine: A Shared Responsibility*, widely referred to as the Nairn review. The report put forward 109 recommendations on how Australia's quarantine system could be improved to comply with WTO regulations, concentrating on a range of areas such as environmental awareness, community awareness, risk analysis, consultation in policy-making, surveillance and preparedness.

With regard to the analysis of import risk, the report makes it clear that the pursuit of a 'zero risk' quarantine structure is nonsensical. The sheer abundance and diversity of quarantine pests makes zero risk an impossibility, so a much more realistic basis for Australia's quarantine system is 'manageable risk'. At the core of this concept is *risk analysis*, which is a general term encompassing the elements of:

- Risk Assessment – the process of identifying and estimating risks associated with a policy option and evaluating the likely consequences of taking those risks;
- Risk Management – the process of identifying, documenting and implementing measures to reduce these risks and their consequences; and
- Risk Communication – the process of interactive exchange of information and views concerning risk between analysts and stakeholders (Nairn *et al*, 1996; Nunn, 1997).

By utilising risk analysis techniques, the Nairn review suggested, quarantine could be targeted at areas representing the greatest risks and so produce the highest social and environmental returns with available funds. The report went on to list several fundamental principles to be included in the analytical process, which included: stakeholder/industry consultation; objectivity and robustness in scientific methodology and political independence; transparency; consistency and harmonisation; subject to appeal on process, and; subject to periodic external review. This asserts that a successful risk assessment should, in essence, exhibit each of these principles if it is to facilitate a socially optimal allocation of relatively scarce quarantine resources.

An official response from the federal government to the Nairn review and its recommendations was not put forward until August 1997 (DPIE (1997)). This was to come in the form of a joint response to the Committee's report and the report of a National Task Force on Imported Fish and Fish Products presented to the government in December 1996 (DPIE (1996))[7]. While not accepting all the recommendations of the review committee, the response acknowledged the need for Australia's acceptance of the rules and guidelines of international trade to which it expects trading partners to adhere to. To bolster the national quarantine system, it indicated that additional funding of A$76 million would be delivered over the next four years and be targeted towards increasing community awareness, manageable risk (science-based), protection of Australia's unique environment and recognition of the continuum of quarantine (Tanner

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[7] The National Task Force on Imported Fish and Fish Products was established in June 1995 to examine issues related to imports of aquatic animals and their products. Particular emphasis was placed on quarantine issues raised in a significant scientific review of aquatic animals health and quarantine (Humphrey (1995)) and the recommendations of a national working party that examined this review (Nunn (1995)) (Tanner and Nunn, 1998).

and Nunn, 1998). The report also expressed the government's endorsement of the risk analysis process put forward by the Nairn review, with only a few minor changes[8].

2.4 The 'Traditional' Role of Economics in Quarantine Policy Analysis

2.4.1 An Overview of Methodologies Employed in Previous Economic Assessments

Despite the increased budgetary attention placed on quarantine in the wake of the Nairn review, it is perhaps surprising that there are currently few examples of published risk assessments dealing with specific national import risk situations that include an appropriate economic welfare analysis. This is particularly true in the context of plant health since a relatively large number of species are employed commercially, and pests and diseases affecting them can be quite generalist. Moreover, pest predictability is generally low, and predictive models of spread and impact are not powerful (Lonsdale *et al*, 2001). Intuitively, such a situation would lend itself towards the development of enhanced risk management techniques designed to lessen the economic, environmental and socio-economic impacts of pest incursions in the face of limited information. On the whole, this has not transpired, and the role economics has to play in facilitating socially desirable policy outcomes with regard to quarantine policies has yet to be amply demonstrated.

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[8] These included a decision not to establish AQIS as a statutory authority, and another not to establish a centre for quarantine-related risk analyses. In regard to the latter, the government's response indicated that AQIS and the Bureau of Resource Sciences (BRS) would continue to provide risk analysis services (DPIE, 1997; Tanner and Nunn, 1998).

The economic analyses of quarantine issues that have been completed in Australia to date have tended to concern long-standing, high profile requests, and focus on specific quarantine decisions as opposed to the broader aspects of policy options (Nunn, 2001; Roberts, 2001). Examples include Hinchy and Low (1990), McKelvie (1991), McKelvie *et al*, (1994) and Hafi *et al*, (1994), each of which is discussed below. These have taken the form of either cost-benefit analyses of decisions to move from a trade ban on a product (due to the risk of exotic pest entry) to conditional importation, or a simplistic exploration of possible costs to selected industries if pests become established. This has meant they have emphasised those factors specified in the SPS Agreement as being paramount to WTO-compliance, and consequently failed to suggest a socially-optimal course of action taking into account the welfare of others outside production circles.

While not defining ALOP as such, Article 5 of the SPS Agreement identifies those factors that would be deemed relevant from a WTO perspective in assessing quarantine risks. These "relevant economic factors" are specified in Paragraph 3 (GATT, 1994), which states:

> In assessing the risk to animal or plant life or health and determining the measure to be applied for achieving the appropriate level of sanitary or phytosanitary protection from such risk, Members shall take into account as relevant economic factors: 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 Member; and the relative cost-effectiveness of alternative approaches to limiting risks.

What is missing from this list of factors is *consumer gains from trade*. This omission is of paramount importance when attempting to use measures of societal welfare to examine the impact of quarantine policies on specific regional and national economies simply because consumers constitute a large proportion of society. Although reference has been made to consumer welfare (e.g. Hinchy and Low, 1990; Hafi *et al*, 1994), economic analyses of quarantine issues have largely overlooked the broader implications of their inclusion.

In the following discussion, let the term 'social welfare' refer to *gains from trade*. Simply stated, these are the extra consumption benefits achieved through trade less production costs brought about by competition. Australian consumers of agricultural commodities enjoy a wider range of products obtainable at a cheaper price than would otherwise be the case by trading with other nations. This enables them to maintain a higher level of welfare than if they were forced to rely solely on domestic producers for supplies[9]. But, trade flows between different geographic areas open up the possibility of non-indigenous pest incursions that may harm domestic agricultural industries. In addition, domestic producers are subjected to higher degrees of competition from rival growers elsewhere in the world if borders are open to trade. In terms of an appropriate modelling framework, this means that ideally the scope for an accurate economic analysis must be broad. Not only is there a need to account for benefits to agricultural industries (and in some instances the environment) from preventing costly exotic pest incursions, but also the costs to consumers resulting from import restrictions. Yet, to repeat, consumer concerns are not usually recognised in analyses using WTO-relevant criteria to assess pest threats and the effectiveness of SPS measures, only potential producer effects.

SPS measures affect markets by altering the conditions of competition between local and imported products, and consequently the prices domestic growers receive for

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[9] In short, consumers have a broader range of goods on which to spend their money

their produce and consumers pay for the privilege of consuming them. Consider a hypothetical exotic pest to Australia that is established in a WTO Member country wishing to export host products to the Australian market. The probability of the pest entering Australia through these traded goods in sufficient quantities to reproduce is maximised under a situation of unrestricted trade between the two countries, and minimised by an import ban. By ensuring the goods are subjected to quarantine treatments before they are permitted into Australia the risk of pest importation will be lower than if no restrictions applied. But, the reduced risk of incurring a loss as a result of pest damage comes at the cost of higher prices since quarantine treatments are not without costs. So the net result in terms of producer and consumer welfare is conceptually ambiguous.

It is this *net welfare change* an analytical model must encapsulate if it is to be an effective policy guide, or at least a tool that can effectively indicate a 'socially optimal' course of action. A static, single commodity, partial equilibrium framework, as shown in Figure 2.1 (p.29), is often the most feasible tool for specific regulatory proposal analyses (Roberts, 2001). It provides a useful conceptual model through which the effects of SPS measures can be seen, and how previous attempts have been made to estimate the costs and benefits of quarantine policy changes empirically. In general, national quarantine laws have been conservative in their approach to quarantine risk mitigation, and this is reflected in economic analyses carried out to examine quarantine risks. They have tended to focus on the movement from an import ban to a quarantine-restricted trade setting. Before proceeding with a theoretical discussion however, it is necessary to state a number of simplifying assumptions governing the way in which the model is represented.

First, assume the fruit or vegetable product subject to quarantine regulation is homogenous, there being no distinction made between individual varieties within the commodity type. Second, assume the domestic market for the good is perfectly competitive. Third, suppose the domestic price for the product is higher than the 'landed' price of overseas product, so trade would take place in the absence of blanket restrictions. Fourth, assume the contribution of Australia to the total supply of the good is insufficient to exert influence on the world price, the exchange rate and domestic markets for other commodities. Fifth, assume society has a neutral attitude to risk, and so demands no premium over and above an expected level to protect against damage resulting from pest importation[10]. Sixth, assume pests are host specific and only impact upon the costs of their host industry alone. Finally, where quarantine protocols require procedures such as chemical treatments to be undertaken upon importation into Australia, assume the costs of these procedures are borne by the exporter, and are transferred to consumers via the price mechanism (James and Anderson, 1998).

If a market with these characteristics were suddenly to move from a closed state to one of quarantine-restricted trade, consumers can be seen to gain in welfare at the expense of producers. If P_c represents the closed economy, domestic equilibrium price and P_q the prevailing price if imports are allowed into the market after undergoing quarantine procedures, consumer surplus increases by the area P_cCEP_q (i.e. from ACP_c to AEP_q) under quarantine-restricted trade. At the same time, producer surplus decreases by the area P_cCFP_q (i.e. from BCP_c to BFP_q). Hence, the *gains to trade* are represented by the triangle CEF. However, since no quarantine procedure has a 100 per cent guarantee of restricting pests associated with a product, the probability of importing

[10] Fraser (2000) asserts that the impact of risk in determining the net effect of quarantine policies on an industry is relatively minor.

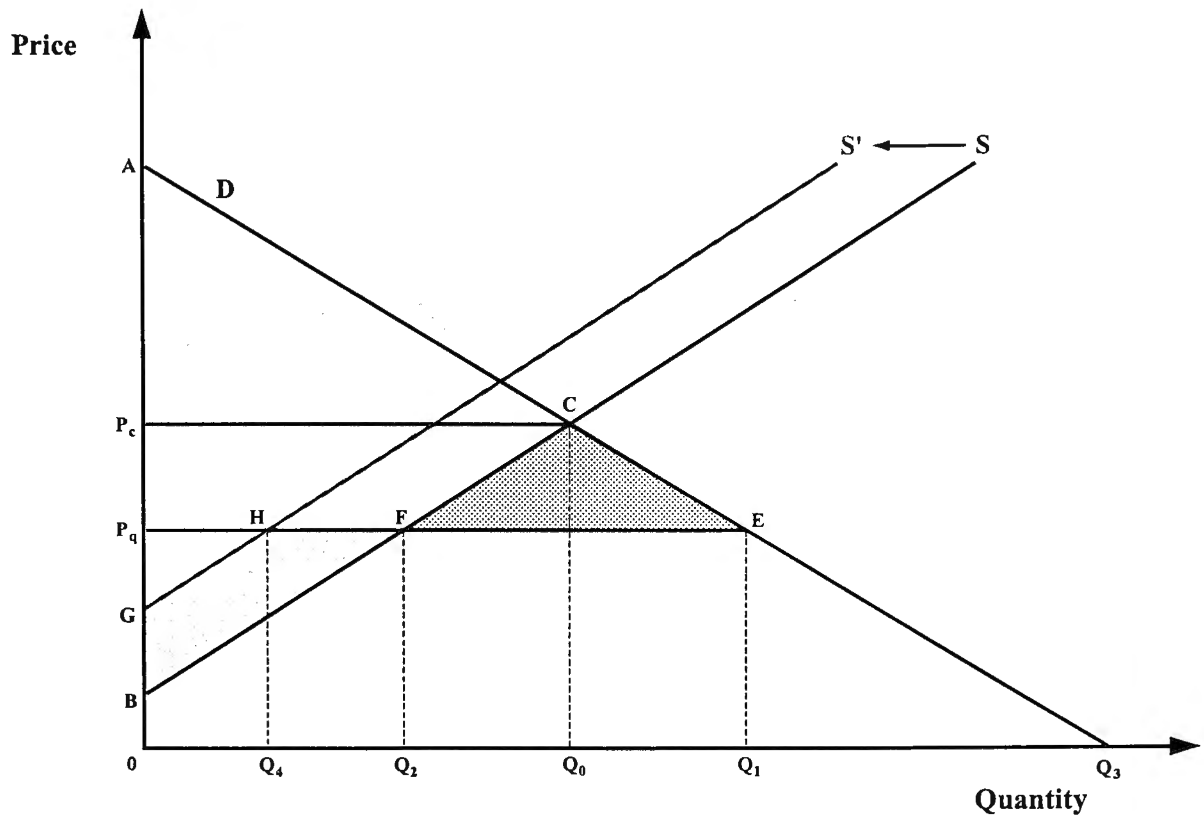

Figure 2.1: 'Traditional' Cost-Benefit Approach to Economic Analyses of Quarantine Decisions

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a pest species established in overseas growing centres through the exchange of host material is greater than zero.

Although not always identified as a key point of interest, the most comprehensive of models used to date focus very heavily on this issue of entry probabilities. By speculating as to the extent of damage potentially caused by pests should they enter Australia in sufficient numbers to breed, it is possible to perform a benefit cost analysis of the decision to allow quarantine-restricted trade. If a pest inflicts direct, on-farm damage and/or requires costly management techniques to minimise this damage, it will have the effect of contracting the domestic supply of the affected commodity. This is represented by the shift from S to S' in Figure 2.1. Such a shift will reduce the domestic producer surplus from P_qFB to P_qHG. So, if this loss in producer surplus (BFHG) is compared with the consumer gains from trade (CEF), it is possible to calculate a *critical initial probability* of the introduction and establishment of the pest which will bring benefits and costs into balance. At this level of probability, the expected economic impact of the decision to allow quarantine-restricted trade will be zero.

Other studies have merely attempted to estimate the likely loss of producer surplus in the event of pest incursions (i.e. area BFHG in figure 2.1), paying little (if any) attention to the likelihood of such an event taking place. This approach ignores the potential gains to be had by trading with other countries and enjoying a greater range of products at cheaper prices. Primary examples of quarantine policy analyses completed over the last ten to fifteen years using these different techniques to assess import risks are discussed below. They concern decisions of whether or not to allow imports of apples, salmon meat and poultry meat to Australia from areas where pests are present.

2.4.2 Apples

The bacterial disease fire blight has been at the centre of two substantial economic studies in the last decade, both relating to applications by New Zealand apple producers for access to the Australian market. The disease is found throughout many pome fruit (apple, pear and nashi) growing areas of the world, including New Zealand. If left uncontrolled, it can inflict severe loss of fruit yield and, in some cases, the death of host trees. However, chemical treatments can be used to minimise fruit loss in orchards where the disease is present, effectively raising the average variable cost of production. Despite having to employ such techniques, New Zealand producers are capable of producing and transporting apples and pears to Australia at a lower price than their Australian competitors. But, due to the threat of introducing the fire blight disease to domestic growing regions, importation was (and remains) prohibited.

In the wake of the Lindsay Review of 1988 (DPIE, 1988), Australia's response to the 1990 application by New Zealand was to be consciously open and transparent. It consisted of a biological component, Roberts (1991), and an economic component produced by the Australian Bureau of Agricultural and Resource Economics (ABARE) at the request of AQIS, Hinchy and Low (1990). The latter draws heavily from the theoretical discussion subsequently outlined in Hinchy and Fisher (1991). The study is essentially a cost-benefit analysis of possible changes in quarantine regulations relating to pome fruit to allow New Zealand apples access to the Australian market. Benefits are measured in terms of the increase in consumer surplus gained through the importation of New Zealand apples and subsequent downward pressure on domestic prices, while costs are assessed in terms of the expected reduction in producer surplus brought about by the introduction of fire blight.

On the consumer side, Hinchy and Low (1990) assume that if quarantine controls were to be relaxed, the volume of New Zealand pome fruit entering Australia from the specified regions would be in the order of 3-7,000 tonnes. This represents an increase of 1 to 3 per cent of the national consumption levels of the period. With an assumed price elasticity of demand of between –0.2 and –0.4, and a supply elasticity of 0.3, the estimated gain in consumer surplus produced is calculated at between $0.2 million and $2.8 million per year. Relating this back to figure 2.1, the change in consumer welfare is represented by the area P_cCEP_q.

On the production side, it is acknowledged that Australia has seven major apple-producing regions, the largest being the Goulburn Valley in Victoria. In the event of an outbreak, production losses of 20 per cent are assumed for apples, and 50 per cent for pears. If the disease were to initially establish in the Goulburn Valley, it is estimated that total losses could be in the order of $77 million and $30 million per year if the outbreak is confined to one of the other six production regions. Hence, with a 100 per cent certainty of the disease entering Australia via New Zealand imports, there is a one in seven chance of a loss of producer surplus of $77 million, and six in seven chance of a loss of $39 million. This gives an average loss of just under $45 million, represented in figure 2.1 as the area BFHG.

Using the consumer gain and average producer loss information, Hinchy and Low (1990) calculate a break-even (or critical) probability of disease entry and establishment via New Zealand apple imports. This is the probability required to bring consumer gains and 'expected' production loss into balance. By taking a risk-averse stance with regard to quarantine decision-making, the objective of policy is assumed to lie in minimising the risk of the worst-case scenario occurring. With consumer benefits at a minimum ($0.2 million) the critical probability is estimated to be in the order of 0.0096 (or 1 in 1040), but when trade benefits are at their maximum ($2.8 million), this probability increases to 0.0133 (1 in 75). On the basis of these findings and supplementary information (e.g. Roberts, 1991) about the biology of the fire blight disease, New Zealand's application was denied.

Hinchy and Low (1990) adopts the concept of a 'zero risk' quarantine regime, reflecting the view of AQIS at the time. As such, the critical probability estimate relates to the probability of fire blight entry and establishment through New Zealand apple imports. In fact, under a closed economy situation the risk of the disease entering is not zero, and therefore the expected damage cost despite the prohibition of imports is also positive. For this reason, the critical level of probability calculated overstates that required to bring benefits and costs into balance. To have assumed otherwise would have presented a move towards 'managed risk', which was not formally adopted in Australian quarantine circles until the release of the Nairn Review (Nairn *et al*, 1996).

A more pressing point involves the failure of Hinchy and Low (1990) to take into account the fact that consumers were disadvantaged in the base-case scenario, that of a closed economy. By allowing New Zealand imports, consumers would certainly be better off than under a closed economy, but they would be even better off under a free-trade scenario. Of course, the probability of importing the disease and suffering an adverse supply curve shift would be maximised under a free trade regime, and this is what a net welfare investigation must compare in order to direct quarantine policy towards a socially optimal outcome, as opposed to a domestic producer optimum. By not calculating the net welfare losses of a closed-economy and a quarantine-restricted scenario relative to a free-trade scenario, the study fails to recognise the level of expected damage cost prevented by the respective policies necessary for them to have no welfare impact[11].

In the mid-1990s, New Zealand made another request to access the Australian apple market. As with the previous response, AQIS requested ABARE to carry out an investigation into the likely costs of a fire blight outbreak in Australia. The resultant report, Bhati and Rees (1996), is somewhat different to Hinchy and Low (1990) in that it does not delve into the issue of consumer welfare at all. Instead, the study is more along the lines of a producer welfare analysis concentrating solely on the effects on domestic pome fruit growers in the event of an outbreak. In fact, the stated objective of the study is to "...carry out a cost analysis of changing quarantine regulations which prevent imports of fresh apples into Australia" (Bhati and Rees, 1996). The fact that a closed-economy situation imposes a cost on consumers is not mentioned.

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[11] Section 2.5 suggests a more appropriate methodology that takes the free trade scenario into account when calculating net welfare changes.

Like Hinchy and Low (1990), Bhati and Rees (1996) base their assumptions about the impact of the fire blight disease on the information contained in Roberts (1991). However, the two studies differ in their treatment of the probability of entry and establishment. Bhati and Rees (1996) run a sensitivity analysis on the likelihood of the disease impacting on one or more of Australia's seven pome fruit growing regions rather than estimate a critical probability. The study found that if the probability of introduction and establishment as a result of imported apples was between 0.5 and 1 per cent, a loss of producer surplus of between $20,000 and $125.7 million could be expected, depending on whether the disease was confined to one or all growing regions. This broad range of possible outcomes is in general agreement with Hinchy and Low (1990). Further verification can be found in Viljoen *et al* (1997), which claims that the pear industry in Australia might well collapse entirely under the pressure of a fire blight outbreak.

2.4.3 Salmon Meat

An application for market access by New Zealand is also at the centre of an economic analysis conducted by ABARE (at the request of AQIS) in 1991. The resultant report, McKelvie (1991), explores the possible consequences for the Australian salmonid (trout and salmon) industry of introducing an exotic disease by allowing salmon meat from New Zealand into the country after undergoing quarantine procedures. Specific industries potentially under threat from disease introduction include the rainbow trout farming (worth an estimated $8.7 million a year 'at the farm gate' in 1990) and salmon farming (worth around $30 million a year) (McKelvie, 1991; McKelvie *et al,* 1994) [12]. A disease of primary concern for Australian fisheries is Whirling Disease (*Myxobolus cerebralis*), and McKelvie (1991) presents the possible costs domestic producers would face if this pathogen were to be introduced to Australian waterways. It does so by forming a gross estimate, represented by the area BFHG in figure 2.1, rather than a probability-weighted (or expected) producer welfare loss.

Although whirling disease rarely causes high levels of mortality in salmonids, if left untreated it causes exhaustion, malnutrition and deformities which reduce the proportion of crop that can be marketed each year. The severity of impact depends on the species of fish concerned, but generally juvenile salmon and trout show disease symptoms. Although they can act as carriers, mature fish rarely develop clinical signs when exposed to infection. Once it has become established the disease can not be eradicated from a waterway due to the proliferation of intermediate host tubificid worms. However, experience with the disease in Europe and the United states demonstrates that it is possible to manage its impact effectively by rearing fish in isolated, disease-free tanks before transferring them to 'grow-out' facilities and diseased waters (McKelvie, 1991). This adds to the costs of production, particularly since rearing tank water must be treated with ultraviolet irradiation and filtration systems not currently used in Australia.

The potential costs to the salmonid industry if whirling disease were to become established in Australia presented in the report by McKelvie (1991) are assumed to fall on just three fisheries. One of these supplies Atlantic salmon smolt (fish of or near

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[12] Varieties of salmonid species found in Australian waters include rainbow, brown and brook trout, and Atlantic and Chinook salmon, all of which are introduced species.

yearling age), the total production costs of which were purported to rise by almost $154,000 per annum. This includes purchase and installation costs for nine filtration units (equivalent to an annuity of $75,240 at a real interest rate of 6 per cent) as well as variable cost increases (estimated at around $78,650 per annum)[13]. The remaining two fisheries affected supply ocean trout fingerlings, for which alterations in husbandry techniques are similar to those necessary for salmon. Due to the smaller scale of these operations the likely costs of this alteration were estimated to be around $28,000 per annum of which $36,120 are variable cost increases. In addition to these costs, export losses of a minimum $2.4 million per annum were considered likely on the basis of losing a $2/kg premium enjoyed in the Japanese market for salmon products from disease-free destinations[14].

The simplistic approach of 'gross industry loss' calculation used in McKelvie (1991) does not do justice to the complexities inherent in forming a judgement about the overall risk of allowing imports of salmon meat. With no derivation or speculation of the probability of disease introduction as a result of infected imports it is not possible to form an estimate of expected damage. Moreover, despite the number of fisheries potentially affected by whirling disease being low relative to the number of consumers of salmon meat in Australia, McKelvie (1991) makes no mention of the potential consumption benefits of allowing imports of salmon products. This information is essential to fully appreciate the social welfare implications of allowing imports of salmon products.

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[13] Variable cost increases include electricity, repairs and maintenance.

[14] A maximum of $14.5 million export revenue was believed to be at risk, but the minimum estimate was used in calculations (McKelvie, 1991).

Canada has also sought access to the Australian salmon market since the imposition of quarantine restrictions on imported in 1975, claiming its products do not represent an excessive risk of disease transfer (AQIS, 1995). As explained in section 2.3.2, the situation came to a head when Canada sought GATT consultations with Australia in 1994. In preparing a response to this access request, AQIS once again enlisted the help of ABARE to complete an economic analysis of the threat posed by the diseases of salmon that may potentially be imported via salmon meat. Some twenty-four diseases were identified, but the economic component of Australia's response, presented in McKelvie *et al* (1994), deals with just two, Furunculosis and Infectious Haematopoietic Necrosis (IHN). Like McKelvie (1991) before it, this report simply puts forward a gross estimate of producer surplus loss in the event of an incursion of these diseases.

Furunculosis is a bacterial infection affecting salmonid (as well as other fish) that can colonise an organ causing lesions that render the fish unmarketable. It is common in Canada, North America, the British Isles, Europe and Japan, and is easily transmitted by contact with contaminated water, equipment and infected fish. Infected animals, which have a tendency to be up to two seasons old, experience a general deterioration in condition and loss of appetite, and eventual premature death. The causal bacteria, *Aeromonas salmonicida*, can be controlled through the use of water filtration and ultraviolet irradiation equipment and vaccines, options that involve considerable cost. IHN is a disease found in the wild in North America and Japan, and is now also found in Europe. It affects most salmonid species with the exception of

Atlantic salmon[15]. Symptoms include high mortality rates amongst young fish, swelling, discoloration and haemorrhages, affecting marketability. Although not always fatal, fish that survive the disease become vectors for its transmission for the rest of their lives. There are currently no vaccines or control techniques available for IHN other than culling infected brood stock. However, the detection of infected individuals is labour intensive and imprecise (McKelvie *et al*, 1994).

In calculating the expected costs resulting from disease introduction, treatment costs (including monitoring, ultraviolet irradiation, vaccination and antibiotic treatments) and yield losses are considered. Only those additional production costs associated with furunculosis are included in McKelvie *et al* (1994) (due a lack of accurate information concerning culling for IHN), and a cumulative yield loss of around 20 per cent per year from both diseases. Because of the range of treatment programs possibly employed, and uncertainty over their effectiveness, a broad range of expected costs is put forward in the report. Depending on the treatment program employed and the fish survival rate associated with it, total industry losses are estimated to be between $4.3 million and $80 million per annum. This is a good illustration of how the intricacies of modelling the response of an industry to disease introduction can lead to broad estimates of total costs even when the approach used is truncated.

As with McKelvie (1991), the issue of consumer gains from importation is not considered in McKelvie *et al* (1994). Likewise, a discussion of the probability of entry and establishment is not combined with the estimated economic consequences to produce an expected level of damage. If this were to have been provided it would add

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[15] Although the disease has been observed in Atlantic salmon, infection was only achieved when the disease is injected directly into the bloodstream. No natural transmission has been observed (Wolf, 1988; McKelvie *et al*, 1994).

significantly to the power of the study to influence decision-makers in that it would present a 'most likely' cost estimate in addition to the minimum and maximum cost estimates. Given the complexities and range of unknown parameters in models of pest impact, even the minimum and maximum cost figures presented contain subjective elements[16]. Therefore, in isolation, these estimates do not provide sufficient information to allocate quarantine resources to produce socially-optimal welfare outcomes[17].

2.4.4 Poultry Meat

In the early 1990s, the United states, Denmark, Thailand and New Zealand governments raised concerns over Australia's strict quarantine regulations relating to the importation of chicken meat. ABARE was again approached by AQIS to complete an economic analysis of pest importation risks presented by imports from these countries. Their findings are presented in Hafi *et al* (1994), which uses the example of Newcastle disease to illustrate the economic implications of relaxing quarantine protocols and allowing

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[16] McKelvie *et al* (1994) acknowledges this subjectivity and includes a sensitivity analysis on the rate of fish survival under each treatment technique, showing that the model results are highly sensitive changes in this value.

[17] It should be noted that the Federal Government of Australia did not appeal the WTO ruling against the banning of uncooked Canadian salmon entering Australia in 2000. This decision brought it into conflict with the Tasmanian State Government who felt such action could potentially leave it with a decimated salmonid industry in the long term. Interestingly, the state still possesses the power to impose quarantine restrictions of its own on products entering Tasmania, and so is still able to offer its domestic industry a certain degree of protection. However, this represents a breach of the Memorandum of Understanding signed on the 21st December 1995 (Commonwealth of Australia, 1995), and may cause WTO-legal retaliatory actions by Canada who has previously requested permission to do so. The issue has now stagnated.

conditional access to the Australian chicken meat market. Newcastle disease is brought on by a virus known as avian paramyxovirus, and affects domestic fowls, turkeys, pheasants, pigeons, quail, guinea fowl and many species of wild and captive birds. While some avirulent strains of the disease are naturally occurring in Australia they do not pose a problem, but other highly virulent strains found outside of Australia have the potential to cause significant commercial losses. Symptoms of the disease are highly varied, but generally include loss of appetite, a decline in egg production, diarrhoea and a severe cough, and are usually followed by head tremors and wing paralysis, and eventual death. The disease is easily spread through contact with diseased birds, carcasses and offal, and mortality rates can be between 10 and 100 percent in affected flocks in a very short space of time (24 to 72 hours) (Hafi *et al*, 1994). A vaccination is available for the disease, which would add to the variable cost of production, but eradication is the current policy stance under the Australian Veterinary Emergency Plan (AUSVETPLAN) (DPIE, 1990).

The method used by Hafi *et al* (1994) to determine the possible implications of imports is similar to Hinchy and Low (1990) in that the primary objective of the analysis is to establish a critical level of probability of disease entry and establishment. The benefits of importing chicken meat are calculated as the change in consumer surplus resulting from lower domestic prices for chicken products (since exporting nations are capable of producing products at a lower cost than domestic producers). Due to uncertainty surrounding the volume of imports arriving on Australian shores in the absence of quarantine restrictions, a range of possibilities (between 5,000 and 100,000 tonnes per year) is used. Assuming a supply elasticity of 2.0 (for both chicken meat and eggs) and price elasticity of demand of - 0.84, the benefits accruing to domestic consumers of chicken products is estimated to be between $7.7 million and $155.8 million. At the same time, the rigors of competition are estimated to cause a loss in producer surplus of between $7.6 million and $138.9 million. So, with no disease outbreak, the gains to consumers of allowing imports are calculated to exceed the consequent loss in domestic producer surplus at each level of importation.

It is this net economic gain that is used to calculate the critical level of entry probability by comparing it under each scenario to the expected level of damage produced by an incursion. The technique used to do so involves Markov chains, and is explained in more detail in section 7.4[18]. Using this method the initial probabilities of the *transition probability matrix* are vital to the calculation of the critical initial probability of disease entry and establishment. Sufficient information does not exist to calculate these values with any degree of certainty, and in acknowledgement of this Hafi *et al* (1994) provide a sensitivity analysis. In doing so, it is revealed that the critical initial probability calculated was sensitive to changes in the probabilities used, and that varying these probabilities by 25 per cent produced a directly proportional effect on the value calculated. Despite the analytical rigor of the study, this is a significant weakness of the approach employed for the data simply does not exist to achieve greater levels of accuracy in results.

This issue aside, in the event of an outbreak of Newcastle disease (as a result of imports), a specific turn of events is assumed to occur representing a worst case scenario. The disease is assumed to first affect the New South Wales poultry industry, beginning in Sydney and being spread to broiler farms in outer Sydney and the Hunter Valley area by prevailing winds. Having spread this far, it is assumed the outbreak will be contained, and eventually eradicated if the procedures outlined in the AUSVETPLAN are followed. In terms of economic consequences, such an outbreak is

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[18] See also Hinchy and Fisher (1991) for a comprehensive discussion.

assumed to reduce New South Wales chicken meat production by 50 per cent and egg production by 57 per cent on affected farms. In national terms, this equates to an 18 per cent production loss, a total loss of around $69 million ($15 million to the egg industry, and $54 million to the meat sector).

As with Hinchy and Low (1990), Hafi *et al* (1994) fails to indicate the social welfare implications of a free-trade scenario. Under the closed economy scenario, consumers pay higher prices for chicken products than they would in a quarantine-restricted or free-trade setting, which is to be contrasted against gains in producer surplus. Therefore, the analysis represents a cost-benefit analysis of moving from one trade setting to the next, ignoring the welfare implications of a free-trade policy. Another approach would have been to measure the net welfare loss associated with placing quarantine restrictions or banns on imported chicken products and raising prices above a free-trade level (i.e. the loss in consumer surplus minus the gain in producer surplus). For such policies to have no welfare effect the expected damage associated with the pests and disease they are designed to keep out must exactly offset these net welfare losses.

Future risk analyses may wish to adopt a broader approach drawing on the techniques presented in section 2.3. This necessitates the use of multidisciplinary assessment techniques to draw together the full range of scientific and economic factors involved in quarantine decisions. However, far from making the process more complicated, it is possible to construct a framework that directs attention to crucial areas. Although information constraints exist for domestic market analyses and the effects of varying levels of competition, the number of variables can be less than those required for expected pest damage assessments. By focusing on these, scientific information concerning the likely impact of specific pests can be placed into context.

2.5 Integrating Expected Damage and Trade Benefit Analysis

As alluded to a number of times in the discussion of the economic assessments above, the 'traditional' methodologies employed to examine the economic implications of SPS measures are, in a sense, incomplete since they place sole emphasis on producer welfare effects of pest entry and establishment. In fact, it could be argued that by emphasising the potential impact of the pest concerned rather than the damage that could be prevented through quarantine measures that the approach used was totally inadequate for social welfare optimisation. Quarantine policies affect the welfare of all members of society, and regulatory decisions made on the basis of impacts on a select group of society (i.e. agricultural producers) may therefore misrepresent social preferences.

A more appropriate approach to policy analysis can be demonstrated using the partial equilibrium model developed in section 2.4. It centres on the comparison of producer and consumer welfare under each scenario, and recognises that using a closed economy as a base case carries with it some cost to consumers. By placing a total ban on imports of a certain product, regulatory authorities provide domestic producers of that product with a monopolistic trade environment that maximises the prevailing market price[19]. If the same market were to suddenly move to a free trade situation the price would fall to the world price and produce large consumption benefits, but at the cost of domestic producer surplus. Therefore, by imposing quarantine restrictions on product entry such that prices are higher than the prevailing world price but lower than

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[19] In some settings trade restrictions will not create monopolistic trade environments, but rather restrict the degree of competition operating in an otherwise competitive market. To reiterate, this has not been recognised in the studies outlined in section 2.4, which only dealt with producer welfare effects of moving from a closed economy to a quarantine restricted trade scenario.

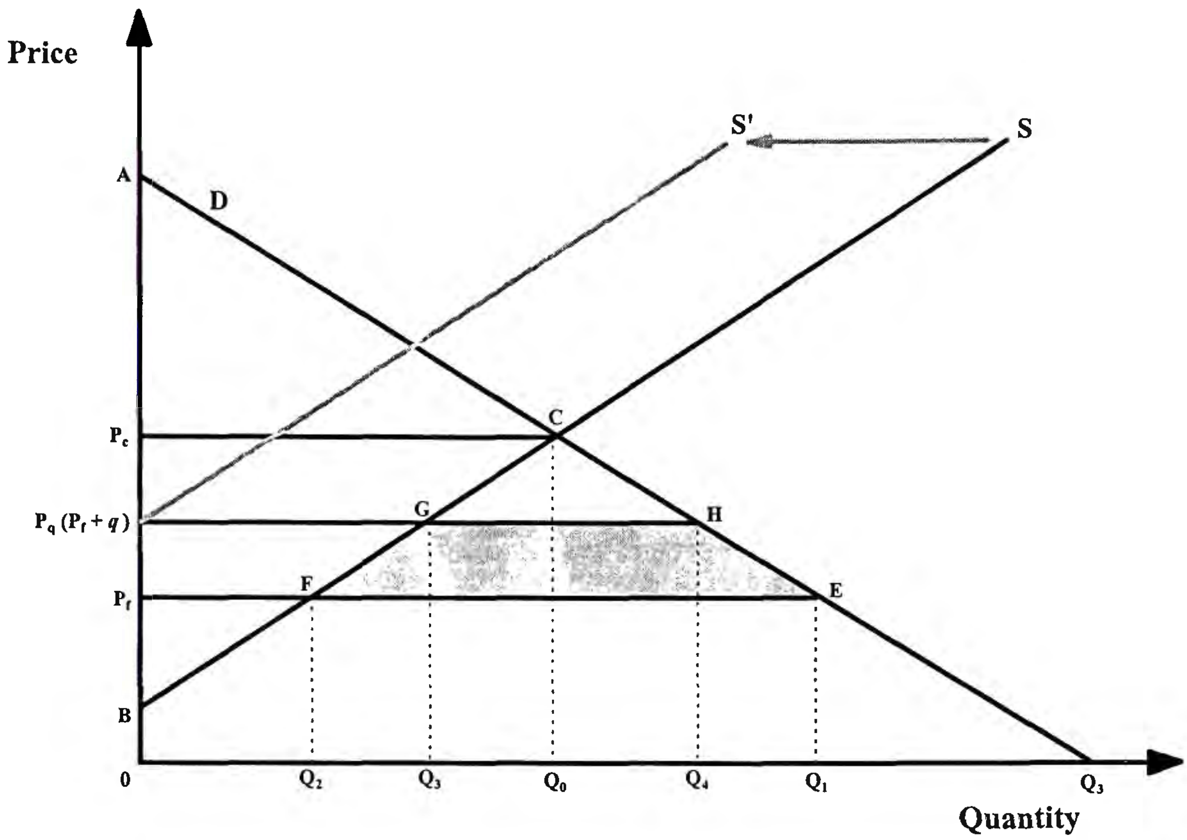

Figure 2.2: Net Social Welfare Loss Resulting from SPS Measures

under a closed economy, producer surplus is above a free trade level (and below a closed economy level) while consumer surplus is below a free trade level (and above a closed economy level).

This situation is illustrated in Figure 2.2. Assume the market it depicts exhibits the same characteristics as mentioned in relation to figure 2.1, and initially has a ban in place on imported product before moving to a free trade situation[20]. If P_c represents the closed economy, domestic equilibrium price and P_f the free trade price, consumer surplus increases by the area P_cCEP_f (i.e. from ACP_c to AEP_f) when trade is unimpeded, while producer surplus decreases by the area P_cCFP_f (i.e. from BCP_c to BFP_f). Hence, the *net gains to trade* are represented by the triangle CEF. However, with absolutely no screening mechanisms to guard against a likely pest incursion, the probability of importing a pest species endemic in other growing centres through the exchange of host material is effectively maximised. So, it may be optimal for regulatory authorities to impose entry requirements on susceptible trade goods to reduce this probability, costing a certain amount *q*. This will push the price above the free trade level to P_q. At this higher price, consumer surplus will contract (relative to the free trade situation) by the area P_qHEP_f (i.e. from AEP_f to AHP_q), and producer surplus will expand by P_fFGP_q (i.e. from BFP_f to BGP_q). There are still gains to trade since P_q lies below P_c, which are represented by the triangle CHG. However, since they are smaller than under a free trade regime, a net social welfare loss results from inflating prices above the free trade level, as represented by the area EFGH.

Under each scenario, the probability of importing a pest from other growing regions changes. The expected damage inflicted by exotic pest incursions depends on the presence or absence of measures to prevent their movement across State borders via host material. From an analytical perspective, it is these expected damages prevented by quarantine measures that must be weighed against the net welfare loss of artificially inflating prices. For instance, assume the consequences of pest entry to the market in

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[20] To repeat the assumptions of section 2.3, assume: 1) a homogenous product; 2) perfect competition in the domestic market for that product; 3) the domestic price for the product is higher than the 'landed' price of overseas product; 4) the domestic industry is a 'price-taker'; 5) society has a neutral attitude to risk; 6) pests are host specific; and 7) the costs of quarantine treatments are borne by the exporters (James and Anderson, 1998).

question would be particularly catastrophic in that the entire domestic industry would be laid waste and all domestic producer surplus lost. If this were the case, an incursion would have the disastrous effect of moving the supply curve inwards from S to S′, thus dissolving all domestic producer surplus represented by the area BGP_q. So, efforts to determine the full extent of benefits and costs of quarantine must compare net welfare losses of quarantine (EFGH) to the change in the probability of importing a pest and incurring a loss equivalent to BGP_q in Figure 2.2. While this portrays an extreme example, it serves to illustrate the workings of an appropriate benefit cost analysis using the partial equilibrium framework. In reality the consequences of pest outbreaks may not be so severe as to annihilate an entire production system, but a proportion of it may be lost before it is brought under control or measures to counter its effects become part of standard management practice.

A fine example of how this methodology can be used to examine SPS measures is presented in James and Anderson (1998). This examines the economic justification underpinning Australia's ban on international banana imports. By measuring the consumer surplus loss resulting from the trade ban and speculating as to the expected loss of producer welfare, James and Anderson (1998) clearly demonstrate that the production gains from the trade ban are more than likely outweighed by the cost to consumers. Therefore, the policy of an import ban can be questioned on grounds of social welfare. The model used in this investigation forms the basis of the model presented in the next chapter.

2.7 Conclusions

There can be little doubt that the composition of Australia's quarantine system is set to change following the formation of the WTO. A purely precautionary approach to quarantine policy is no longer appropriate, and trade restrictions must be justified by a clear and transparent assessment of the risks posed by probably pest importations. However, such assessments completed in the past have tended to concentrate on WTO-compatibility rather than social welfare maximization. As this chapter has explained, the issue of consumer effects brought about by quarantine policies have been largely ignored. Typically, analytical models have been designed with the goal of measuring potential pest impacts on domestic industries. But, while such an approach provides important information about the benefits of quarantine policies, it does not fully explore the costs. This has major implications in terms of the ability of policy-makers to deliver regulatory actions that reflect social preferences.

This chapter arrived at an appropriate model for examining the impact of quarantine and trade on markets, the James and Anderson (1998) model. Before suggesting some extensions to this model to make it more suitable to certain industry structures, it is to be applied to two interstate quarantine issues in the following chapter. Here, it is referred to as the *aggregate* trade model due to its use of aggregate industry information to estimate social welfare. Unlike quarantine analyses of the past, the emphasis in chapter three is not on performing an expected damage estimate by hypothesizing as to likely damage scenarios if quarantine pests enter WA. To do so would be to duplicate techniques already applied in quarantine circles to assess pest threats. Rather, by focusing on lost consumer surplus resulting from quarantine restrictions on trade, a critical level of expected damage can be identified which is sufficient to offset these costs.

3. The 'Aggregate' Trade Model†

3.1 Introduction

One means of examining protection policies affecting imported horticultural commodities in WA involves the use of industry aggregation. By using industry-wide data, and making a series of assumptions about its components, it is possible to form an estimate using a minimum of information. Such a characteristic necessarily makes such a model preferable to other more data intensive techniques since the issue of data gathering can often be the most limiting factor in applied research. However, there exists a trade-off between model accuracy and the level of information used to make social welfare assessments, the extent of which is largely dictated by the composition of the industry under investigation. This chapter defines and applies the aggregate trade model to the domestic markets for mangoes and tomatoes, both of which are protected by quarantine regulations restricting interstate competition. The objective of this exercise is to estimate a critical level of expected pest damage necessarily abated if quarantine policies are to cause equal costs and benefits.

Using time series price and quantity data from the Perth wholesale fruit and vegetable market, *inter* and *intra*-state production costs, estimates of demand and supply elasticities and marketing margins, the aggregate model measures the net welfare effects of interstate quarantine protocols from an industry perspective[21]. It does so by

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† A version of this chapter has been published in the *Australiasian Agribusiness Review* (Cook, 2001a).

[21] *Aggregate* as distinct from the regionally disaggregated analysis reported in chapter 4.

calculating producer and consumer surplus under a closed economy, a free trade, and a quarantine-restricted trade scenario. By comparing these, the model estimates the change in net economic welfare induced by quarantine protocols for respective agricultural commodities. This can then be used to form an estimate of the expected damage prevented by quarantine procedures restricting the entry of destructive pests to WA required for the policy to have no net welfare effect. This is termed the critical level of expected damage.

The aggregate model utilised in this chapter is based heavily on the model presented in James and Anderson (1998) that is used to assess national economic welfare implications of restricting banana imports to Australia. Section 3.2 examines the model in full, and details the assumptions to be used to simplify empirical analyses of quarantine restrictions on the mango and tomato case studies presented in sections 3.3 and 3.4 respectively. In sections 3.5 and 3.6 the results of applying the aggregate model to these two industries are presented, and a comprehensive sensitivity analysis appears in section 3.7 to identify those variables with the greatest impact on the results. Having applied the model to two very different horticultural commodities, it is possible in section 3.8 to explore the implications of industry characteristics, specifically size, for the critical level of expected damage. Thereafter, the chapter draws some conclusions in section 3.9.

3.2 Static Analytical Framework

3.2.1 Simplifying Assumptions

To maintain a level of simplicity conducive to the effective communication of results to multidisciplinary decision-making bodies, it is useful to employ several assumptions concerning the nature of fruit and vegetable markets in WA. These were described fully in sections 2.3 and 2.4, and repeated below for clarity. Assume:

(1) The domestic markets for fruit and vegetable products (at least those modelled) are perfectly competitive. Growers within a production region have access to the same technologies and production information, and are equally proficient in production[22];

(2) WA is a "price-taker" in that the size of its fruit and vegetable industries are insufficient for domestic market variability to directly influence national (or international) market prices;

(3) Modelled products are homogenous, there being no distinction made between individual varieties of the same product type;

(4) Consumers and producers exhibit a neutral attitude to risk;

(5) Potentially imported agricultural pests attack one host exclusively, with no polyphagous tendencies that might affect other industries;

(6) Under quarantine-restricted trade, the onus is on importing centres to abide by certified protocols, bearing any necessary costs in order to do so

(James and Anderson, 1998).

These assumptions describe a relatively simple trade model. While more complex methodologies can be used to examine the impact of pests, using techniques such as Markov chains (discussed in section 7.4) to model the dynamics of pest spread and impact, constraints on input data and extension limit the effectiveness of these in

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[22] The implications of this assumption are explored at a regional level in Chapter 4.

practice. Here, emphasis is placed on (potentially) pest-affected markets, rather than the nature and dynamics of pest impact.

3.2.2 The Aggregate Trade Model

The following discussion develops the aggregate model using the hypothetical example of the domestic market for a commodity *x*, as depicted in Figure 3.1. Consider firstly a closed WA economy where no trade in *x* takes place with the eastern states of Australia. Ignoring the D_R, D_W and S^* curves initially, assume local suppliers face a downward sloping demand curve (D_F) for their product in the domestic market, and an upward sloping supply curve (S). The intersection of these two curves (at E_c) determines the domestic, or closed economy producer price (P_c) and quantity supplied at this price (Q_c), and is termed the *closed economy equilibrium*.

Before moving on, it is necessary to incorporate marketing margins into the model to properly examine the social welfare implications of interstate quarantine restrictions. Most WA fruit and vegetable growers sell their wares on the Perth market through a market agent, who in turn sells them to retail outlets, from which they are purchased by consumers[23]. The size of the marketing margins applied at each stage and the manner in which they are applied is difficult to verify. Sources close to the market indicate wholesale margins to be in the order of 10-15 per cent (Mercer Mooney; Quality Produce International; Central Fruit Sales; Etherington & Sons, pers comm, 23/11/1999), and retail margins around 33 per cent (Woolworths – Fresh Produce, pers comm, 22/11/1999; Quality Produce International, pers comm, 23/11/1999). Further

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[23] There are around 23 Perth market agents in WA (PMA, pers comm, 23/11/1999).

details of the idiosyncratic nature of fruit marketing are difficult to extract, and hence marketing margins are assumed constant in percentage terms. Consequently, the model infers that (generally) the price paid for x 'at the farm gate' is around 12.5 per cent below the wholesale price of fruit and vegetables, which is in turn is approximately 33 per cent below the retail price.

Figure 3.1 shows the demand curves for x at the wholesale and retail level as D_W and D_R respectively. For the most part the D_W curve can be ignored since demand at the retail level is of primary concern. Looking once more at the closed economy equilibrium, when the producer price is P_c and the quantity supplied is Q_c, the corresponding retail price is P^R_c. Therefore, although producer surplus remains constant,

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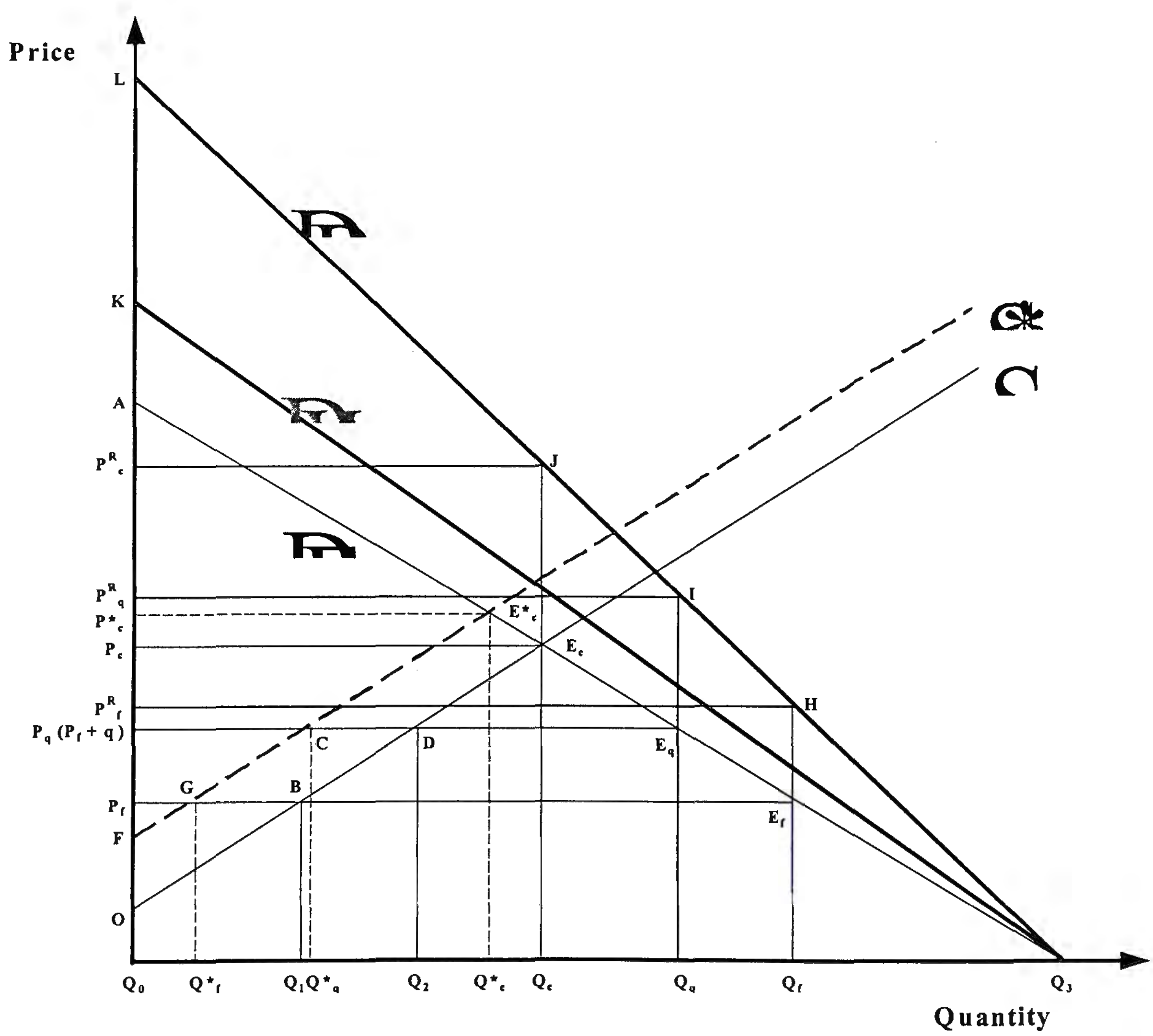

Figure 3.1: Interstate Import Clearance & Social Welfare Loss

consumer surplus with marketing margins in place becomes P^R_cJL. If the market is now opened up for unrestricted trade with other states, WA suppliers will be thrown into direct competition with imported product. Instead of dictating terms in the market, WA producers will become price-takers assuming the prevailing State producer price (P_c) exceeds the national producer price (P_f) of *x*. At P_f domestic suppliers are willing to supply Q_1, while demand is Q_f.

Hence, imported *x* makes up Q_f-Q_1. As it has been drawn in the diagram, consumer surplus increases by the area $P^R_cJHP^R_f$ (i.e. from P^R_cJL to P^R_fHL) as the economy is opened up to free trade and producer surplus decreases by the area $P_fBE_cP_c$ (i.e. from OE_cP_c to OBP_f). With this information it is possible to calculate the net gains to trade by subtracting the loss in producer's surplus from the gain in consumer surplus. In the case of the economy moving from a state of autarchy to one of free-trade net gains can be calculated as $P^R_cJHP^R_f - P_fBE_cP_c$.

With no restrictions on trade in place the probability of exotic pest incursions is maximised, there being Q_f-Q_1 imports entering the State free of screening mechanisms. Suppose now that a quarantine restriction is introduced on imported *x* in an effort to decrease the likelihood of pest entry. The cost to interstate producers of complying with the specified protocols, *q*, is passed on the consumers as higher prices. Hence, with the quarantine restriction in place the market faces the producer price P_q and retail price P^R_q. At this price, consumers remain better off than under the closed economy scenario, but worse off than under a free trade regime. Their consumer surplus is now P^R_qIL, an increase of $P^R_cJIP^R_q$ relative to autarchy. The opposite is true of producers, being worse off than under autarchy and better off than under free trade. The producer surplus is now ODP_q, a decrease of $P_qDE_cP_c$ relative to the no trade situation. Therefore, the net gains of quarantine-restricted trade as opposed to a closed economy can be calculated as $P^R_cJIP^R_q$ - $P_qDE_cP_c$.

Using this framework, the impact of quarantine restrictions on consumer and producer surplus can be clearly seen. Consider what happens when there is an incursion of an exotic pest that is highly host-specific. Once it has entered and been detected, certain measures will be taken to manage the spread of the pest according to its biological characteristics, the existence of nationally co-ordinated management strategies, the size and structure of the affected market, and so forth. For now, assume the impact of these management strategies is to raise the domestic cost of *x* production. In the absence of any demand shocks domestic supply will contract from S to S^* while the volume of *x* imported increases[24]. Under the quarantine-restricted price P_q domestic supply will be Q^*_q, and imports Q_q-Q^*_q. Domestic consumer surplus will remain constant at $P^R_q IL$, and producer surplus will contract to FCP_q. Therefore, the net loss to the WA economy of importing the pest becomes the area ODCF.

An estimate of the potential economic benefits and costs of adopting any one strategy (either a free trade policy or quarantine-restricted trade) can now be calculated by comparing the net gains from trade with the potential loss of domestic producer surplus should a pest enter. For instance, the potential net benefits to a free trade policy (PB_{ft}) relative to a closed economy situation are given by:

$$PB_{ft} = (P^R_c JHP^R_f - P_f BE_c P_c) - (p \times OBGF) \qquad (3.1)$$

where;

p = probability of pest entry under free trade

$P^R_c JHP^R_f$ - $P_f BE_c P_c$ = net gains from trade under a free trade regime

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[24] It is conceivable that consumers will switch to rival goods if the pest has a negative impact on product 'image'. However, the model ignores this possibility, recalling assumption (3) above. The implications of this are discussed in section 7.4.

OBGF = potential loss of producer surplus under free trade

With unrestricted trade, p is expected to be relatively high when compared to a restricted environment assuming quarantine only affects the probability of a pest outbreak, and has no impact on the severity. The potential net benefits to a quarantine-restricted trade policy (PB_{qt}) with respect to a closed economy situation is calculated as:

$$PB_{qt} = (P^R_cJIP^R_q - P_qDE_cP_c) - (p^* \times ODCF) \quad (3.2)$$

where;

p^* = probability of pest entry under quarantine-restricted trade (i.e. $p^* < p$)

$P^R_cJIP^R_q - P_qDE_cP_c$ = net gains from trade under a quarantine policy

ODCF = potential loss of producer surplus brought about by a pest incursion

If expected losses under a free trade regime are sufficiently low when compared to those expected under a quarantine policy, then it is very difficult to justify this protection. On the other hand, if the pests which could potentially enter WA through imported x are capable of inflicting severe damage, it may be that free trade is not worth the risk. By simply subtracting (3.2) from (3.1), an expression is derived indicating the potential benefit of quarantine policies relative to free trade ($PB_{qt/ft}$):

$$PB_{qt/ft} = [(P^R_cJIP^R_q - P_qDE_cP_c) - (p^* \times ODCF)] - [(P^R_cJHP^R_f - P_fBE_cP_c) - (p \times OBGF)] \quad (3.3)$$

Estimating ($p^* \times$ ODCF) and ($p \times$ OBGF), the expected losses to producer surplus from pest incursions under quarantine and free trade respectively, involves a high degree of subjectivity. An alternative is to calculate ($P^R_cJIP^R_q$ - $P_qDE_cP_c$) - ($P^R_cJHP^R_f$ – $P_fBE_cP_c$), the total net welfare loss to society resulting from choosing quarantine restrictions over free trade, and assume the policy will break even (i.e. total net gain = total notional producer surplus loss):

$$(P^R_c JIP^R_q - P_q DE_c P_c) - (P^R_c JHP^R_f - P_f BE_c P_c) = (p^* \times ODCF) - (p \times OBGF) \qquad (3.4)$$

or

$$(P_f BDP_q - P^R_q IHP^R_f) = (p^* \times ODCF) - (p \times OBGF) \qquad (3.5)$$

In doing so, it is possible to estimate the minimum value of the right hand side of (3.4) necessary for the quarantine policy to have equal welfare benefits and costs. Comparing the figure on the right to an estimate of total producer surplus in WA post-quarantine restriction allows the expected damage to the domestic *x* industry which is avoided by trade restrictions to be placed in perspective[25].

Having developed the aggregate model and demonstrated how it can be used to determine the effects of quarantine policies within a market, it can now be applied to real situations. Two case studies have been chosen for this purpose, both of which involve horticultural commodities protected by interstate quarantine measures, mangoes and tomatoes. Before performing an economic analysis of these policies, an outline of each case study is to be provided.

3.3 Case Study 1 – Mangoes

3.3.1 World Production

The mango (*Mangifera indica*) has been described as the "most extensively grown of all fruits" (Alexander, 1987). It is believed to have evolved in the tropical rain forests of south and south east Asia (Kaur *et al.*, 1980), and is now grown in every country

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[25] Alternatively stated, equation (3.4) essentially means $PB_{qt/ft} = 0$.

throughout the tropical areas of the world in both hemispheres. Mango plants can live over 100 years, and can stand over 30 meters high at maturity. There are now thousands of known mango varieties available throughout the world, of which 277 are listed in the 1999 Commonwealth Plant Quarantine active list. The names of some of these apply to the same variety, so the real number of species is likely to somewhat less.

Commercial Mango growing enterprises predominate in tropical lowland areas roughly 23° 26′ north and south of the equator. Approximately 60 per cent of the world's mango supply comes from India, which has a 6,000 year history of growing the fruit (Alexander, 1987). There it remains an important cultural and religious symbol. Other major growing areas are found on the Indian subcontinent, south east Asia, and central and South America. With advances in cultivation techniques, a limited amount of production also takes place in subtropical areas such as in Israel and Spain. In 1993, world mango production was estimated to be in excess of 17.7 million tonnes (Litz, 1997). This represented an increase of some 30 per cent since the early 1980's (Alexander, 1987). However, despite this increase and the huge global production, mangoes remain insignificant in world trade when compared with other fruit varieties such as bananas, apples, and citrus fruit.

3.3.2 Australian Production

In Australia, mangoes are grown throughout the northern tropical and subtropical regions where they are picked from late September to early April (Liz, 1997; White, 1997). National production accounts for around 2 per cent of the recorded world output of mangoes, producing just over 27,000 tonnes in 1995/96 (ABS, 1998). With a history of broad acre agriculture, it is not surprising that the national mango industry has never been prominent, but it continues to grow in size and stature. In the early 1970's, production (of 1-2,000 tonnes at that stage) was marketed mainly from Sydney and Brisbane, but by the mid-1980's mangoes were available from all major Australian markets (Alexander, 1987). The major producing states are Queensland, New South Wales and Western Australia.

3.3.3 Western Australia's Production

Whilst its history has been characterised by continual growth, the WA mango industry remains small by world standards. In 1995/96 it accounted for around 5 per cent of national output, producing a total of 1,258 tonnes (ABS, 1998). This made it the third largest producer behind Queensland (85 per cent) and the Northern Territory (NT) (9 per cent) (White, 1997). Production is centred on two main regions, Carnarvon (890 tonnes, 1995/96) and Kununurra (550 tonnes). The former's production peaks from late December to February, while the latter is one of the earliest producers in Australia, peaking during October and November. Other growing centres include Broome (52.4 tonnes), Gingin (22 tonnes) and Derby (2.2 tonnes) (ABS, 1998). This dispersion of producers across the State causes a lengthy picking time, and a continuous supply to the Perth Market from October through to April (White, 1997).

Generally, WA is free from serious mango pests and diseases, although isolated occurrences of Bacterial Black Spot (*Xanthomonas campestris* pv. *Mangiferaeindicae*) and Anthracnose (*Colletotrichum gloeosporioides* Penz. Var. *minor*) are detected from time to time, as are several common fungal diseases. The only insect pest of significance to mangoes which is endemic in the State is Mediterranean Fruit Fly (*Ceratitis capitara*), and a pilot eradication programme is currently underway in the

Broome region to provide information for future feasibility studies of more extensive campaigns.

3.3.4 Import Protocols for Mangoes

Although mango trees are relatively hardy, there are several pests that pose a significant threat to their health and productivity. Because of WA's freedom from many major pests, quarantine plays a vital role for the domestic industry (Strickland, 1992). Pests exotic to WA but endemic in other states and territories of Australia include invertebrates such as Queensland Fruit Fly (*Bactrocera tryoni*), Mango Seed Weevil (*Sternochaetus mangiferae*), Mango Pulp Weevil (*Sternochaetus frigidus*), Northern Teritory Fruit Fly (*Bactrocera aquilonis*), European Red Mite (*Panonynchus ulmi*), Melon Thrips (*Thrips palmi*), Spiraling Whitefly (*Aleurodicus dispersus*), Mango Leaf Hopper (*Idioscopes niveosparsus* and *Idioscopes clypealis*), and diseases such as Mango Scab (*Elsinoe mangiferae*). These pests have the potential to severely hamper mango production in WA if outbreaks (if and when they occur) are not detected and treated early, and/or to add significantly to the marginal costs of production if they were to become endemic in WA.

Up to the early 1990s, importation from the largest eastern states rivals were prohibited (Hawkins, 1994). The presence of exotic pests like Mango Seed Weevil (MSW) and Northern Territory Fruit Fly in the Northern Territory, and Queensland Fruit Fly (Q-fly) in Queensland meant that the risk of importing such pests was deemed too high. However, in 1994 a new set of protocols was introduced to permit imports from the former under certain circumstances. The quarantine requirements for imported product currently in place are strict, with specific preventative measures undertaken to reduce the risk of entry of all the pests mentioned above. Queensland imports remain prohibited. All costs are born by the interstate growers seeking to export mangoes into WA, the most significant of which are made up of post harvest sprays for fruit fly, and sampling costs for MSW.

Protocols to prevent the introduction of fruit flies to the State are very specific. In the case of Q-fly, they require product from all statess and Territories to be certified as having been immersed in a dip containing 400mg/L of dimethoate or fenthion for 1 minute; or having been flooded as part of a single layer of produce with 400mg/L of dimethoate or fenthion at ambient temperature in a high volume application of at least 16L/m^2 per minute for at least 10 seconds and as having remained wet for at least 1 minute before drying; or having been fumigated with methyl bromide at rates between 24 g/m^3 (at 26° - 31.9°C) and 48 g/m^3 (at 10° - 14.9°C) for 2 hours. at one of the following rates (WAQIS, 1999). Dipping or flood spraying must be the last treatment before packing (Scott, 1998).

Detection of MSW requires the fruit to be dissected and inspected for evidence of larvae in the seed, as the name would suggest, rendering it unfit for sale. A property wishing to export to WA must undergo sampling for two years prior to the first consignment being permitted across the border to demonstrate *property freedom*. This involves up to 4,000 fruit being inspected at the commencement of each season. If approval is given by the Western Australian Quarantine and Inspection Service (WAQIS) and export takes place, a market sample of 600 fruit will be taken either prior to or immediately upon arrival. Maintenance of property freedom is accepted on the basis of there being no MSW infestation within 50km of the property, and no detection in annual fruit sampling or consignment sampling (WAQIS, 1999; Manbulloo Mangoes Australia, pers comm, 26/8/99).

3.4 Case Study 2 - Tomatoes

3.4.1 Australian Production

The fresh tomato (*Llycopersicon esculentum*) is thought to have originated in Mexico or Peru and was taken to Europe where it is now grown extensively. Generally, tomatoes are not traded on the world market, and it is therefore very difficult to determine quantities produced world-wide.

In Australia, fresh tomatoes are available on all markets every day of the year, but are produced in a variety of conditions depending on climate, soil type and preferred variety. Queensland is the largest growing centre in Australia, producing approximately 115,000 tonnes in 1993/94. Victoria is the next largest, producing just over 15,000 tonnes, followed by WA with 8,000 tonnes, South Australia with 6,700 tonnes and New South Wales with 5,100 tonnes (Maltby, 1995). The majority of these are sold through the central wholesale markets of each capital city, although direct selling between growers and retailers is increasing in popularity.

3.4.2 Western Australia's Production

Tomatoes are one of the most important and valuable horticultural crops grown in WA (Burt, 1997). A total of around 220 hectares is devoted to growing tomatoes state-wide, and due the diversity and geographical spread of primary growing areas a year-round supply to the Perth market can be maintained. The Perth area contains approximately half of the total plantings, which take place between August right through until early February. These are mainly concentrated in the Wanneroo and Serpentine-Jarrahdale Local Government Areas (LGA), which produced 1,280 tonnes and 540 tonnes respectively in 1995/96. Numerous LGAs in the South West region of the State, including Donnybrook-Balingup and Harvey, collectively produced over 1,660 tonnes in the same year. Here, planting generally takes place between September through to early December. The remainder is made up mainly by Geraldton (150 tonnes), where planting takes place from February to June/July, and Carnarvon (4,770 tonnes) planted between late February and mid-September (ABS, 1998). Between September and December tomatoes are also grown in the hills districts near Perth, and in the southern agricultural areas (Graham, 1994; Burt, 1997).

3.4.3 Import Protocols for Tomatoes

Several pests and diseases present in the tomato growing regions of other states are not present in WA, and so measures are taken to minimise the risk of these being introduced with consigned fruit. The four pests of primary concern for tomatoes are Q-fly, European Red Mite (ERM), Melon Thrips and Spiralling Whitefly, although several other species of quarantine significance are mentioned below.

Protocols to prevent the introduction of fruit flies to the State are the same as those outlined in section 3.3. A closely related species to Q-fly is *Bactrocera neohumeralis*, which is also exotic to WA and a quarantine concern. The two are so similar that they have been shown to mate and produce fertile offspring under laboratory conditions, although in the wild they are prevented from doing so due to different mating times (Gibbs, 1967). Also of quarantine significance is Cucumber Fly (*Bactrocera cucumis*), which is essentially a tropical species restricted mainly to a relatively narrow fringe on the east coast of Queensland and the northern extremes of the Northern Territory (HPC, 1991). To prevent the entry of these species (collectively) from Queensland, New South Wales and the Australian Capital Territory, imported tomatoes must be certified as having come from properties demonstrating area freedom.

This status can only be reached the property concerned and the area within a 50km radius it have been free from *B. neohumeralis* and Cucumber Fly for the twelve months preceding export to WA (WAQIS, 1999).

To guard against the introduction of ERM from Victoria, Tasmania, Queensland, South Australia, the Australian Capital Territory and New South Wales tomatoes must originate from an approved property or certified as examined and found to be free of European Red Mite, and grown and packed at least 50km from a known outbreak of European Red Mite. Alternatively, they must be fumigated with methyl bromide at rates between 56 g/m^3 (at 5.0° - 10.0°C) and 16 g/m^3 (at 31°C and above) for 2 hours. These conditions do not apply to produce from the Northern Territory where ERM is exotic (WAQIS, 1999).

Measures to reduce the likelihood of importing Melon Thrips with interstate tomato imports are very similar. This pest can be found in Queensland, the extreme north east of New South Wales and the Northern Territory. For these states, produce from any area within 100km of an outbreak of Melon Thrips is prohibited unless it undergoes the same methyl bromide fumigation process required for ERM.

Spiraling Whitefy, exists only in limited abundance. It only affects tomatoes in Queensland, and outbreaks have been discovered in the extreme north of the State, around the Cairnes area, and most recently in the Townsville area (WAQIS, 1999). Produce from these regions moving into WA is prohibited.

3.5 The Aggregate Model Applied to Mangoes

3.5.1 Data Specification

The data used to form parameter estimates for the model are detailed below. Each parameter is listed with a reference to the relevant point in figure 3.1.

Elasticity of Supply - White (1997) offers an estimate of **0.80** for the own-price elasticity of supply for mangoes in WA.

Elasticity of Demand – an estimate of **–2.30** was derived using the methodology to that described in Kane (1989) using WA data[26].

Post-Quarantine Quantity Supplied (Q_a) - using ABS time series data supplemented by White (1997), an estimated proportion of total supply was formed based on a three year average from 1993/94 to 1996/97. Prior to 1994, interstate importation of mangoes was prohibited due to the risks associated with exotic pests like MSW, Northern Territory Fruit Fly and Queensland Fruit Fly (Hawkins, 1994). However, in 1994 a set of protocols was introduced to permit imports from the Northern Territory under strict conditions while Queensland imports remain prohibited. So, using post-1994 supply data the *most likely* quantity of mangoes supplied by

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[26] Kane (1989) estimates two separate elasticities of demand for mangoes due to the seasonal nature of demand, - 1.86 and - 4.21. Details of the brief econometrics exercise performed using the same methodology to derive an estimate specific to WA has been omitted here, and a sensitivity analysis performed in section 3.6 to test the sensitivity of results to this value, and hence the significance of any error.

domestic producers with interstate quarantine restrictions in place was assumed to be in the order of **1,410 tonnes** (ABS, 1998; White, 1997)[27].

Post-quarantine Price (P_q) - calculated (in real terms) as a five-year average from the period following 1994 when imports from the eastern states were no longer prohibited using PMA and FAO data. On this basis the most likely value for P_q is **$1,800/tonne** (PMA, 2000b; FAO, 2000)[28].

Closed Economy Price (P_c) - taken as a five-year average from the period following 1994 using PMA and FAO data. This gives the most likely real value for P_c as **$1,950/tonne** (PMA, 2000b; FAO, 2000; ABS, 2000).

Free Trade, or National Price (P_f) - indicates the marginal cost of mango production for eastern states growers. If there were no restrictions to trade, these producers would be inclined to take advantage of the WA market and increase supply to the point where all profits are diminished, and price equals Average Total Cost (ATC) in the long run. White (1997) presents estimates of marginal cost of production and transport to local markets for producers in Carnarvon, Kununurra, Katherine in the Northern Territory, and Mareeba in Queensland. By substituting transport costs to Perth for local transport costs (i.e. Brisbane-Perth = $410/tonne; Sydney-Perth =

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[27] Note that the term "most likely" is used on numerous occasions throughout the analyses presented in chapters 3 and 4 to describe *point estimates* of parameters, as distinct from values drawn from distributions.

[28] This represents the mean of the combined FAO and PMA data sets discounted using Central Price Index (CPI) data (ABS, 2000).

$380/tonne (Harris Transport, pers. comm., 4/10/99)) for eastern states producers, the lowest marginal cost was found to be in Queensland at around **$1,750/tonne**[29].

Wholesale and Retail Marketing Margins - sources close to the market indicate wholesale margins to be around **10-15 per cent** (Mercer Mooney; Quality Produce International; Central Fruit Sales; Etherington & Sons, pers comm, 23/11/99), and retail margins around **33 per cent** (Woolworths – Fresh Produce, pers comm, 22/11/99; Quality Produce International, pers comm, 23/11/99). These are assumed constant in percentage terms.

3.5.2 Results of an Aggregated Modelling Exercise

The information outlined above was used to calculate the net gains from trade in both a free trade and post quarantine setting, in line with the methodology outlined in section 3.2. To clarify, the objective of the model is to estimate the expected value of producer surplus loss avoided by quarantine measures for mangoes required to exactly offset the net welfare loss to consumers caused by inflating prices above a free trade level.

Table 3.1 reports the results derived from the model based on the prices, quantities and elasticities outlined in section 3.5.1 with references to Figure 3.1 in brackets. These results indicate that the potential loss to producer surplus avoided by maintaining quarantine protocols must be at least $55,720 for the quarantine restrictions

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[29] Under a free trade scenario those States capable of supplying mangoes to the WA market at lower costs than WA growers would commence exporting. Hence, the short-term price could be estimated by taking the mean of the marginal costs of production in these regions plus a profit margin. However, since the

to the industry to have no net welfare effect. With the demand and supply curve specifications used in this exercise, domestic producer surplus in a quarantine-restricted trade situation (i.e. post-1994) is estimated at around $588,950. Therefore, in order for interstate quarantine policies for mangoes to have a zero net economic impact, the expected value of producer surplus saved by excluding mango pests must constitute around 9.5 per cent of the current total value of the industry. In other words, the critical level of expected damage required to bring the benefits and costs of quarantine restrictions into balance is around $55,720.

Table 3.1: The Welfare Effects of Interstate Quarantine Protocols for Mangoes

	Free Trade	Post Quarantine
Change in Producer Surplus	-\$304,870	-\$225,125
	($P_fBE_cP_c$)	(P_fBDP_q)
Change in Consumer Surplus	\$492,900	\$357,435
	($P^R_cJHP^R_f$)	($P^R_cJIP^R_q$)
Net Gains to Trade	\$188,030	\$132,310
	($P^R_cJHP^R_f$ - $P_fBE_cP_c$)	($P^R_cJIP^R_q$ - $P_qDE_cP_c$)
Total Net Welfare Loss	\$55,720	
	(P_fBDP_q - $P^R_qIHP^R_f$)	

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assumption of perfect competition was made in section 3.2.1, the long run price must be taken as the minimal marginal cost of the supplying States since eventually all profits are diminished.

3.6 The Aggregate Model Applied to Tomatoes

3.6.1 Data Specification

Elasticity of Supply - comparative static estimates are not available, but examples of dynamic estimation techniques being used to estimate tomato supply functions can be used as an approximation. In a study of the winter tomato supply in Florida, Shonkwiler and Emerson (1982) imply an own price elasticity of 0.92 using a *rational expectations hypothesis*, and 0.46 using a *cobweb* model. These can be used as rough upper and lower bounds. In contrast to Florida, much of the land used to grow tomatoes in WA is privately owned, and so growers would be expected to be more interested in alternative enterprises than perhaps the opportunity cost of purchased inputs. Hence, in the case of WA tomato supply, an elasticity of supply closer to the upper bound, say **0.80**, is assumed most likely.

Elasticity of Demand – an estimate of **–1.00** was derived using the methodology described in Kane (1989) using WA data.

Post-Quarantine Quantity Supplied (Q_q) - a five-year average up to 1996/97 was calculated using data from the ABS (1998), and supplemented from PMA (2000a). The annual quantity of tomatoes supplied by the domestic market with interstate quarantine restrictions in place is assumed to be approximately **21,370 tonnes**.

Post-quarantine Price (P_q) - PMA time series data of tomato prices was used to form an estimate of P_q. The most likely value, based on a five year average from 1994 to 1999, was **$1000/tonne** (PMA, 2000b).

Closed Economy Price (P_c) - Reliable cost estimates for products undergoing the quarantine treatments listed in section 3.4.3 are not available, which makes the task of formulating a closed economy price for tomatoes somewhat difficult. Despite stringent procedures being in place for tomatoes moving in to WA from interstate, imports have continued (if sporadically) over the past 15 years[30]. In the absence of time-series price differentials in a closed and quarantine restricted market, an approximate closed-economy-induced price rise of 8 per cent (above P_q) is specified, which is the same as that in the mango case study. The required quarantine procedures themselves differ for imported mangoes and tomatoes, but given the lack of adequate price information it will suffice as a broad estimate which can be examined more closely in a sensitivity analysis. The most likely value of P_c is assumed to be **$1,080/tonne**.

Free Trade, or National Price (P_f) – specified to approximate the marginal cost of tomato production for eastern states growers. Fullelove *et al* (1999) calculated the marginal cost of production and transport to local markets for Queensland producers. By substituting transport costs to Perth for local transport costs (i.e. Brisbane-Perth = $390/palate, Harris Transport, pers comm, 3/2/00)) for eastern states producers, estimated free trade price was found to be around **$950/tonne**.

Wholesale and Retail Marketing Margins – sources close to the Perth market indicate wholesale margins to be in the order of **15 per cent** (Mercer Mooney, pers comm, 23/11/99; Quality Produce International, pers comm, 30/07/99), and retail margins around **33 per cent** (Woolworths – Fresh Produce, pers comm, 22/11/99; Quality Produce International, pers comm, 23/11/99). As with the mango case study, these are assumed to be fixed in percentage terms.

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30 Tomato imports averaged around 75 tonnes per year between 1994 and 1999, and primarily sourced from primarily from Queensland and New South Wales (PMA, 2000a).

3.6.2 Results of an Aggregated Modelling Exercise

Results from the model using the stated parameters for tomato quarantine are detailed in Table 3.2 with references to Figure 3.1 in brackets. These results suggest that the potential loss to producer surplus avoided by maintaining quarantine procedures for interstate tomato growers must be in the order of $785,700 for the policy to have no net welfare impact. As the demand and supply curves have been defined, domestic producer surplus in a quarantine-restricted trade situation is estimated at over $6.1 million, implying the expected value of producer surplus saved by excluding tomato pests constitutes around 12.8 per cent of the current total value of the domestic tomato industry. In other words, the critical level of expected damage that will bring the costs and benefits of tomato quarantine restrictions into balance is in the order of $785,700.

Table 3.2: The Welfare Effects of Interstate Quarantine Protocols for Tomatoes

	Free Trade	**Post Quarantine**
Change in Producer Surplus	-$4,725,300	-$2,844,400
	($P_fBE_cP_c$)	(P_fBDP_q)
Change in Consumer Surplus	$2,871,800	$1,775,500
	($P^R_cJHP^R_f$)	($P^R_cJIP^R_q$)
Net Gains to Trade	$1,853,500	$1,068,900
	($P^R_cJHP^R_f - P_fBE_cP_c$)	($P^R_cJIP^R_q - P_qDE_cP_c$)
Total Net Welfare Loss	$784,700	
	($P_fBDP_q - P^R_qIHP^R_f$)	

3.7 Sensitivity Analysis

The subjective nature of many assumptions used to derive the results presented in sections 3.5 and 3.6 requires an extensive sensitivity analysis to indicate the areas most likely to cause inaccuracies. The impact of each key input variable on net welfare loss was tested, and used to produce Tables 3.3a and 3.3b.

A first point to note about these tables is that the net welfare loss does not appear to be overly sensitive to changes in the elasticities of demand and supply. On the demand side, the relationship is positive, as might be expected, but the sensitivity is low since changes in P_c lead to less than proportional changes in net welfare loss of the same sign. Similarly, very large changes in the supply elasticity produce only minor changes in the same direction.

The model behaves somewhat differently when the value assumed for the price of products under autarky, P_c, is varied. Changes in P_c lead to slightly more than proportional changes in net welfare loss of the same sign, so the results could be said to be relatively sensitive to P_c.

However, the areas of highest sensitivity are associated with the free trade price, P_f, and post-quarantine price, P_q. The former displays a negative relationship with the net welfare loss, and the latter a positive relationship. Relatively small changes in these values have a large impact on the net welfare loss, which is perhaps best explained by returning to Figure 3.1. By altering the distance between P_f and P_q, the size of the areas $P^R_qIHP^R_f$ (the welfare cost of maintaining quarantine protocols) and P_fBDP_q (expected damage resulting from pest importations) is also altered. It follows that raising the value of P_f diminishes the loss in consumer surplus and gain in producer surplus, whilst the opposite effect is had by increasing P_q.

Table 3.3a: Sensitivity Analysis - Mango

Variable (Most Likely Value)	Value	Relative Change in Value from Most Likely Scenario	Net Gain Under Free Trade	Net Gain Under Quarantine Restricted Trade	Net Welfare Loss Due to Quarantine	Relative Change in Net Welfare Loss from Most Likely Scenario
Free-Trade Price ($/kg)	$1.70	-2.9%	$249,050	$132,310	**$116,740**	109.5%
(Farm: $1.75)	$1.79	2.3%	$143,030	$132,310	**$10,720**	-80.8%
Post-Quarantine Price ($/kg)	$1.76	-2.2%	$188,030	$176,460	**$11,570**	-79.2%
(Farm: $1.80)	$1.85	2.8%	$188,030	$81,905	**$106,125**	90.5%
Closed Economy Price ($/kg)	$1.90	-2.6%	$137,150	$85,995	**$51,155**	-8.2%
(Farm: $1.95)	$2.00	2.6%	$252,370	$191,565	**$60,805**	9.1%
Wholesale Marketing Margin	10.00%	-20.0%	$177,075	$124,370	**$52,705**	-5.4%
(12.50%)	15.00%	20.0%	$220,890	$156,140	**$64,745**	16.2%
Retail Marketing Margin	25.00%	-25.0%	$157,220	$109,970	**$47,250**	-15.2%
(33.33%)	50.00%	50.0%	$249,640	$176,990	**$72,650**	31.4%
Elasticity of Demand	-1.00	-56.5%	$178,390	$126,960	**$51,425**	-7.7%
(-2.30)	-3.00	30.4%	$193,220	$135,190	**$58,025**	4.2%
Elasticity of Supply	0.30	-50.0%	$173,195	$124,080	**$49,115**	-11.8%
(0.60)	1.00	66.7%	$193,960	$135,605	**$58,355**	4.7%

Table 3.3b: Sensitivity Analysis - Tomato

Variable (Most Likely Value)	Value	Relative Change in Value from Most Likely Scenario	Net Gain Under Free Trade	Net Gain Under Quarantine Restricted Trade	Net Welfare Loss Due to Quarantine	Relative Change in Net Welfare Loss from Most Likely Scenario
Free-Trade Price ($/kg)	$0.91	-4.2%	$2,545,865	$1,068,865	**$1,477,000**	88.2%
(Farm: $0.95)	$0.99	4.2%	$1,218,620	$1,068,865	**$149,755**	-80.9%
Post-Quarantine Price ($/kg)	$0.96	-4.0%	$1,179,105	$1,029,185	**$149,920**	-80.9%
(Farm: $1.00)	$1.03	2.5%	$2,303,770	$1,095,585	**$1,208,185**	54.0%
Closed Economy Price ($/kg)	$1.01	-6.5%	$753,155	$116,315	**$636,835**	-18.8%
(Farm: $1.08)	$1.12	3.7%	$2,585,215	$1,718,665	**$866,549**	10.4%
Wholesale Marketing Margin	10.00%	-33.3%	$1,648,085	$945,193	**$702,890**	-10.4%
(15.0%)	20.00%	33.3%	$2,058,983	$1,192,535	**$866,450**	10.4%
Retail Marketing Margin	25.00%	-25.0%	$1,558,200	$891,085	**$667,110**	-15.0%
(33.3%)	50.00%	50.0%	$2,444,200	$1,424,415	**$1,019,785**	30.0%
Elasticity of Demand	-0.70	-30.0%	$1,825,540	$1,058,265	**$767,280**	-2.2%
(1.00)	-1.50	50.0%	$1,900,185	$1,086,530	**$813,655**	3.7%
Elasticity of Supply	0.40	-50.0%	$1,708,525	$1,005,545	**$702,980**	-10.4%
(0.80)	1.30	60.0%	$2,054,385	$1,156,135	**$898,250**	14.5%

Model sensitivities to marketing margins at both the wholesale and retail levels appear to be relatively weak. This is especially true for wholesale marketing margins, with large changes producing only minor effects. Net welfare loss is more sensitive to the size of retail marketing margin, although changes in this value still produce less than proportionate changes to net welfare.

From these findings it can be concluded that the most critical input for the aggregate model concerns the prices of the product concerned under a closed economy, a free trade and a quarantine-restricted trade scenario. Imperfections in these variables, however small, will have a more than proportionate impact on the net welfare loss indicated by the aggregate model. This being the case, mis-specified prices may lead to inappropriate policy recommendations. The highly seasonal nature of horticultural markets and the subsequent volatility of prices over time make this a potentially harmful property since model accuracy greatly depends on the rigor with which price variables are determined[31].

3.8 The Implications of Industry Size

Given the differences in size between the mango and tomato industries, it is interesting to note the disparities in results produced by the aggregate model. It appears the relative size of an industry has a major bearing on the economic viability of quarantine policies designed to protect it, or the ease with which SPS measures can be justified using a static, partial equilibrium trade model. The results presented in tables 3.3a and 3.3b

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[31] See PMA (2000b)

would suggest that the expected gain in producer surplus produced through the restriction of pests required to equate benefits and costs *increases* with industry size.

Consider the tomato example. When compared to an industry like mangoes, the increased price of tomatoes in WA is amplified by the sheer volume flowing through the Perth market. It should be noted that the relative price increase of tomatoes induced by quarantine measures in relation to the closed economy price is assumed to be the same as that for mangoes, as Table 3.4 indicates. However, the consumer side of the ledger carries a good deal more weight. The proportion of the WA food consumer's budget affected by quarantine-induced price inflation is more substantial in the case of tomatoes, and therefore the level of expected damage prevented by these policies must be higher to bring benefits and costs into balance. Hence, the probability of pest entry and establishment required to equalise the benefits and costs of the quarantine restriction, the break-even probability of incursion, will be higher.

Such a finding may be of some concern to domestic tomato growers. After all, it could be argued that relaxing interstate quarantine protocols in the interests of

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Table 3.4: Relative Price Increases Induced by Interstate Quarantine Measures

	Mangoes	Tomatoes
Price increase resulting from quarantine procedures (%)	7%	7%
Proportion of total WA fruit (including tomatoes) GVAP*	3%	6%
Break even probability of incursion	9%	13%

* ABS (1998)

consumers could spell disaster for their business if a pest were to gain entry as a result. Indeed it could, and this is precisely why an economic assessment of this nature should be used in conjunction with a scientific risk assessment and traditional damage estimation so that the critical level of expected damage equalising the benefits and costs of quarantine measures probability of incursion can be viewed in context. It may be that the nature and number of endemic pest species in the east of Australia would pose too great a risk to domestic industry under a free trade or relaxed quarantine scenario. Perhaps the expected damage would be greater than $785,000, or 13 per cent of producer surplus (presented in section 3.4). The answer requires supplementary information for which the critical level of expected damage identified provides a point of reference.

3.9 Conclusions

The aggregate model presented in this section is able to provide estimates of the likely effects on social welfare of interstate quarantine policies aimed at excluding exotic pests from WA with a minimum of input variables[32]. When it is used to examine the effects of interstate quarantine regulations for mangoes imported into the State, the most likely scenario involves a net welfare loss of around $55,720 per annum, or 9.5 per cent of the

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[32] Note that the phrase "with a minimum of input variables" relates to the issue introduced in section 1.2, that of the complexity involved in estimating the impact of quarantine protocols through the use of expected damage estimates. These assessments require many parameters, many of which deal with biological characteristics of specific pests, their hosts and environment. The technique derived throughout chapter 3 describes a far simpler estimation method which draws on far fewer input variables, thereby adding to the practicality of economic analyses when used as a decision-making aid.

total domestic producer surplus for that industry. This represents the critical level of expected damage that must be prevented by quarantine policies if they are to have no net welfare implications. When the model is applied to the tomato industry, a much larger net welfare loss of around $785,700 is estimated to result, implying that the critical level of expected damage is in the order of 12.8 per cent of the total producer surplus. Sensitivity analysis has revealed that these results are particularly sensitive to variations in price information, and it is here that a concerted effort should be made to ensure accuracy if policy recommendations are to reflect the interests of society.

Through the interpretation of the aggregate model results to the mango and tomato case studies presented in this chapter, it would appear that the size of an industry has a significant bearing on the economic viability of quarantine restrictions. Generally, the larger the industry, the greater the consumer welfare implications of restricting interstate competition. In the case of tomatoes, small price changes are effectively amplified by the sheer volume of product demanded by consumers, and consequently the effects on consumer welfare of any price rise (such as from a free trade price to a quarantine-restricted price) will tend to weigh heavily on the decision to place restrictions on competition. In a small industry like mangoes, the producer welfare implications are generally larger and interstate import restrictions become somewhat easier to justify on economic grounds.

While the aggregate model can reveal much information about the welfare implications of quarantine policies, there may be situations where a decision-maker requires more. It is not necessarily the case that aggregation across the industry produces parameters that are truly representative of all producers within it. Where industries are fragmented and have different cost structures, the ability of one region to survive and flourish when exposed to various degrees of competition may be quite different to another. Consequently, the political ramifications of decisions made at an aggregate level may not always be foreseen. In the next chapter, a spatial technique is demonstrated which better explains these regional differences, and enables quarantine policies to be examined at the level of a production region. With both an aggregate and a spatial analytical tool at their disposal, regulatory authorities can estimate the consequences of their actions to individual industries accurately, regardless of their structure. This is particularly relevant in the context of interstate trade in Australia since industries are typically heterogeneous, and an aggregate model may not provide sufficient information in every circumstance.

4. THE SPATIAL TRADE MODEL[†]

4.1 Introduction

The trade model developed in chapter 3 dealt with welfare changes brought about by quarantine regulations at an aggregate, or industry level. It is often the case with agricultural industries that aggregation does not produce parameter estimates that are truly representative of all producers, and allowance may need to be given to spatial characteristics. This is a particular concern when dealing with industries in a diverse zone like WA with a large land area, and climatic and geographical variations. Both large and small agricultural industries are sometimes fragmented into smaller production regions, each of which is characterised by a different set of production circumstances. It follows that the capacity of each region to absorb the impacts of varying degrees of competition may be quite different, as dictated by their production costs. These spatial differences within an industry are not captured by an aggregated assessment.

In view of this weakness of the aggregate model, this chapter focuses on the question: *is an aggregated, industry-wide approach to modelling the effects of quarantine measures appropriate where there are differences in component growing regions of an industry?* In answering, a spatial model is presented by which the regional implications of quarantine decisions can be examined. To encompass different regional characteristics requires greater amounts of data, but the model is shown to

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[†] A version of this chapter has been published in the journal *Food Policy* (Cook and Fraser, 2002).

produce outputs that are more relevant and more revealing from a regional perspective. In some circumstances, this information will merely imitate the findings of the aggregate approach. But, in others decision-makers may receive a valuable insight into the economic and social repercussions likely to result from policy options that they would not have otherwise had.

The spatial model is derived in section 4.2 of this chapter, and then applied to the mango and tomato case studies in sections 4.3 and 4.4 respectively. Using the results obtained, section 4.5 suggests which modelling technique is warranted in different industry situations, before conclusions are drawn in section 4.6.

4.2 The Spatial Estimation Technique

4.2.1 Impact of Pest Introductions at the Farm Level

In a country the size of Australia, or a State as large as WA the technical conditions of production are seldom equivalent across all producers and production regions. Where conditions vary between different growing areas, the *marginal cost* and *average variable cost* curves (and the *total cost* curves from which they are derived) also vary. Hence, a commodity may present a viable production option for primary producers in several different growing areas despite certain regions being more suited to its production than others. Where this is the case, separate assessments may be made of producer surplus accruing in different areas facing different average variable costs to determine the impact of quarantine-induced price changes on regional economies.

In the discussion that follows assume there are two component regions within WA supplying the domestic market for a fruit or vegetable commodity x, call them regions 1 and 2. To keep the analysis simple, let the set of assumptions outlined in section 3.2.1 apply to the market for x such that growers within specific regions face equivalent technical production conditions, whilst those in other regions vary according to growing environment[33].

The production function describes the relationship between physical quantities of factor inputs (I) and the physical quantities of output involved in producing x given the state of technological knowledge possessed by growers in each region. So, the level of output produced by an individual grower is some function, call it f, of I:

$$x = f(I) \qquad (4.1)$$

In reality, several of the inputs into agricultural production processes have a considerable degree of risk associated with them, particularly those directly influenced by notoriously unpredictable weather conditions. However, a formal treatment of risk is omitted in this investigation. In defining the nature of the production function, it is assumed that risky factors simply take on their average values.

Figure 4.1 provides a geometric representation of a possible regional production function with and without a pest. Generally, to be of quarantine significance a pest is deemed to have a negative impact on output when endemic in a production area. An exception may occur where there are human health and/or environmental implications to pest introductions, but in the majority of cases it is assumed that the "one host" referred

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[33] Once again, assume: 1) a homogenous product, x; 2) perfect competition in the domestic market for x; 3) the domestic price for x is higher than the 'landed' price of overseas product; 4) the domestic industry is a 'price-taker'; 5) society has a neutral attitude to risk; 6) pests are host specific; and 7) all costs of quarantine treatments are borne by exporters (James and Anderson, 1998).

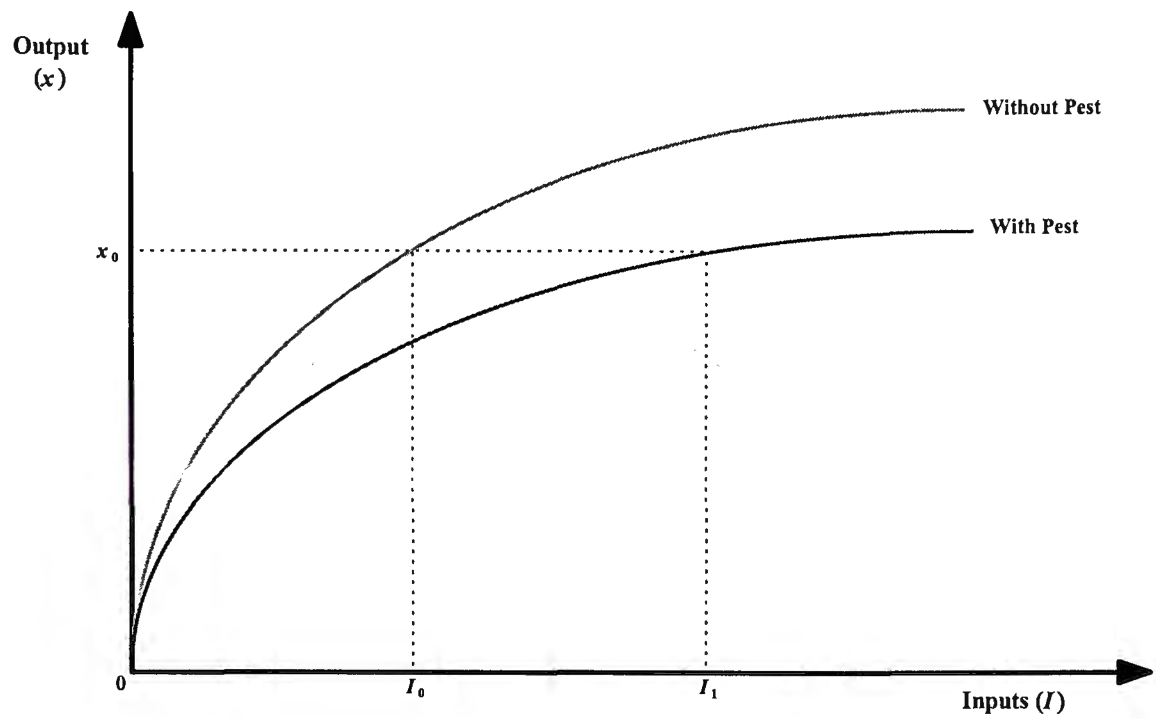

Figure 4.1: The Production Function With and Without a Pest in the System

to in assumption (5) of section 3.2.1 is a crop of commercial significance, such as x. Where this is the case, the production function can be seen to move to the right since the quantity of inputs required to produce any given level of output increases due to the presence of the pest. For instance, should a grower of x have to use an additional chemical treatment to those already used for other pest control to produce x_1, the quantity of inputs required will increase from I_0 to I_1 (as Figure 4.1 has been constructed). Thus, a pest impact can be seen in much the same light as a negative technological change[34].

To examine the economic welfare implications of such a change requires some discussion about cost and revenue functions. In short, Total Revenue (TR) for any grower supplying the market for x depends on the quantity sold and the price (p) at

[34] An equivalent means of explaining Figure 4.1 is to state that the amount of output produced by a given set of inputs is reduced in the presence of a pest.

which it is sold (i.e. TR = px), while Total Costs (TC) are a function (call it c) of output (i.e. TC = $c(x)$). It follows that profit (π) is given by TR minus TC. Given that the price facing a competitive, profit-maximising grower of x is dictated by the market as a whole, their profit maximisation decision can be stated as:

$$\max_{x}.\pi = px - c(x) \tag{4.2}$$

Assume the technical conditions of producing x are such that the function c is characterised by varying returns to factor inputs. At low output levels, assume c exhibits increasing returns to successive increases in inputs used, and decreasing returns at high output levels. If this is the case, the first-order condition for profit maximisation is:

$$p = c'(x) \tag{4.3}$$

Where the slope of the cost function (or the Marginal Cost (MC)) is equal to the slope of the TR function (or Marginal Revenue (MR)), p, the differential between the two is maximised. This is a *necessary* condition for profit maximisation. Since the slope of the demand curve is constant and zero in a perfectly competitive environment, *sufficiency* is dependant on the sign of the cost function, which must be positive if the profit maximising solution lies on the portion of the TC function where MC are increasing. So, the second-order condition can be stated as:

$$c''(x) \geq 0 \tag{4.4}$$

It is not necessarily the case that the profit maximising grower's choice of output of x will be positive. Under certain circumstances the most profitable (or more correctly, the least costly) course of action is to produce no output at all. Breaking the

TC function, $c(x)$, into its fixed (C_f) and variable ($c_v(x)$) components, the function can be expressed as:

$$c(x) = c_v(x) + C_f \tag{4.5}$$

Fixed costs must be paid even if output is zero, while variable costs are only incurred when the grower produces output. It is therefore logical for a profit-maximising grower to produce a positive level of x when the profits from doing so outweigh the losses incurred by producing zero output ($-C_f$):

$$px(p) - c_v[x(p)] - C_f \geq -C_f \tag{4.6}$$

Here, $x(p)$ denotes the volume of x produced at a given price, p. Rearranging this condition, it can be shown that a grower will produce positive levels of output when the price is greater than Average Variable Costs (AVC):

$$p \geq \frac{c_v[x(p)]}{x(p)} \tag{4.7}$$

At prices below the minimum value of AVC, it is in the interests of a profit maximising farmer to produce no output in order to minimise losses. At prices above the minimum value of AVC the MC curve relates the grower's profit-maximising output to price, and thus represents their supply curve, $x(p)$. Hence, $x(p)$ must identically satisfy the first-order and second order conditions:

$$p \equiv c'[x(p)] \tag{4.8}$$

$$c''[x(p)] \geq 0. \tag{4.9}$$

The supply curve for the collective industry can simply be found by horizontally summing the supply curves of all growers supplying the market for x. If there are n

suppliers and the supply curve for the i^{th} firm is denoted $x_i(p)$, then the supply curve for the industry ($X(p)$) is given by:

$$X(p) = \sum_{i=1}^{n} x_i(p) \tag{4.10}$$

So, this industry supply schedule, which formalises the relationship between industry output and collective marginal costs of production, can be used to calculate industry profit under different production conditions (Varian, 1992; Laidler and Estrin, 1989).

Returning now to the production functions of Figure 4.1 (with and without a pest in the system), the implications of a pest introduction for a grower's profit-maximising output decision become clear. As the level of inputs needed to produce each unit of x increases in response to costly efforts to keep a newly introduced pest at bay, or at least subdued, so too must MC and AVC. Recalling the characteristics of $c(x)$, the AVC curve will be U-shaped, as depicted in Figure 4.2. Here, two sets of aggregated cost curves are shown dealing with both a 'with pest' (MC_1 and AVC_1) and 'without pest' scenario (MC_0 and AVC_0).

To simplify the following discussion, assume fixed costs of production are zero, so average total costs equal AVC. A profit-maximising grower will produce that quantity of x at which MR equals MC. In the absence of a pest, the grower will choose to produce quantity x_0 in order to maximise profits at the market price p. At this level of outputs, producer profit is given by the area ABCp[35]. However, if through the

[35] To repeat, growers in production regions must pay fixed costs in the short run even if output is zero. However, since it has been assumed the fixed costs are zero here for simplicity, the area ABC_p can be said to represent profit. If fixed costs are greater than zero, the area indicating profit will be smaller since the average total cost curve would lie everywhere above the AVC curve.

introduction of a pest the cost curves faced by the producer shift upward from MC_0/AVC_0 to MC_1/AVC_1, profits will be maximised by producing the lesser quantity x_1. At this level of output, profit is reduced. This loss of producer welfare, or producer surplus, represents an expected benefit of quarantine strategies to exclude the pest in question. The producer surplus associated with a given level of output is analogous to profit, as defined in equation (4.1) above (i.e. $\text{PS}(x) = px - c(x)$), and is represented in Figure 4.2 as the area between the industry supply curve (or MC curve) and the price line. Hence, where there is sufficient information to determine precise movements of the cost curves in response to specific pest introductions, the benefits of strategies to exclude them can be determined in terms of expected producer surplus losses.

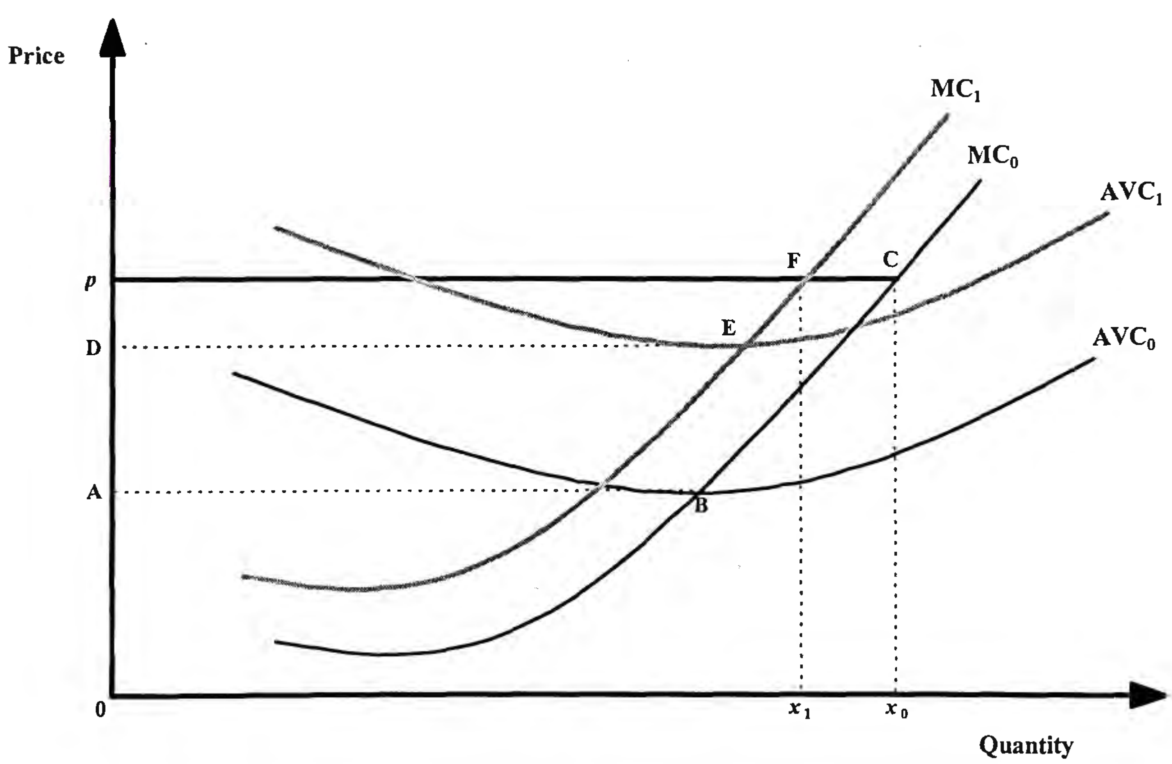

Figure 4.2: The Effects of a Pest on the Costs of Production

In reality however, it becomes extremely difficult to calculate precise movements of the cost curves in response to pest introductions in the static model[36]. This is simply caused by a lack of information concerning quarantine pests and their likely behaviour and destructive capacity in environments where (in many cases) they have not been observed previously. A number of shift parameters are subject to huge variability, and will depend very much on the idiosyncrasies of the time and place of the initial introduction. Several factors to be considered include the:

- biological characteristics of the pest concerned and its quarantine status;
- suitability of pests and their reproductive capacity to the State's weather patterns;
- abundance and location of suitable hosts;
- scope for the development of pest resistant varieties of these hosts;
- marketing implications;
- size of the initial incursion;
- nature and abundance of spread vectors;
- availability of effective treatments; and
- capacity of the pest to develop resistance to these treatments.

It stands to reason then that any assessment that estimates the movement of the cost curves and the resultant impact on farm profits will necessarily involve a high degree of subjectiveness.

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[36] This problem would be exacerbated in a dynamic model requiring assumptions of pest impact over several time periods.

4.2.1 Impact of Pest Introductions at a Regional Level

Rather than use a speculative assessment of likely pest impacts avoided by maintaining quarantine protocols, the model developed in this analysis simply calculates producer surplus under different prices. Quarantine requirements for goods imported into WA impose costs on suppliers outside of the State that are passed on to domestic consumers through the price mechanism[37]. By estimating the total producer surplus accruing to WA producers facing different AVC under a quarantine-restricted trade scenario, the expected benefits of pest exclusion can be implied. This requires the grouping of growers from component regions of an industry, and an investigation of the impact of varying degrees of competition (i.e. closed economy, quarantine-restricted trade and free trade) on each.

Recall the two regions mentioned above making up the domestic industry for the good x, regions 1 and 2. Assume now that region 1 is characterised by a relatively low cost of production and region 2 by a relatively high cost of production. If the technical conditions for producing x in each area are such that the TC function exhibits increasing returns to factor inputs up to some high-output capacity, after which decreasing returns set in, the AVC curve will resemble that depicted in Figure 4.3. This diagram illustrates the impact of price changes on each regional industry profits by plotting the MC and AVC curves for regions 1 and 2, and the demand (or price) curve faced under different quarantine regimes.

Consider firstly a closed economy situation where competition from rival producers in other parts of Australia is completely restricted, and domestic producers face a price p_c for x. Region 1 will maximise profits by producing a level of output x_{c1}

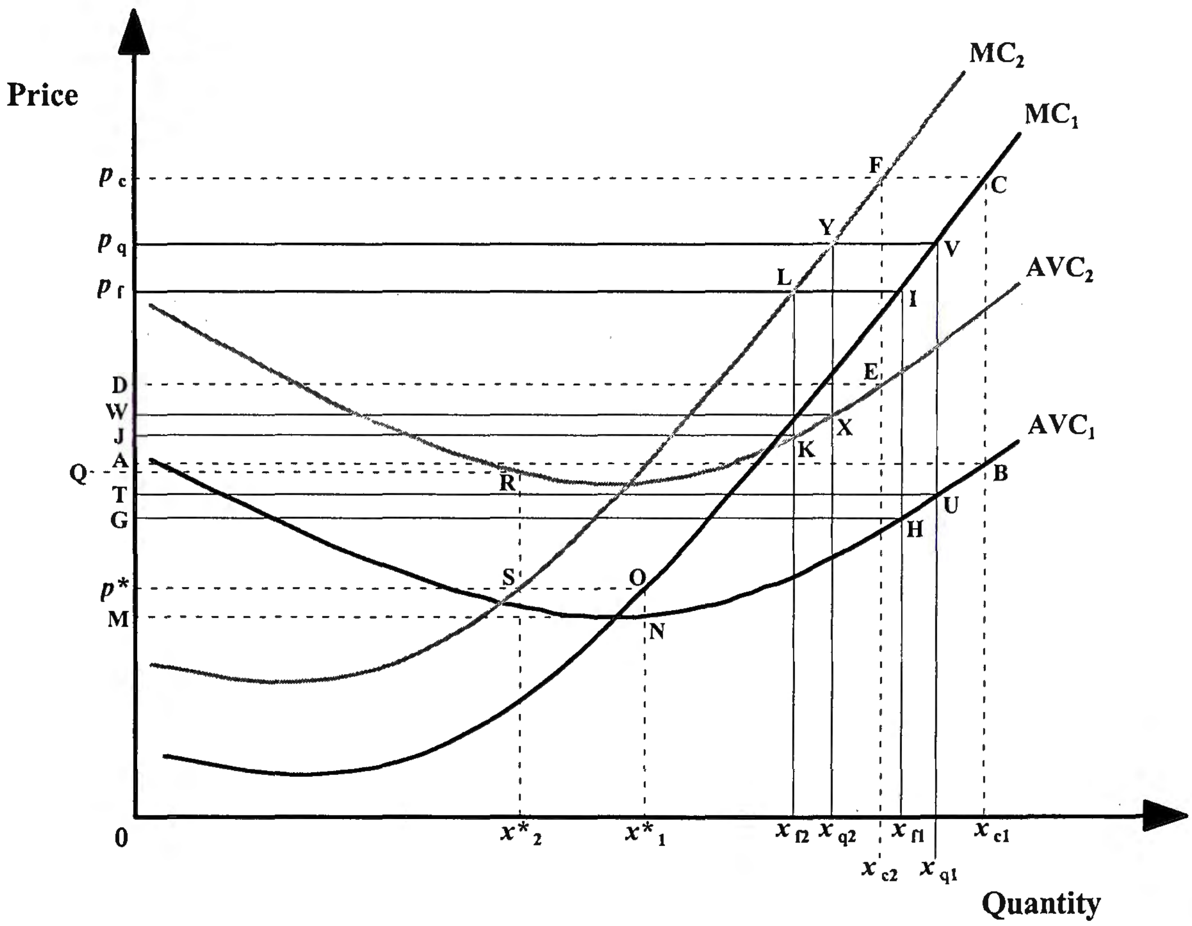

Figure 4.3: The Regional Impact of Quarantine Protocols

(i.e. $p_c = MC_1$), where profit is indicated by the area $ABCp_c$ (i.e. $(p_c - AVC_1) \times x_{c1}$). Region 2 will behave in the same manner, producing x_{c2} to maximise its profit at $DEFp_c$ (i.e. $(p_c - AVC_2) \times x_{c2}$). Since it faces a higher cost of production, it is impossible for region 2 to enjoy the same profit margin as region 1, but so long as the price paid for its output remains above the minimum value of AVC_2 short-run profits will be positive.

Now assume that the ban on interstate produce is lifted, and goods are permitted to move across State borders into WA unimpeded. Suddenly the priced faced by domestic producers will fall to the national, or free trade level p_f. Region 1 will adjust

[37] Recall assumption (6) of section 3.2.1.

its output in response, choosing to produce the lower quantity x_{f1}, where profit is maximised at GHIp_f. Region 2 will also adjust its output to a new lower level x_{f2} where its profit falls to the area JKLp_f. Hence, both experience a significant loss of profit under the increased competition from growers elsewhere in Australia, but both remain profitable since p_f exceeds the minimum value of AVC_1 and AVC_2. The extent of this loss relative to the closed economy situation for region 1 is represented by (ABCp_c-GHIp_f), and for region 2 by (DEFp_c-JKLp_f).

Had the free trade price been lower however, say p^* for instance, the situation would be quite different. At this price, region 1 must reduce output even further (to x^*_1) to maximise its profit, which declines to the area MNOp^*. If region 2 were to follow suit and produce x^*_2, it would make a loss of QRSp^* since AVC_2 exceeds p^*. Producers in the region would be better served producing no output at all to minimise short-run losses. That is, they do not demonstrate the same capacity to absorb the impact of competition when compared to the lower cost region 1. In effect, region 2 will pay the price for its relative inefficiency by being squeezed out of the market entirely while efficient producers in region 1 remain[38].

Since free trade maximises the risk of importing exotic pests from other states and Territories of Australia, assume interstate quarantine protocols are put in place for x such that consignments moving in to WA must undergo specified treatments before they can be sold on the Perth wholesale market. If the cost of these treatments inflate the market price from p_f to p_q region 1 will choose to produce x_{q1} to maximise profit at

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[38] It may be argued that herein lies one of the principal benefits of increased competition, but there are a host of other factors that need to be considered - not the least of which are adjustment costs for secondary domestic industries in the value chain for x and socio-economic impacts associated with the loss of income to communities in region 2. These are explained further in chapter 7.

TUVp_q. Region 2 will do likewise and produce x_{q2} to earn a profit of WXYp_q. Hence, the former's decrease in profit relative to the closed economy situation is represented by ABCp_c - TUVp_q, and the latter's by DEFp_c - WXYp_q.

The extent of changes to profit in each region brought about by different quarantine strategies is not fully appreciated in an aggregated model. Whilst it requires a more detailed knowledge of the cost curves faced by different producing regions, the spatial approach demonstrated above has the advantage of supplying the policy-maker with an indication of where the highest losses or gains will be felt under different quarantine circumstances. This raises certain problems from an analytical point of view in the sense that it is not clear when an aggregated model with a relatively low demand for input variables is appropriate, and when a more detailed, spatial assessment is necessary. It is this dilemma which is to be explored in the following sections through the application of the spatial model to the mango and tomato case studies.

4.3 The Spatial Model Applied to Mangoes

4.3.1 Variables

Production figures from the Australian Bureau of Statistics (ABS) used in this analysis group centres (local government areas, or shires) by statistical division (i.e. ABS, 1998). As a consequence, and in the absence of accurate information on the sources of mangoes passing through the Perth market over time, production from Carnarvon and Geraldton have been combined in the Central statistical division. An outline of the most likely values for key parameter estimates for each production region and details of information sources are provided below[39]:

Marginal Cost (MC) - In a competitive environment the MC curve for a particular growing region represents its supply curve. Since MC is assumed to become infinitely elastic at prices below the minimum AVC of a region's producers (as the cost minimising decision for producers becomes zero output), the portion of the curve above AVC is of primary interest. The model assumes that the own-price elasticity of this supply curve can be approximated by that of the industry supply curve. Hence, an elasticity of **0.80** was assumed to be most likely (White, 1997)[40].

Average Total Cost (ATC) – this represents AVC plus a fixed cost component. Production costs for each growing region are provided in White (1997). The ATCs for the Central region are specified as **$1,440/tonne**, and **$1,460/tonne** for the Kimberley statistical division.

Post-Quarantine Quantity Supplied (P_q) - using ABS time series data supplemented by White (1997), an estimated proportion of total supply was formed based on a three year average from 1994-1997. Recall from section 3.3, protocols for the importation of mangoes from interstate were introduced in 1994, prior to which all imports were restricted. Using post-1994 supply data and relative contributions to production from the Central and Kimberley statistical divisions, the former comprises of some

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[39] The details of some parameter estimates also appear in section 3.5.1 and 3.6.1, and are repeated in sections 4.3.1 and 4.4.1 for convenience.

[40] Recall from section 4.5 that the sensitivity of net welfare change resulting from quarantine-induced price inflation to the elasticity of supply is low.

56 per cent **(790 tonnes)** of total production, and the latter around 43 per cent **(610 tonnes)** (ABS, 1998; White, 1997).

Post-quarantine Price (P_q) - **$1,800/tonne** (PMA, 2000b; FAO, 2000).

Closed Economy, or Autarky Price (P_a) - **$1,950/tonne** (PMA, 2000b; FAO, 2000).

Free Trade, or National Price (P_n) - **$1,750/tonne** (White, 1997).

Wholesale and Retail Marketing Margins - wholesale margins are assumed to be around **15 per cent** (Mercer Mooney; Quality Produce International; Central Fruit Sales; Etherington & Sons, pers comm, 23/11/99), and retail margins around **33 per cent** (Woolworths – Fresh Produce, pers comm, 22/11/99; Quality Produce International, pers comm, 23/11/99).

4.3.2 Results of a Spatial Modelling Exercise

Results from the spatial model appear in Table 4.1, which includes profit figures for both of the significant growing regions in WA. Collectively, the regions modelled account for over 90 per cent of total mango production in WA (White, 1997; ABS, 1998). Recall that the sum of profits from each region given any one scenario (i.e. closed economy or quarantine-restricted trade) equates to the total profit estimates the aggregate model (given in the 'industry' column).

Table 4.1: The Welfare Effects of Interstate Quarantine Protocols for Mangoes – Spatial Model

	Kimberley	Central	Industry
ATC - Closed Economy	$1,470	$1,495	
ATC - Quarantine	$1,435	$1,460	
Quantity Supplied - Closed Economy	660T	860T	1,800T
Quantity Supplied - Quarantine	610T	790T	1,410T
Profit - Closed Economy	$319,290	$393,985	$916,160
Profit - Quarantine	$220,745	$267,475	$588,945

4.4 The Spatial Model Applied to Tomatoes

4.4.1 Variables

Marginal Cost (MC) – an elasticity of supply of **0.80** was assumed most likely (Shonkwiler and Emerson, 1982).

Average Total Cost (ATC) - production costs for the Swan Coastal Plain are provided in Gartrell (1998) from which a most likely value of **$660/tonne** post quarantine is taken (and $710/tonne under a closed economy inferred). Production costs for the South West Region are specified as approximating those for the Manjimup district, the details of which are contained in Gartrell (1997). Using these figures, a value of **$540/tonne** post-quarantine was estimated ($590/tonne under a closed economy). Finally, production costs for the Central statistical division are specified to approximate those of the Carnarvon district, which are detailed in White (1998). A most likely value of **$880/tonne** was used ($925/tonne under a closed economy).

Post-Quarantine Quantity Supplied (Q_q) - Using PMA time series data the total supply from each growing region was formed based on a five year average from 1994 to 1999. Although not the case with every commodity passing through the market, the source of tomatoes has been recorded over time. The Central district (principally Geraldton and Carnarvon) supply is specified at **10,800 tonnes**, the Swan Coastal Plain region at **8,700 tonnes**, and the South West region at **1,300 tonnes** (PMA, 2000a).

Post-quarantine Price (P_q) - PMA time series data of tomato prices was used to form a five-year average from 1994 to 1999, calculated at **$1,000/tonne** (PMA, 2000b).

Closed Economy Price (P_c) - **$1,080/tonne**.

Free Trade, or National Price (P_f) - **$960/tonne** (Fullelove *et al* 1999; Harris Transport, pers. comm., 3/2/00).

Wholesale and Retail Marketing Margins - wholesale margins are likely to be in the order of **10-15 per cent** (Mercer Mooney, pers. comm., 23/11/99; Quality Produce International, pers. comm., 30/07/99), and retail margins around **33 per cent** (Woolworths - Fresh Produce, pers. comm., 22/11/99; Quality Produce International, pers. comm., 23/11/99).

4.4.2 Results of a Spatial Modelling Exercise

Modelling the domestic tomato industry using most likely values produces the following profit figures for each of the growing regions included. Collectively, the tomato-growing regions modelled account for over 90 per cent of total production in WA (ABS, 1998; White, 1998; PMA, 2000a). So, the sum of profits from each region given any one scenario (i.e. closed economy, free trade or quarantine-restricted trade) would be expected to equate with the total producer surplus estimates of the aggregate model. Table 4.2 includes profit figures for both of the significant growing regions in WA. As mentioned in section 4.3.1, production figures used in this analysis group centres by statistical division, and production from Carnarvon and Geraldton has been combined in the Central statistical division (presented in the 'Industry' column).

Table 4.2: The Welfare Effects of Interstate Quarantine Protocols for Tomatoes - Spatial Model

	Central	**Swan Coastal Plain**	**South West**	**Industry**
ATC - Closed Economy	$925	$705	$585	
ATC - Quarantine	$880	$660	$540	
Quantity Supplied - Closed Economy	12,175T	9,790T	1,445T	22,360T
Quantity Supplied - Quarantine	11,295T	9,080T	1,340T	21,370T
Profit - Closed Economy	$2,149,355	$3,881,540	$746,685	$8,654,360
Profit - Quarantine	$1,355,370	$3,087,385	$616,855	$6,123,360

4.5 Interpretation

While it is recognised that the case studies used here are only two of a large number of commodities traded across State borders and subject to interstate quarantine restrictions, the results for mangoes and tomatoes represent some interesting findings. At the very least, they provide an indication of the usefulness of different analytical techniques when dealing with varying market circumstances.

The results appear to lend support to the idea that an aggregated, industry-wide approach to modelling the effects of quarantine measures may not be appropriate where there is significant variation in ATC between growing centres. The ability of different regions to absorb competition-induced price decreases (below a closed economy level) will vary according to the commodities in question, and so too the impact of quarantine. If these differences are minor, as in the case of mangoes grown in the Central and Kimberley districts, an aggregated model will provide an accurate indication of the effects of interstate quarantine regulations. On the other hand, when dealing with commodities like tomatoes with sizeable differences in growing costs between each of the main growing regions, the impact of import protocols will vary across the industry.

The primary cause of this high production cost is the price of water. There are variations in water prices throughout the State, and in some rural areas there may be no controls at all. On the Swan Coastal Plain, the Water and Rivers Commission may grant a private water allocation to a block of land if there are sufficient underground water reserves[41]. In contrast, there is a fixed quota throughout the year in the Carnarvon

[41] This will be allocated in terms of total land area based on a general water requirement of 15,000 kiloliters per hectare for vegetable crops like tomatoes. Properties are not metered, but may be inspected for area of cropping at any time (Burt and Gartrell, 1998).

district, which is dependent on the flow of the Gascoyne River, and properties are carefully metered. In the case of mangoes grown in this area, the effect of water quotas is offset by more intensive growing techniques and higher yield per hectare, but where tomatoes are concerned growing techniques are (in general) more uniform between regions (Burt and Gartrell, 1998)[42].

The range of regional competition-induced impacts these ATC differences produce using the spatial model is perhaps best illustrated by expressing the change in regional profit with the move from a closed economy in percentage terms. Table 4.3 shows the percentage decline in profit (relative to post-quarantine profit) estimated under both modelling approaches. This table shows that in the case of mangoes the percentage decline in aggregate profit following a move from closed economy to post-quarantine is similar to that of each component region, reflecting their similarity in terms of ATCs. However in the case of tomatoes, the impact for each region is very different from that represented by the weighted average in the aggregate result, reflecting differing levels of ATC.

Table 4.3: Percentage Decline in Producer Surplus - Closed Economy to Quarantine-Restricted Trade

Mangoes			Tomatoes			
Central	Kimberley	Aggregate	Central	Swan Coastal Plain	South West	Aggregate
-31%	-32%	-36%	-37%	-20%	-17%	-29%

[42] Most recent plantings in Carnarvon are high density plantings of 400 to 600 trees per hectare, as opposed to traditional management styles where trees are planted at around 200 per hectare and thinned to 100 trees per hectare after 12 years (to avoid overcrowding and subsequent yield loss). Under a high density management style, mangoes are pruned and shaped manually in the initial stages and later hedged by a machine to restrict tree size (Hawkins, 1994).

An alternative way of presenting this finding is contained in Table 4.4, which expresses spatial profit under each trade scenario in percentage terms to illustrate the effects on individual regions more closely. Here it is clearly shown that the relative contribution of each mango growing region remains constant as the economy moves from a state of autarchy to one of quarantine-restricted trade and free trade[43]. In contrast, the contribution of each tomato-growing region changes quite markedly. Downward pressure on prices exerted by increased levels of competition will see a shift in production significance towards lower cost areas like the Swan Coastal Plain and the South West, and away from high cost areas like the Central statistical division.

These results are not captured by an aggregated approach. Cost differences are simply embedded in weighted averages used to describe the industry concerned. While this may not be a direct concern in terms of satisfying the requirements of the SPS Agreement, they are certainly important for domestic policy-makers striving to act in

Table 4.4: Regional Profit as a Percentage of Modelled Growing Centres

	Mangoes		**Tomatoes**		
	Central	Kimberley	Central	Swan Coastal Plain	South West
Closed Economy	45%	55%	30%	59%	11%
Post Quarantine	45%	55%	22%	65%	13%
Free Trade	45%	55%	27%	61%	12%

[43] Percentages shown represent the relative contribution of each growing region in terms of all of the regions modelled rather than total producer surplus of each industry.

the public's interest. While aggregation may be warranted in the case of some commodities with similar cost characteristics across production regions, for others it would be to the detriment of the decision-maker's capacity to encompass domestic producer effects.

4.6 Conclusions

Both the aggregated and the spatial techniques presented in chapters three and four can provide large amounts of information about the likely benefits and costs imposed by interstate quarantine strategies by exploring their effects on producer and consumer welfare. However, circumstances have been identified under which one technique can be recommended over the other. The two case studies presented in this chapter indicate that an aggregated trade modelling approach is warranted when the industries concerned are characterised by uniform production costs across all growing regions, as is the case for mangoes. When an industry is characterised by cost uniformity aggregation does not diminish the power of the model to demonstrate the welfare implications of various levels of competition induced by quarantine strategies. If, on the other hand, industries are characterised by significant cost variations between growing regions, as in the case of tomatoes, a spatial technique can be used to make these differences explicit and hence determine the capacity of each to absorb the pressures imposed by competition.

The findings presented in this chapter suggest that the choice of analytical models to be recommended for a social welfare analyses of quarantine regulations will largely depend on the industries concerned. Where the production cost characteristics are similar across growing regions, an aggregated approach is justified under which the size of the industry and the potential consumer welfare implications exert an influence on the result. Where there are significant production cost variations between individual growing regions within an industry, a spatial approach is more appropriate which will also be influenced by industry size.

Using the information provided by the aggregate and spatial models, it is possible to make some comment about WA's import risk preferences in regard to interstate quarantine. If quarantine policies are used to reduce the expected damage of exotic pests to a socially acceptable level, it may be possible to express this in terms of consumer surplus forfeited by restricting trade. A conventional approach to determine whether or not a perceived pest risk is 'acceptable' involves estimating the likely consequences of a pest incursion and the risk of entry and establishment. If this could be done in conjunction with an estimation of consumer surplus loss using an aggregate or a spatial partial equilibrium framework regulatory authorities will be equipped with a comprehensive information package with which to come to a decision. The next chapter explores this notion, and develops a conceptual framework based around the concepts of *isorisk* and the *Appropriate Level of Protection.*

5. A Proposed Framework For Economic Analyses Of Quarantine Measures

5.1 Introduction

Traditionally, quarantine has been considered a subject of the biological sciences, so the primary decision criteria have been centred on the producer effects of pest introductions. However, since measures designed to ensure imported products are pest-free often involve costly sampling, chemical and temperature treatments they affect all consumers of those products by raising domestic prices, and therefore reducing the benefits from trade. Only recently have methods of integrating these trade effects with import risk assessments been discussed, but these have a variety of problems in terms of practical use in policy analysis and design.

This chapter draws on these methods and attempts to overcome, or at least avoid some of their inherent problems by applying them to the mango and tomato case studies completed in chapters three and four. Before doing so, a discussion of the practical need for alternative approaches to interstate quarantine analyses is presented in section 5.2 that makes reference to the current techniques used to assess and prioritise pest threats to WA. With these practical issues in mind, the concepts of *iso-risk* and the *Appropriate Level Of Protection* (ALOP) are introduced in section 5.3, and a conceptual framework put forward in section 5.4. This framework, derived from a model put forward in Snape and Orden (2001), is then used to explain the social welfare implications of the aggregate and spatial analytical trade model results in section 5.5. Section 5.6 then draws conclusions.

5.2 A Practical View on the Need for Alternative Approaches to Economic Analyses

Many disciplines have been characterised by an increased level of quantification in recent years, particularly since the advent of the personal computer. For instance, in engineering and related disciplines, fully quantitative assessments are widely undertaken with minimal information constraints. However, in the biological and natural resource management fields a lack of basic data prevents the same level of quantification being achievable in analytical work (Nunn, 2001). Nevertheless, there has been a continual progression towards quantification in economic research into international quarantine activities and their impact on domestic industries in the belief that they present a greater level of accuracy than qualitative analyses[44]. In view of the uncertainty surrounding risk assessment methods, the SPS Agreement allows for all levels of quantification. But, this has failed to dissuade trading centres from investing resources into quantitative analyses that are highly demanding of skilled analysts, data and computer technology.

This situation also describes the modern role of economic analysis in aiding quarantine decisions regarding interstate trade in WA. Assessments are carried out on

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[44] 'Qualitative', as distinct from 'quantitative' assessments, are those which draw on philosophical and anecdotal evidence to derive intrinsic values. Purely quantitative studies rely solely on numerical expressions of value.

selected pests by the Department of Agriculture Western Australia (DAWA) to ascertain their impact on domestic producer surplus in host industries over a ten to thirty year time period[45]. These are termed *Impact Assessments* (IA). Any IA dealing with such an extended period of time is data intensive, and complicated to communicate to stakeholders in extension activities. Moreover, in a majority of circumstances the complete absence of necessary data requires the use of risk software packages enabling the use probability distributions in place of point estimates[46]. The specification of these distributions can be as subjective as asking one individual with experience of a pest to provide a minimum, maximum and most likely parameter estimate. Hence, the estimation of important variables like the increment to Average Total Cost (ATC) of production brought about by the introduction of a pest to an industry used in an IA has a tendency to be subjective. This opens up an opportunity for experts in one particular area to strategically overstate assessment parameters if they believe that it may result in higher concentrations of resources being placed in their area of interest.

Even with these attempts to simplify analyses and decrease the need for accurate data, sufficient resources are not available for detailed quantitative analyses on each and every pest from which the State is perceived to be under threat. As a result, simple classification techniques are frequently used as screening devices to establish pest priorities in which the expected damage is inferred rather than calculated in full. For example, a *Threat Data Sheet* (TDS) produced by DAWA contains several sections designed to establish an overall 'risk rating' for specific insect, weed and plant

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[45] The threats chosen to be analysed are suggested by industry representatives and specialised DAWA staff members.

[46] The software packages used extensively in the *HortGuard*™ initiative of DAWA to examine exotic horticultural threats to WA are *@Risk*, *Risk Optimizer* and *Toprank*, by Palisade Corporation©.

pathogenic pests (eg. Botha and Hardie, 2000; Pratt, 2001; Stansbury, 2001). Appropriate DAWA staff members are asked to classify pests according to their impact on host industries (High - H, medium - M or low - L), the size of the host industry/industries (small, medium or large), the likelihood of introduction (H, M or L), the likelihood of establishment upon introduction (H, M or L), and the relative ease by which the pest can be spread from one host area to the next (H, M or L). Where possible, economic assessments are used to supplement this information using the techniques referred to above. But, when this is not possible the loss of domestic producer surplus expected to result from the introduction of a specific pest that is required to set appropriate quarantine regulations is simply estimated from the TDS[47]. Although qualitative information, the fact that it has been deduced by relevant experts does not necessarily make it less informative than a quantitative economic assessment. In fact, it may achieve a higher level of accuracy than possible through a quantitative economic analysis due to the unavailability of adequate information on the dynamics of pest spread.

In view of these difficulties encountered when conducting quantitative assessments of expected producer surplus losses for exotic pests, the analytical models discussed in chapters three and four can potentially play an important role. Since they largely rely on price and quantity information the results of these models may enable conventional IAs to be 'calibrated', aiding in the design and implementation of regulatory measures. Regardless of the process of justification, SPS measures imposed on commodities have an adverse effect on the welfare of consumers which has to date remained absent from information provided to decision-makers. It is here that there can be no substitute for detailed economic welfare analysis if consumer concerns are to be

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[47] A simple high, medium or low rating is assigned to describe the likely *economic impact* of the pest.

formally recognised as a relevant factor in Import Risk Analyses (IRA). The following sections of this chapter deal with this issue conceptually.

5.3 Iso-risk and the Appropriate Level of Protection

When discussing allocation options for relatively scarce quarantine resources, it is important to have a means by which alternatives can be evaluated and compared. This represents a sizeable challenge due to the diversity of threatening organisms to agriculture and the range of techniques (potentially) employed to restrict their entry to a geographic region. The bulk of literature completed on this issue to date has focused on methods of eliciting values for trade barriers by way of potential economic damage assessments and/or probability estimates of that damage occurring through the importation of infested material[48]. Because this method of pest risk evaluation relies solely on producer welfare implications, decisions made in regard to the allocation of quarantine resources based on such assessments tend to be biased. In terms of a practical resource allocation decision-making aid, this constitutes just one component of a much broader framework capturing both consumer and producer welfare implications.

It is generally accepted that pest risk, or expected damage related to a specific pest be defined as the product of the *economic consequences* of importing the organism concerned, and the *probability of introduction and establishment* of that organism (Bigsby, 2001). Assessments of the risks posed by specific goods rely on expected

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[48] See for example Che and Cook (1999); Cohrssen and Covello (1989); FAO (1996); Hafi *et al* (1994); Hinchy and Low (1990); Kaplan and Garrick (1981); McKelvie (1991); McKelvie *et al* (1994); Miller *et al* (1993); Orr (1995); and Viljoen *et al* (1997).

damage assessments for each pest associated with it, and so the damage expected to result from the importation of a commodity is determined as the sum of expected damage for each and every pest for which it is a host.

i.e. $$\mathrm{ED}_c = \sum_{i=1}^{n} \mathrm{EC}_i \times p_i \qquad (5.1)$$

where;

ED_c = Expected Damage resulting as a consequence of importing a particular commodity *c*

EC_i = the economic consequences of an incursion of pest *i*

p_i = the probability of the entry and establishment of pest *i*, and

n = the number of pests for which *c* is a host.

A locus of varying combinations of EC and *p* with a given product (ED) is referred to as an *iso-risk* line (Bigsby, 2001), being analogous to the concept of 'isoquants' in neo-classical production economics. Figure 5.1 depicts three different iso-risk lines, IR_1 - IR_3, each corresponding to different values of ED. Both axes are shown on a log scale such that iso-risk lines are linear, with EC (measured in dollars) plotted on the vertical axis and *p* (ranging between 1 and 0) on the horizontal axis (Bigsby and Crequer, 1999). Assuming that point estimates of ED (and therefore EC and *p*) can be determined, it is possible to show how two commodities can share a unique value upon an iso-risk line (e.g. IR_2) whilst having different values for EC and *p*,

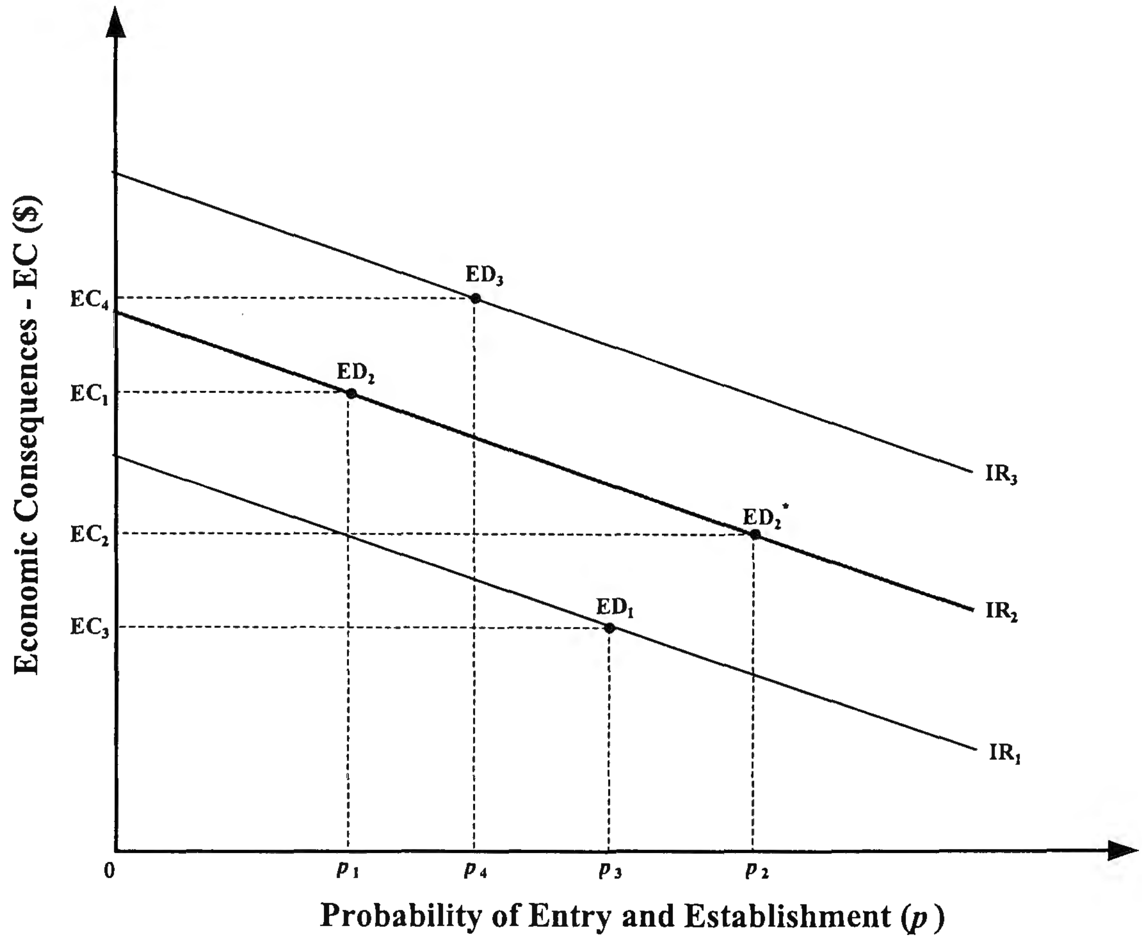

Figure 5.1: 'Iso-Risk' Framework (Bigsby, 2001)

and thus present the same quarantine threat[49]. Moreover, the further the iso-risk line from the origin, the greater the quarantine risk presented. Hence, ED_2 presents the same quarantine threat as ED_2^*, a greater threat than ED_1, and a smaller threat than ED_3.

There are two main advantages of using such a method to assess commodity-based risk. Firstly, it allows all goods to be assessed using a common measure of potential risk, which in turn allows goods to be evaluated relative to one another on a

[49] Due to the uncertainty surrounding estimates of both determinate variables, it is difficult to arrive at a point estimate of ED. It is more practical to form a probability distribution of possible outcomes based on the distributions of EC and *p*. Nevertheless, to keep things as simple as possible, assume a point estimate can be formed pertaining to a particular pest.

common basis (Bigsby and Crequer, 1999). This, in itself, is significant in that the pest organisms associated with commodities can be very different biologically and in the manner they affect their hosts, yet goods may still be compared and ranked according to one common monetary measure. It follows that a quarantine authority who is able to assess pests on this basis can channel funds into protection activities against high risk pests and away from those whose risk can be tolerated[50].

The second advantage lies in the ability of the iso-risk framework to openly express a standard by which pest risk can be assessed. For instance, if the iso-risk line for IR_2 is proclaimed a standard above which the risk presented by a commodity is unacceptably high, it is then possible to identify those commodities to be restricted, and those presenting a tolerable level of danger. Such a standard can be termed the *Appropriate Level of Protection* (ALOP), defined in Henson (2001) as "...that level of protection deemed to be acceptable and which the SPS measures applied [by a trading entity] aim to achieve". So, if the ALOP resembles that of Figure 5.1, the decision of whether or not to permit imports of the two commodities corresponding to ED_2 and ED_2^* is marginal since they fall on the frontier of acceptable risk. The decision relating to imports of the goods associated with ED_1 and ED_3 is more straight forward (at least conceptually). ED_1 represents a level of risk below that corresponding to the ALOP, and hence imports of the good concerned would be acceptable, whereas ED_3 represents an unacceptably high level of risk and there are grounds for restricting imports of the

[50] The term *high risk* is used to describe a commodity with a relatively high number of pests per unit, and/or a relatively high expected damage cost from pest incursions resulting as a direct consequence of its importation.

product concerned despite the risk of it entering being lower than the product represented by ED_1[51].

Attempts have recently been made to conceptualise the welfare effects of trade and pest risk across different commodities traded internationally. Snape and Orden (2001), for instance, present a simple diagram illustrating the traditional 'risk focused' verses a benefit/cost approach to assessing the relative merits of trading goods potentially posing SPS risks. The monetary value of each product's iso-risk curve is plotted along the horizontal axis, while the 'traditional' gains from trade are shown on the vertical axis[52]. The ALOP is depicted as perpendicular to the horizontal axis corresponding to a pre-determined level of acceptable risk. Using this framework, the relative merits of importing products can be assessed by comparing the gains from trade with the expected level of damage under respective import conditions.

Nevertheless, such an exercise is not possible in practise since it is unclear just what level of expected damage constitutes an ALOP. This ambiguity stems from difficulties encountered in the risk assessment process through which its *critical value* is determined, for this merely provides a means of forming an approximation of pest risk based on scientifically plausible hypotheses rather than established facts (Somogyi, 1999). Consequently, risk assessment involves subjective elements, making it difficult

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[51] By summing the expected damage estimates of pests associated with specific commodities, the IAs produced by DAWA effectively identify the relevant iso-risk curve for that commodity. However, the ALOP used to determine whether or not the risk posed by the commodity is socially acceptable is unspecified.

[52]The term 'traditional gains from trade' is used to describe the net social benefits resulting from trade excluding the effects of pest-induced supply curve shifts. The costs of treatment or testing for quarantine purposes are included in traditional gains from trade (Snape and Orden, 2001).

to develop international guidelines on appropriate evaluation techniques, or to reach an international consensus regarding an ALOP specification (Somogyi *et al*, 1999; Henson, 2001). This partly explains why no WTO Member has articulated its ALOP with any degree of precision (Gascoine, 2001).

The politically sensitivity nature of quarantine issues also goes some way to explaining this situation, particularly where human health is concerned. Conventional neo-classical demand analysis for health care is often challenged by the view that health is such an important good that it can not be traded off against other goods that society consumes. While it may not be the case that preferences for health are lexicographic, they may be relatively high (Besley, 1989)[53]. To infer just how high society values such goods by way of an explicit policy statement concerning the ALOP is to court political disaster. As Gascoine (2001) points out, "...stakeholders are likely to be more comfortable with a policy statement that risk of illness or death from, say, pesticide residues in food is to be minimised than with a statement that a certain number of illnesses or deaths per million of exposed population per year is regarded by government as acceptable"[54].

Another factor to consider in relation to the practical use of commodity-based expected damage assessments is the lack of comprehensive data on the economic consequences and probability of entry and establishment of pests associated with a certain commodity. Hinchy and Fisher (1991) argue that ideally, when estimating expected pest damage a probability distribution of the possible outcomes should be produced to reflect the uncertainty inherent in such a figure. The same will hold true for

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[53] Whereby consumer preferences for health are evaluated regardless of preferences for other goods and services.

[54] A similar dilemma arises when dealing with environmental health, which is discussed in section 7.3.

commodity-based assessments. Given a distribution of outcomes based on a probability distribution for both the economic consequences and probability of entry and establishment of relevant pests, a decision maker would be in a position to make a better-informed assessment of the appropriate management actions than would be the case with only a point estimate (Bigsby, 2001). However, in practice there is often insufficient information to attempt to form probability distributions[55].

5.4 An Operational Framework

Despite the problems inherent in the 'Snape-Orden' framework outlined in section 5.3, it remains possible to use it in practice by concentrating on *measureables*. That is, rather than relying solely on expected damage estimates involving subjective probability and impact assessments, a more effective decision-aid can be constructed using observable time series price and quantity data to measure the gains from trade under different scenarios, as demonstrated by the aggregate and spatial modelling techniques outlined in chapters three and four. If the welfare gains resulting from trade can be measured, it is possible to identify the minimum value of expected damage that would neutralise the economic impact of trade in a commodity susceptible to exotic pests.

Under such an approach, the objective of economic assessments becomes the estimation of that level of Expected Damage (ED) resulting from the importation of a

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[55] For instance, in evaluating the economic consequences of importing fire blight into Australia, Hinchy and Low (1990) were unable to produce adequate distributions (section 2.4.2). Instead, estimates of the best and worse case scenarios were formed, and a point estimate simply selected to reflect an intermediate case on which to base calculations.

commodity (c) which is required to exactly offset the gains from trade stemming from its importation (GT)[56]. This represents the *critical level* of ED.

i.e. $$\text{ED}_\text{c} = \sum_{i=1}^{n} \text{EC}_i \times p_i \geq \text{GT} \qquad (5.2)$$

In terms of the iso-risk framework described in section 5.2 (Figure 5.1), such an estimate will indicate the iso-risk line that is relevant to the commodity in question.

By assuming quarantine policies reflect WA's ALOP for interstate imports, the minimum value of ED_{ALOP} in Figure 5.2 can be estimated *ex post* using the gains from trade under a quarantine-restricted trade scenario. The critical level of expected damage required to exactly offset the gains from trade in the product c with interstate quarantine measures in place reflects that level of damage above which society is unwilling to risk importation. It follows that by measuring the change in the traditional gains from trade resulting from a move from a free trade to a quarantine-restricted trade setting (ΔGT), an estimate of the change in expected damage (ΔED) is formed in which ED_{ALOP} is implied. In the absence of a clear specification of the ALOP from relevant quarantine authorities, this method of approximating its true position provides useful information in discussing

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[56] Recalling section 2.4, this is similar to the approach adopted by Hinchy and Low (1990) and Hafi *et al* (1994). In both cases, an indication of the break even, or critical *probability* of pest incursion and establishment (p_{crit}) was provided by estimating the net welfare gain, or net change in consumer and producer welfare resulting from a decision to allow the importation of a potentially infested commodity (GT) and dividing through by a hypothetical economic consequence of the entry and establishment of each pest i associated with that commodity ($\sum_{i=1}^{n} \text{EC}_i$), of which there is a total of n (ie. $p_{crit} = \frac{\text{GT}}{\sum_{i=1}^{n} \text{EC}_i}$).

The value obtained for p_{crit} therefore represents that level of pest risk that will equate costs and benefits.

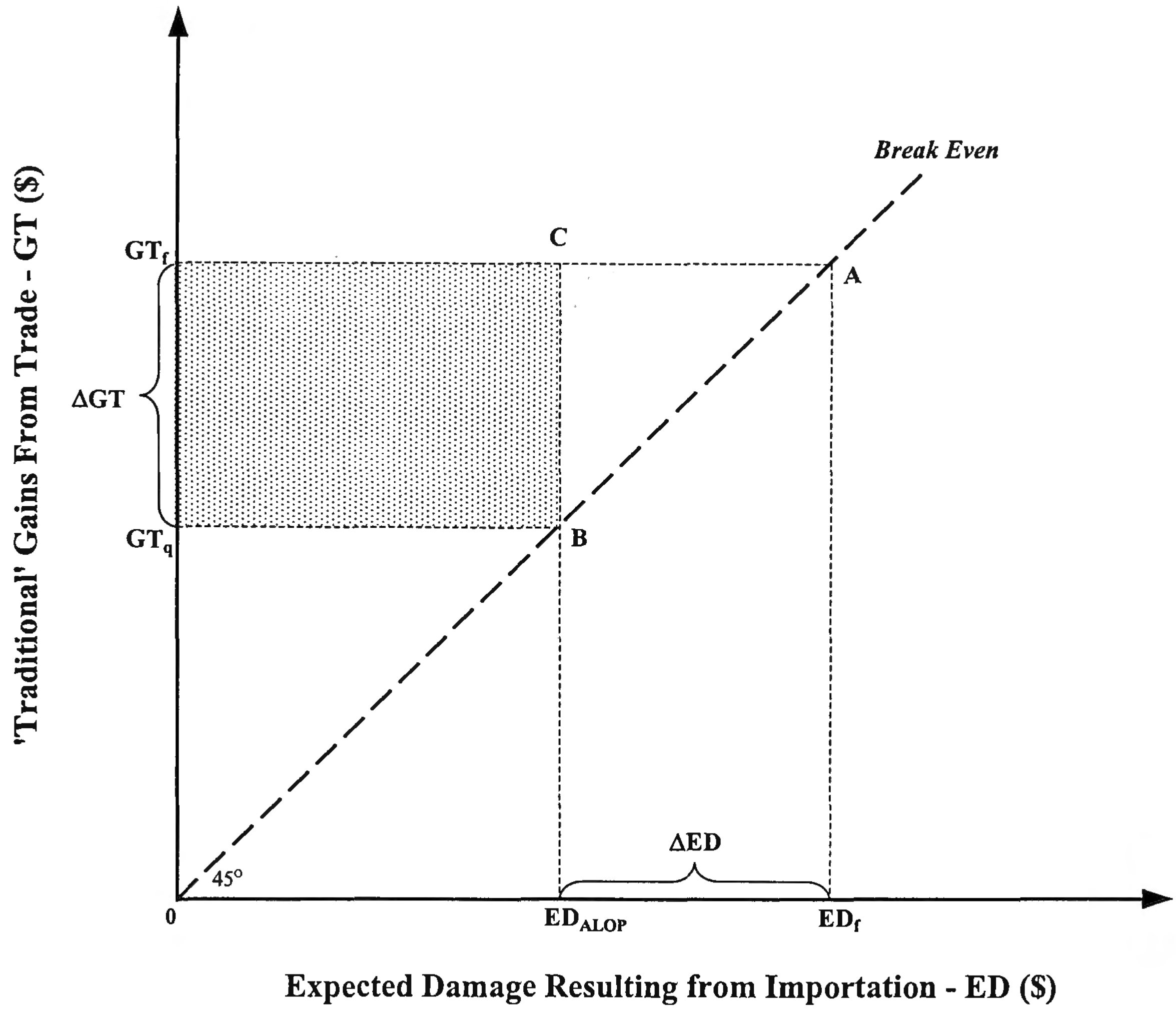

Figure 5.2: Implied Appropriate Level of Protection (Snape and Orden, 2001)

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the welfare implications of quarantine policies, and provides some insight into into perceived social preferences with regard to quarantine.

5.5 Interpretation of Results

The provision of a means of expressing quarantine motivation explicitly represents a departure from the traditional use of (*ex ante*) economic analysis to extract estimates of likely production losses resulting from pest incursions with limited information (as with IAs). In such assessments the welfare of consumer society is not taken into consideration, necessarily distorting the information transferred to quarantine decision-makers, and leading to quarantine decisions misrepresentative of social preferences.

Nevertheless, analyses biased towards the supply side have become recognised as standard practice when examining interstate quarantine policies (eg. McElwee and Cook, 1999; McElwee, 2000; Cook, 2001b). Results of economic analyses that take the welfare of both consumers and producers into account may therefore be politically sensitive, and should be used with caution. For example if such analyses were to reveal that the WA community would receive a boost in welfare if all trade barriers to a particular agricultural commodity were abolished, one could expect domestic producers to lobby for a full policy reversal due to the pressures of increased competition. However, this may also work in reverse. If a foreign market were to enforce costly chemical treatments on commodities imported from WA to protect against a certain pest, it may be possible to demonstrate to foreign governments that the welfare of their communities may be lower than if they were to relax the required treatments for importation.

5.6 Conclusions

This chapter has provided an introduction to an alternative approach to the economic modelling of quarantine issues. A framework was developed in which the results of the aggregate and spatial partial equilibrium modelling techniques presented in chapters three and four can be used to supplement subjective assessments of expected pest damage. This relatively simple model effectively inverts a conventional benefit costs analysis by measuring consumer losses rather than probable producer gains. By doing so it has a much lower requirement for data, and may therefore be incorporated into the conventional IRA template with minimum effort. If so, decision-makers can receive a better indication of the social welfare implications of their actions relating to quarantine.

Rather than speculate as to social and political reaction to the inclusion of consumer welfare in quarantine trade analyses, it is more relevant to discuss the findings of this revised approach when applied to specific cases. Chapter six uses the findings of the aggregate and spatial modelling approaches of previous chapters applied to the mango and tomato case studies. Having calculated a critical level of expected damage for each commodity, the ALOP consciously or unconsciously employed by WA quarantine authorities is deduced. This presents some interesting issues in terms of conformity with the SPS Agreement, and demonstrates the type of information that this alternative approach to modelling quarantine issues can bring to light.

6. The Implied Appropriate Level Of Protection

6.1 Introduction

Information constraints concerning the likelihood of pest introductions and establishment, and their likely impact in foreign environments make it particularly difficult to design appropriate protection strategies on the basis of conventional expected damage estimates. While the aggregate and spatial partial equilibrium models developed in chapters three and four are capable of providing a useful supplement to these methods, they can also provide a useful insight into the Appropriate Level of Protection (ALOP) being exercised in WA. If it is true to speak of quarantine policies as reflecting a society's tolerance of import risk, then by measuring the consumption benefits forfeited in the interests of safety it becomes possible to specify the level of expected damage corresponding to the ALOP relating to that society (ED_{ALOP}).

This chapter demonstrates that through the provision of an ED_{ALOP} estimate on a case-by-case basis, the extent of expected pest damage being prevented by quarantine can be viewed in relation to the size of the industries it endeavours to protect. Section 6.2 uses the examples provided by the mango and tomato case studies of chapters three and four to reveal information about the ALOP expressed by interstate quarantine regulations. However, external economies produced by interstate SPS measures make it very difficult to separate an implied value of ED_{ALOP} into its component parts. Not only does it reflect the value of the industries protected by quarantine, but also community attitudes to environmental health, rural community cohesion, cross-industry impacts and to risk. These external effects partly explain why no trading nation has yet specified a level of protection appropriate for its individual circumstances, and why the use of techniques to extract implied levels of protection are required in the analysis of SPS policies. They may also explain inconsistency in quarantine protection levels for different industries if the *precautionary principle* is exercised by regulatory authorities. These issues are discussed in section 6.3, before section 6.4 concludes.

6.2 Western Australia's Implied Appropriate Level of Protection

6.2.1 Expected Damage Estimates

Recall from section 5.4 that the value of expected damage that exactly offsets the gains from trade in a product with interstate quarantine protocols in place indicates that level of damage above which society is not willing to risk importation. This was termed the ED_{ALOP}. The objective of the economic assessments of chapters three and four, using the aggregate and spatial models respectively, involves the estimation of the level of damage expected to result from importation that will exactly offset the gains from trade, or the *critical level* of expected damage. Since it can be assumed quarantine policies are a reflection of a trading centre's ALOP, the minimum value of ED_{ALOP} for a product can be estimated from the gains from trade under a quarantine-restricted trade scenario[57].

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[57] The terms ALOP and ED_{ALOP} are repeatedly used throughout this chapter, and require clarification. ALOP describes the equivocal protection standard quarantine authorities are motivated to achieve. The term ED_{ALOP} describes a suggested means of defining this standard in terms of expected damage to domestic agricultural industries resulting from imports from other regions.

Table 6.1: Implied Level of Protection Afforded to Mango and Tomato Imports in to WA

	Mangoes	**Tomatoes**
Minimum Value of ED_f Required to Offset GT_f	\$ 188,000	\$1,853,500
Minimum Value of ΔED Required to Offset ΔGT	\$ 55,700	\$ 784,700
Implied ED_{ALOP}	\$ 132,300	\$1,068,900
Post-Quarantine Producer Surplus	\$ 588,900	\$6,123,400
ΔED as a Percentage of Post-Quarantine Producer Surplus	9.5%	12.8%
ED_{ALOP} as a Percentage of Post-Quarantine Producer Surplus	22.5%	17.5%

It follows that the aggregate and spatial trade models developed and applied to the mango and tomato case studies provide an insight into the level of import risk WA quarantine authorities are prepared to accept. The results of the aggregate assessment of domestic producer and consumer surplus under a closed economy, a free trade and a quarantine-restricted trade scenario are summarised in Table 6.1.

6.2.2 Interpretation

Table 6.1 provides a description of the level of pest damage that must be prevented for there to be no net social welfare impact resulting from SPS measures. In the case of mangoes, the *Minimum Value of ΔED Required to Offset ΔGT* is estimated to be in the order of \$55,720. So, there would be zero economic effect of quarantine policies if there was a 19 per cent chance of losing 50 per cent of producer surplus, a 28.5 per cent chance of losing a third of producer surplus, and so on. In the case of tomatoes, the *Minimum Value of ΔED Required to Offset ΔGT* is estimated at around $784,700. These findings are of interest from both an economic and legal perspective since their principal implication is that the ALOP does not appear to be equivalent across commodities.

Due to the relatively large size of the industry, the drop in the domestic price of tomatoes induced by free trade across State borders is expected to produce greater gains from trade than in the case of mangoes. This means the minimum value of expected damage required to offset these gains from trade under a free trade scenario (i.e. ED_f in Figure 5.2) is significantly larger for tomatoes. Similarly, the impact of interstate quarantine measures to prevent the entry and establishment of pests associated with each commodity is more severe in the case of tomatoes. Table 6.1 indicates that to have a negligible economic impact, SPS measures must achieve a reduction in ED equivalent to 12.8 per cent of the total (post quarantine) producer surplus in the case of tomatoes, and 9.5 per cent in the case of mangoes. This would suggest that a more stringent protection strategy is in place for larger industries in that regulatory authorities are prepared to accept a more substantial net welfare loss to maintain a pest free status than for smaller industries.

When related back to the total producer surplus for each industry the implied ALOP is of similar magnitude for both the small and large industries. Based on the results, it could be postulated that ED_{ALOP} for WA related to interstate trade in a horticultural product is approximately 20 per cent of the total domestic producer surplus of the industry concerned. Thus, if the ED_{ALOP} currently used as a 'standard' by WA quarantine authorities is to have a neutral impact on net social welfare, there must be believed to be at least a 20 per cent chance of losing the entire producer surplus of relevant crops as a direct result of interstate trade, or a 40 per cent chance of losing half the producer surplus of relevant crops, and so forth. This, in effect, represents the extent of WA's interstate quarantine system[58].

Such a result implies the use of multiple ED_{ALOP} standards for different industries, which in turn has some intriguing implications in terms of WTO legality. In the mango example, the iso-cost line forming the standard of import risk WA society is willing to accept defines all possible combinations of entry and establishment probabilities and economic damage with a product of just over $130,000 (Table 3.1). This is very different from that implied by the tomato example where the relevant iso-cost line describes all probability of entry and establishment and economic damage with a product of almost $1.1 million (Table 6.1). This does not suggest a *consistent* approach to import risk management at the interstate level. At the same time, it can not be said to represent a blatant breach of the SPS Agreement. Generally, consistency can be viewed as a long-term goal for a quarantine system and to this end the partial equilibrium approaches developed in chapters three and four may play an important role in facilitating moves towards this objective. With no precise definition of an ALOP provided in the guidelines, the SPS Agreement permits a degree of flexibility in the application of standards. An ALOP is not necessarily expected to be applied with absolute consistency, but any differences should be non-arbitrary and justifiable (Henson, 2001). From the results of the partial equilibrium models, it would appear that SPS measures applied at a State level are in need of justification (at least in the long term) since they display inconsistency.

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[58] It is worth noting that the protection offered by interstate quarantine measures is additional to the protection received through national quarantine measures.

In some ways, it is not surprising to find that the ED_{ALOP} is much larger (in terms of dollar value) for relatively large industries like tomatoes. This perhaps reflects the extent of linkages larger industries have throughout the rural community when compared to others of a smaller size, and the consequences of a harmful event to those members of the community employed along the *value chain*[59]. However, the inflationary effects of quarantine measures will also have a much larger impact on net social welfare change since the average consumer demands more of it in comparison to other commodities, like mangoes. Despite it being easier to justify protection to small and developing industries (i.e. having a relatively minor impact on net social welfare) in economic terms, the ED_{ALOP} implied in Table 6.1 would suggest that larger horticultural industries receive a higher degree of protection in practice. The cost of this protection is borne by fruit and vegetable consumers.

Protection for larger industries is in keeping with the traditional perception of quarantine affecting only producers of host commodities, a concept that seems to have been indelibly etched in Australia's social consciousness. A recent example involves community concerns over the risk of the fire blight disease entering Australia as a result of importing apples from New Zealand, discussed in section 2.4.2. Despite two IRAs having been completed on the risks of importing the disease through New Zealand apple imports (Hinchy and Low, 1990; AFFA, 2000), both of which found the risks to be of an 'acceptable' magnitude, regional communities dependent on apple growing in areas like West Gippsland in Victoria do not accept this finding. The front page of *The Warragul and Drouin Gazette* on the 31st of October 2000 begins "West Gippsland's multi million dollar apple industry is at risk of decimation if New Zealand apples are

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[59] See Islam and Johnson (1997) for a discussion of the linkages between agricultural industries and the WA economy. This is discussed further in section 7.2.3.

imported to Australia..."(Turner, 2000). The fact that New Zealand continues to have a strong apple industry in the presence of fire blight casts considerable doubt on such a statement, and hints that perhaps a greater risk comes from international competition. Nevertheless, it is significant that the emphasis is placed on potentially affected domestic producers, despite them making up only one side of the equation. As mentioned repeatedly in previous sections, the other side concerns consumer welfare, and it should be taken into account if quarantine systems are to be truly representative of social preferences. The notion of 'quarantine at all costs' is no longer a viable proposition for any WTO Member.

6.3 The 'Precautionary Principle'

While it is conceded the commodities examined here are only two of a host of horticultural commodities traded across State and Territory borders, the results obtained permit a certain amount of 'qualified' speculation with regard to the perceived ALOP for WA society. Even though the tomato industry enjoys a higher degree of quarantine protection, as a general statement the overall level of protection afforded to domestic industries appears high. This is especially true for mangoes given that pests entering the State in contaminated fruit through the Perth market must overcome considerable geographic obstacles if they are to become established in prominent growing areas. Such a result is to be expected considering the national ALOP has been described as "very conservative" despite never having been specified as such (AQIS, 1999; Tanner, 2001).

The reasoning behind this apparent conservatism may lie in what has come to be known as the *precautionary principle*. This can be defined as the adoption of a risk averse attitude to import risk such that measures are taken to avoid the worst possible incursion scenario in circumstances where the probability of such an occurrence can not be determined accurately. In relation to plant health, this describes the situation for a great many pests. While scientific knowledge of vertebrate pests is extensive, the same can not be said for weeds and invertebrate pests. Of those species currently known to science, there may be much to learn in terms of their resilience when faced with new environmental conditions and population pressures. In Australia, around 20 new species of pests, weeds and diseases are accumulated every year, and predicting their behaviour in an environment they have not been previously observed in inevitably involves some amount of 'guess work' (Lonsdale *et al*, 2001). Furthermore, in some circumstances invasive pests may be completely unknown to science, making it impossible to ascertain their destructive and spread capabilities with any degree of certainty.

While growing conditions in WA are in many ways unique, reasonable deductions about pest behaviour in the event of incursions can be made through the study of pests established elsewhere in Australia. However, it must be pointed out that this need not always be the case. The parasitic weed Broomrape (*Orobanche aegyptiaca*), which was discovered in SA in 1995 and is now present in over 500 hectares, provides an example. Due to a local eradication campaign, the full destructive capabilities of Broomrape have yet to be established. It is not clear what native plant species (and indeed invasive weeds that have already become established) can be used as hosts by the plant, and therefore how far it is likely to spread in the event of an outbreak (Milne, 2000; Pratt, 2001). Furthermore, an effective management strategy for the weed is not known, making it difficult to postulate the likely increase in the average variable cost of production of viable crops[60]. Until such time that the weed has been thoroughly studied, it may be advisable that WA's quarantine system exercise the precautionary principle and make a conscious effort to exclude it.

The SPS Agreement itself does not use the term 'precautionary principle', but Article 5.7 states that "in cases where relevant scientific information is insufficient [Members may provisionally adopt] sanitary and phytosanitary measures on the basis of available pertinent information". The SPS Agreement goes on to stipulate such action can only be undertaken if a concerted effort is made "to obtain the additional information necessary for a more objective assessment of risk and [to] review the sanitary or phytosanitary measure accordingly within a reasonable period of time" (GATT, 1994).

There are two points to note about Article 5.7 that suggest preventative measures against extended use of the precautionary principle may be difficult to put into effect. Firstly, the precise definition of a "reasonable period of time" is ambiguous, and can only be clarified by judgements made in the WTO Dispute Settlement process. While a panel should bear in mind that Member governments can be expected to act from perspectives of caution where risks are deemed irreversible, appropriate time constraints are unclear (WTO, 1998; Goh and Ziegler, 2001). Secondly, no where in the article is it clearly stated to whom the responsibility of obtaining the necessary "additional information" belongs, the importing or exporting Member (Nunn, 2001). The approach

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[60] This includes costs involved in crop rotation, which in themselves are difficult to estimate. For instance, in the case of potatoes, the industry is regulated. If a grower is not permitted to grow potatoes due to a Broomrape eradication campaign, it may be possible to sell his/her allocated production area to another grower, or plant an alternative crop. Either way, the costs involved in not growing potatoes are unclear.

demonstrated in WA interstate quarantine measures is therefore questionable if indeed it is the precautionary principle being applied, albeit implicitly.

If WA is a pest damage minimiser, as opposed to a social welfare maximizer, it is in the interests of the State and regulatory authorities to maintain the status quo, at least until such time as a WTO Member protests against behaviour it considers unfair. In view of this, the same behaviour from other trading entities who sacrifice consumer welfare to protect the welfare of their domestic producers can not be discounted. This has implications for WA/Australian exporters trying to tap into overseas markets since it may be possible to demonstrate that a net social welfare loss will result in a country from a ban in imports from WA. This situation may well arise if consumer interests are one day taken into account when conducting import risk analyses.

6.4 Conclusions

The results of the partial equilibrium exercise to extract an implied ALOP for WA reveal a very low tolerance to accept import risk. This supports the long-standing belief that WA's quarantine laws are notoriously strict, but demonstrates a reluctance to adopt the principles of the Nairn review and the WTO with regard to risk assessment. The findings presented in this chapter suggest that there may be an element of inconsistency in WA's application of interstate SPS measures, but this should perhaps only be viewed as a problem if it persists in the long term. There may be some use of the precautionary principle, but this is difficult to determine in light of the vagueness with which WTO Member guidelines specify the obligations of trading partners in that regard. Although this discussion has stopped short of passing judgement on the approach of WA quarantine authorities concerning WTO compliance, the techniques used to imply the prevailing attitude underpinning the ALOP may play a valuable role in future analytical work which aims to be more critical.

As insightful as partial equilibrium trade models can be, there are almost always factors that must be omitted. Although it must be accepted that modelling represents a simplification of reality, but when dealing with quarantine risks with broad ramifications information omissions may lead to misguided perceptions of the expected economic effects of action or inaction. For instance, secondary industries using agricultural imputs whose supply is subject to pest-induced variability may suffer because of the effects of an incursion, but this is not accounted for in the models presented. Environmental concerns may also pose a problem if a pest inflicts significant damage on local ecosystems since this damage is notoriously difficult to quantify. Furthermore, there may be a willingness of society to sacrifice a level of consumer welfare to guard against such an incursion. These inadequacies of partial equilibrium are the subject of chapter seven.

7. Acknowledging The Limitations Of Analytical Trade Models

7.1 Introduction

The aim of previous chapters has been to develop analytical models that use quarantine-induced consumer welfare losses to tease out an expected pest damage estimate corresponding to an Appropriate Level of Protection (ALOP) standard (ED_{ALOP}). While the application of these models reveals some interesting findings in terms of WA's stance on import protection, it is important to realise their shortfalls. A model is essentially a simplification of reality, but where exotic pest introductions are concerned there are many complex and 'risky' variables a model must attempt to encompass. Invariably, some will not be taken into account of in the modelling process, and in certain circumstances this may make model outputs inaccurate.

In the partial equilibrium models used to derive estimates of ED_{ALOP}, there are essentially three omissions that must be acknowledged. The first relates to *externalities* of quarantine caused by the existence of non-host specific pests and secondary industries affected by disruptions to their supply of inputs (discussed in section 7.2). The second also relates to an externality of quarantine, environmental health (7.3). This is treated separately since the failure to incorporate environmental values and expected damage from pest introductions represents a prominent and 'notorious' failing of economic models. Cost-effectively overcoming it is difficult, and may require the extensive use of qualitative information if the environment is to receive a socially acceptable level of protection. Finally, there are dynamic elements that the static framework used to derive estimates of ED_{ALOP} can not represent (7.4). These not only relate to pest spread scenarios over time, but also to the strategic behaviour of those affected by pests. In identifying these weaknesses of the analytical approach developed throughout previous chapters, areas where future research efforts may be directed can be identified.

7.2 Externalities Created by Quarantine

7.2.1 Polyphagous Pests and Cross-Industry Impact

Just as regulatory authorities endeavour to minimise pest damage by focusing on a multitude of exotic pests, many organisms in the natural world have been using a risk management system for millennia. Rather than attacking one host exclusively, often pests will have a variety of preferred hosts to maximise their chances of successful colonisation of new areas. The implications for quarantine strategists are that protocols to keep out a particular pest from one domestic industry may have a positive effect on the welfare of other industries potentially attacked. By definition, this represents an *external economy*, or positive externality that is not appropriated by the original industry at which the policy was targeted.

This presents a limitation of the framework developed in previous chapters in that it was assumed pests were host specific. In applying the aggregate and spatial trade models to real situations on a pest by pest basis, this simplistic assumption will frequently need to be relaxed to allow multiple markets to be examined. For instance, if the producer and consumer welfare effects caused by quarantine protocols to restrict the entry and establishment of Queensland fruit fly (Q-fly) are the focus of attention, many markets must be included in the calculations. Since the pest has an extensive host range including the majority of fruit and vegetable crops grown in WA, the data requirement to complete such a task would be large if the aggregate model is used, but since this comprises mainly of price and quantity data it is not expected to pose a problem (HPC, 1991). However, where component regions of individual industries are heterogeneous and warrant the use of the spatial approach, the information requirement may be prohibitively high. Specifically, information on the average variable cost of production for certain crops in given regions seldom exists, necessitating the use of an aggregated approach.

An association with polyphagous, or multi-host pests may lead to quarantine measures being relatively strict since there are other markets to be considered. In terms of the mango and tomato cases studies, this may well explain why tomatoes receive a greater level of protection. Pests such as Q-fly, melon thrips and European red mite have the capacity to affect many different markets. But, without including measures of both producer and consumer surplus losses in these markets too, the benefits and costs of import protocols can not be assessed on the basis of a single market[61]. It is therefore difficult to speculate what impact these restrictions have on net social welfare when each of the markets is considered. Hence, the ED_{ALOP} related to specific pests (as opposed to commodities) is indeterminate.

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[61] However, this would be a simpler task than forming an expected damage estimate across each industry affected by these pests since it mainly relies on readily available price and quantity information (at an aggregate level).

7.2.3 *'Flow-On' Industry Effects of Pest Damage*

Due to their use as inputs into the production processes of other industries, changing production environments for agricultural goods can have indirect as well as direct consequences. Exploring the nature of these inter-industry relationships within an economy (and consequential flow-on effects from exogenous shocks) lies at the heart of the *input-output* analytical technique first outlined in Leotief (1951)[62]. Because of the interrelationships between industries, the efficient allocation of resources in one is dependent on the input requirements of all other industries in the economy. According to this theory, any *correct* (i.e. shortage-free as well as surplus-free) set of output levels for all industries in an economy must be consistent with all the input requirements in the economy so that no bottlenecks may arise anywhere (Chiang, 1984).

To illustrate, take a typical agricultural industry. Beyond the farm sector, industries using the produced commodity in their production processes might include storage, transport and handling industries, wholesale marketing agents, primary processing industries, packaging and distribution firms, secondary processing industries, retailers and exporters. If a pest is introduced to the initial agricultural industry and causes a reduction in farm output, all subsequent (or 'down stream') industries dependent on it as a source of inputs will also be affected[63]. It follows that if quarantine

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[62] Price-based *General Equilibrium* (GE) models can also be used to determine the flow-on effects of exogenous shocks, but are not discussed here in the interests of simplicity.

[63] It is interesting to note that under a quarantine-restricted trade regime domestic marketing agents have less produce to market than under a closed-economy situation.

measures can be employed to reduce the likelihood of the pest entering in the first place, indirect, or *flow-on* benefits accrue to each sector 'beyond the farm gate'[64].

Input-output tables record all transactions of individual enterprises with other economic agents within a given accounting period, inputs being what it buys and outputs what it sells. By doing so, they provide an intricate dissection of the intermediate transactions in an economy by describing the supplies and uses of the products of an entire economic system (Islam and Johnson, 1997). The table entries must balance, as the total expenditures of all groups equal the total receipts of all groups (and investments equal savings). Using such a table, the flow-on effects of a yield-reducing pest in one industry can be seen on all the other industries which make up the economy by looking at the linkages between each. For instance, it may be of interest to determine which sector absorbs the most agricultural products, or how much of an agricultural industry's output is used as inputs to other industries.

An important application of input-output tables lies in the calculation of *input-output multipliers* that provide a statistical indication of the extent of flow-on effects resulting from an exogenous shock, such as a pest outbreak. An input-output multiplier is simply a ratio of the flow-on effects to the initial effect on a particular industry, thereby providing a measure of the dependence of other enterprises within the economic community on the affected industry. One commonly used multiplier is a *Type 2A output multiplier* which indicates by how much the value of output across all industries of the economy will change in response to an exogenous change in the output of one

[64] This ignores strategic behaviour on the part of secondary sectors (eg. sourcing inputs from other non-affected sources). This possibility is discussed in section 7.4.

particular industry (Islam and Johnson, 1997)[65]. For example, assume the output multiplier for a hypothetical horticultural industry is 2.04. This implies that a $100 fall in the value of output produced by this industry will lead to a $204 total fall in the value of output in all other affected sectors of the economy (including the initially affected industry).

Estimates of input-output multipliers specific to WA are readily available and may be incorporated into economic assessments of (potential) pest damage. Clements and Ye (1995) developed an input-output table for WA using a template of the national input-output table presented in ABS (1996). However, in response to concerns that this model was not truly representative of WA agriculture it was re-visited by Islam and Johnson (1997) [66]. The resultant input-output table was comprised of 111 sectors, 10 of which were agricultural sectors. From this, the estimates of type-2A output and employment multipliers presented in table 7.1 were obtained.

Such estimates can be used in conjunction with expected damage estimates to provide an indication of broader economic effects of pests beyond the farm sector. Recall from section 6.2 that the ED_{ALOP} calculated for mangoes and tomatoes in WA was in the order of $132,300 and $1,070,000 respectively. For the quarantine policies

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[65] Input-output multipliers can be expressed in a variety of forms, of which type-2A is one. Other forms of expression include initial effects, first round effects, industrial support effects, production induced effects, consumption induced effects, simple multipliers, total multipliers, type-1A multipliers, type-1B multipliers, and type 2B multipliers. Precise definitions of each are to be found in Islam and Johnson (1997), Appendix C.

[66] It was felt that WA agriculture differs from a national average due to agro-climatic conditions (eg. soil types, topography, rainfall patterns, temperatures and hydrology), implying that the technological structure and sales patterns on which agricultural industries were formed would also differ (Islam and Johnson, 1997).

effecting these commodities to break even (in terms of their effect on consumer surplus), the damage avoided through pest exclusion must be at least these amounts. However, the output multiplier corresponding to horticultural commodities in table 7.1 implies that the level of avoided damage necessary to offset consumer welfare losses are actually around half of these amounts. For every dollar of output saved through pest exclusion, approximately two dollars in flow-on benefits accrue to downstream industries. If these beneficiaries are taken into consideration, the ED_{ALOP} for mangoes may be closer to $66,000 and $535,000 for tomatoes. This suggests that the omission of information concerning flow-on effects of quarantine-induced changes to domestic industry production environments can lead to an underestimation of the ED_{ALOP}.

Table 7.1: Type-2A Output Multipliers for Agricultural Industries in Western Australia

Primary Agricultural Industries	Estimated Output Multiplier
Sheep Meat	1.64
Sheep Wool	2.05
Grain Cereals	1.51
Grain Pulses and Oilseeds	1.74
Beef Cattle	1.96
Dairy Cattle	2.08
Pigs	2.06
Poultry	2.34
Horticulture	2.04
New Industries and Other Agriculture	2.04
Mean	**1.95**
WA Mean (111-sector)	**2.26**

(Islam and Johnson, 1997).

Estimates of flow-on benefits to pest exclusion calculated in this way are almost certainly overstated since the input-output table from which they are derived assumes no 'second best' use of resources potentially damaged by the pest. In essence, this implies industries using agricultural inputs are unable to source them from unaffected areas. Assuming these industries to be profit maximising, a switch of this nature will involve costs since a slightly higher price for these inputs must be paid. But, so long as the price received for their output remains above the minimum value of the average variable cost of production they will maximise profits by remaining in business. Hence, using input-output multipliers may lead to flow-on benefits being overstated. This problem is difficult to overcome without incorporating subjective assumptions concerning the second-best input options available to producers in the area(s) affected by the pest. But, unless it is taken account of, the inclusion of flow-on benefits measured in this way in quarantine assessments may lead to an over-estimation of the ED_{ALOP} related to specific industries.

7.3 Environmental Values

Quarantine policies not only protect cultivated crops from invasive pests, but also native ecosystems that might be forced to play host to pests in the event of an incursion. But, placing a value on this protection or indeed on the entire natural environment itself is fraught with difficulty. In cases where regulatory measures protect environmental resources as well as market goods, a narrow single commodity method of assessing risk must be supplemented by other information. Generally, difficulties involved in quantifying the environmental impact of invasive pests prevent their inclusion in economic analyses of quarantine strategies. However, if policies directed by such analyses are to reflect social welfare preferences, a more formal recognition of potential ecological damage is needed.

There are numerous ecological factors that may cause non-indigenous species to become abundant and persistent when introduced to new areas. Some of these factors include:

- a lack of natural enemies to regulate pest populations;
- an abundance of prey that have not evolved adequate defence mechanisms against predation from alien species;
- the creation of artificial habitats providing favourable invasive ecosystems for exotic organisms; and
- the ability of some alien species to adapt to new environments and develop new relationships with host species.

(Pimentel *et al*, 2000)

Under such circumstances, devastating losses can be inflicted on ecosystems, which may or may not be reversible. Yet, in spite of these costs it is important to recognise that exotic pests also make a positive economic contribution that is seldom recognised. An obvious example is the humble European Honeybee (*Apis mellifera*) which has been estimated to deliver pollination services to commercial crops in WA to the value of $89 million per annum (Gibbs and Muirhead, 1998; DAWA, 2001)[67].

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[67] In light of these benefits, the labelling of honeybees as introduced 'pests' would hardly seem appropriate. However, the net benefits created by the species, taking into account human health impacts, are ambiguous.

While it is relatively easy to cite the biological causes of pest population explosions, the task of assigning values to environmental losses caused as a result is definitely not. When compared to agricultural commodities with an easily expressed annual value, the natural environment presents a more complex analytical challenge. For not only may it (or its components) have an annual value in terms of use, it may also have existence, bequest or moral values which are dependant on its continued existence, and which could extend over generations in time (Mumford, 2001)[68]. Identifying and capturing these values using stated or revealed preference techniques which are both accurate and cost-effective remains a sizeable challenge for analysts. The exclusion of such information from a regulatory decision-making process would result in policies reflecting an inaccurate interpretation of social attitudes towards the natural environment.

In light of the difficulties in extracting value for environmental goods, it is perhaps unsurprising that few estimates of ecological damage caused by the introduction and establishment of exotic pests have been put forward. An examination of the impacts of introduced pests in the United States completed by the Office of Technology Assessment states that "...from 1906 to 1991, just 79 non-indigenous species caused documented losses of $97 billion in harmful effects" (U.S. Congress, Office of Technology Assessment, 1993). However, a large number of pests were omitted from the total cost calculation on the basis of insufficient information. In a more general assessment of losses, Pimentel *et al* (2000) considered the effects of over 50,000 pest

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[68] It is also worth noting that environmental damage may go unnoticed for a long period of time before exploding into social consciousness. This is often driven by media forces. The situation is different for agricultural pests which tend to be more incremental in spread since they are (in general) more noticeable.

species to form an estimate for annual losses to the US of $138 billion, including environmental damage. However, no values were assigned to species extinctions and loss in biodiversity, or ecosystem service and aesthetics. Despite their omissions, studies of this kind demonstrate that non-indigenous species exact a significant toll (Pimentel *et al*, 2000).

Quantitative information on environmental goods is also noticeably absent from empirical analyses of damage to be expected from exotic invertebrate, weed and pathological pests of plant industries conducted for the Department of Agriculture in WA (DAWA)[69]. Due to the difficulties inherent in environmental value estimation, these assessments are supplemented by qualitative information containing possible environmental consequences of pest entry and establishment (e.g. Botha and Hardie, 2000; Pratt, 2001; Stansbury, 2001). On the basis of these assessments quarantine policies can be directed at specific commodities based on the severity of threat they are believed to present, but generally environmental concerns are considered secondary to losses in domestic producer surplus[70]. Moreover, the existence of native hosts is factored into analyses by assuming these might act as a reservoir for the pest causing continued re-infestation of cultivated areas. The possibility of species depletion or the destruction of natural ecosystems is not formally acknowledged in the process of risk quantification[71]. Unless environmental externalities such as these are included in

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[69] This refers to *Impact Analyses*, outlined in section 6.2.

[70] This does not imply that environmental losses are valued less than agricultural damage, but reflects the fact that risk assessments typically deal with pests of quarantine significance to agriculture. Hence, there tends to be greater emphasis and rigour placed on extracting estimates of likely crop damage rather than environmental damage

[71] An example is presented in Cook (2001b).

economic analyses of quarantine decisions, net social welfare effects will be understated, and the ED_{ALOP} underestimated.

7.4 Dynamics and Time

The static nature of the aggregate and spatial models developed in chapters three and four pose two time-related problems when using them to model net welfare effects of quarantine policies over several time periods. Firstly, producer surplus losses are calculated on the assumption of zero tangible opportunity cost. Once profits are lost, they are lost permanently since no assumptions are made concerning alternative, or 'next best' land uses. This implies all land, labour and capital resources displaced from the industry concerned through pressure from imported goods could not be employed profitably elsewhere in the economy. Hence, the model ignores any form of adaptive behaviour by producers, a result of which may be producer losses being overstated (Sinner, 1999). There may well be important economic, socio-economic and socio-political factors associated with any resource re-allocation to alternative, 'second best' enterprises, but it can not realistically be assumed that these would entirely prevent producer adaptation. Overcoming this shortfall requires an estimate of producer surplus that would be lost in the re-allocation, which would almost certainly involve the extensive use of subjective information.

Changes in consumer behaviour too are ignored when using a static framework. The utility functions of individuals are complex, and consumption patterns can be altered by many different factors. Consumer perceptions of a product can certainly be changed by the presence of pest. For animal products, pests and diseases with potential human health effects can lead to consumer boycotts, and a rise in the demand for rival products. An obvious example concerns the Bovine Spongiform Encephalopathy (BSE) outbreak in Great Britain, which peaked in the early 1990s. In the case of plant industries, instances of direct pest impacts on human health are rare, but the same can not be said for indirect effects. The entry and establishment of an exotic pest may force growers of particular products to employ additional chemical treatments to minimise yield losses, which in turn can damage the marketability of their produce. A loss of 'clean and green' image has the potential to significantly alter the way consumers view the product[72]. Therefore, lost pest freedom status leading to a relaxing of import protocols on imported products and downward pressure on domestic prices may not necessarily translate to an increase in the quantity of the good demanded if consumers are aware of and react to increased pesticide usage. Although difficult to predict, if such a situation were to transpire the estimated ED_{ALOP} according to a static trade model would be underestimated.

A second methodological problem lies in the fact that pest impacts are assumed to persist for one time period. The likelihood of pests affecting production in subsequent time periods is not altered by their presence in previous time periods. However, is not valid where the effects of a pest carry over from one time period to the next. For instance, a variety of horticultural enterprises like orchard fruit growing and viticulture rely on dynamic production processes where inputs purchased in one time period yield benefits over a number of future periods. A pest outbreak affecting inputs in one time period will tend to have carry-over effects in subsequent time periods which may be greater than, equal to, or less than damage suffered in the initial time period.

Hence, such an industry is effectively in a pest-affected state over that time

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[72] In principle, ensuring an optimal pesticide tax regime is in place may provide a solution to this problem by curtailing the use of harmful products, or products perceived to be damaging to human and/or environmental health.

regardless of whether the pest was eradicated in the first time period, so an assessment based on a snap-shot of the epidemiological evidence does not capture the complexities of pest impact. This poses a problem when attempting to model the expected damage of exotic pests over time in that data requirements to track their effects are large. In most cases it is necessary to use deterministic models where spread and impact under different management strategies over time are known with certainty.

An alternative technique, *a Markov chain model*, is presented in Hinchy and Fisher (1991). This is a dynamic mathematical model in which the probabilities of events in a time period are determined by the occurrence of events in previous time periods. A *finite* Markov chain is said to define a system where an agent faces the prospect of one of a finite number of events, X_1, X_2, ..., X_n, occurring in any one time period, t. The probability of an event X_i occurring in a time period, $t + 1$, conditional on event X_j having occurred in period t, is p_{ij}. The probabilities p_{ij} (i = 1, 2,..., n; j = 1, 2,..., n) are positive values, and sum to unity. These may be arranged in a *transition matrix*, $\boldsymbol{P}$, where i defines the row and j the column:

$$\boldsymbol{P} = (p_{ij}) \tag{7.1}$$

The elements in the matrix are conditional probabilities indicating the probability of being in the 'state of the world' defined by the row given that the system was in the state indicated by the column in the previous time period. For instance, the events concerned may be defined as a 'with pest' state and 'without pest' state. If the initial probabilities of being in either state are specified, the likelihood of being in a certain state in any future time period can be determined. If the probabilities of the events X_1, X_2, ..., X_n occurring at any time t are denoted by $p_1(t)$, $p_2(t)$, ..., $p_n(t)$, then:

$$p_i(t+1) = \sum_j p_{ij} p_j(t) \tag{7.2}$$

In virtually all instances however, such a feat will not be possible due to a lack of information on which to estimate transitional probabilities. Environmental and demographic changes may have a large impact on the probability of moving from one state of the world to another over time since the vectors for spread are altered. Here, a subjective estimate of these probabilities is required[73].

The initial probabilities attached to the 'with' and 'without' pest states of the world will be dependent on the effectiveness of quarantine policies in place at the outset of the analysis. So, policy changes will alter these probabilities, so different policies can be specified in this fashion (Hinchy and Fisher, 1991). This technique has been used to good effect in Hinchy and Low (1990) and Hafi *et al* (1994). Yet, their application to interstate issues has been limited due to their complexity, data requirements and a lack of sufficient skills in dynamic modelling. This represents a possible area for the likes of DAWA to investigate. It is difficult to determine if sufficient gains in model accuracy can be made to offset the additional resources required to complete market access assessments with this supplementary information.

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[73] Setting this issue to one side the set of all these equations can be expressed in matrix form:

$$p_i(t+1) = \boldsymbol{P}\boldsymbol{p}(t) \tag{7.3}$$

Here, $\boldsymbol{p}(t)$ represents a column vector with elements $p_1(t)$, $p_2(t)$, …, $p_n(t)$. By applying equation (7.3) repeatedly, expression (7.4) is obtained:

$$p(t) = \boldsymbol{P}^t \boldsymbol{p}(0) \tag{7.4}$$

It can be demonstrated that under a variety of conditions the vector $\boldsymbol{p}(t)$ will converge to a unique vector $\boldsymbol{p}$ as t increases (Moran, 1984).

7.5 Conclusions

The methods of assessing the welfare gains and losses resulting from quarantine restrictions on trade developed in previous chapters are capable of providing a wealth of information. It is envisaged that economic welfare assessments may be used to bolster traditional expected pest damage assessments to enable quarantine policies to be designed and implemented in the interests of a broader range of community members. But, it must be acknowledged that there are still pieces of information that are not captured by these suggested additions, which may distort estimations of ED_{ALOP}.

This chapter has made mention of three broad types of problems inherent in the aggregate and spatial partial equilibrium models relating to externalities, environmental goods and dynamic issues. These are readily identifiable, and their impact in terms of the over or under-estimation of the ED_{ALOP} in specific markets can be predicted. However, correcting for these problems when performing a quantitative analysis may be more difficult. Nevertheless, it must be recognised that the point of building a model is to simplify reality down to a level where ideas and concepts can be tested. In this sense, the inclusion of consumer surplus in economic assessments of quarantine provides a useful addendum for tradition quarantine decision-making methodology.

8. CONCLUSIONS

8.1 Introduction

The preceding chapters provide alternatives to the traditional use of economics in examining quarantine policies. Quarantine analyses of the past have chiefly concerned the estimation of the total damage to be expected if exotic pests enter a region, making them biased towards domestic producers and misrepresentative of social welfare outcomes. Through the use of simple, partial equilibrium trade models, this thesis has shown that consumers are also affected by impediments to trade. This being the case their welfare must be considered in analytical models if decision-makers are to produce policies of a socially desirable nature. Not only that, but by measuring the negative effects of quarantine-induced price inflation on consumer surplus it is possible to determine the level of expected damage corresponding to the Appropriate Level of Protection (ALOP) reflected in SPS measures.

This chapter draws conclusions from each key area of the preceding research and explains how the techniques developed can aid quarantine administration in the future. It begins by revisiting the aggregate model presented in chapter three (section 8.2), which mimics the approach used in James and Anderson (1998). The spatial model presented in chapter four is an extension of this model designed to capture the regional effects of quarantine policies, and the benefits this can provide in certain situations are also discussed (8.3). Finally, the adaptation of the Snape and Orden (2001) framework presented in chapter five and applied in chapter six is commented on, and its possible role in import risk assessment speculated (8.4). The problems with the partial equilibrium models outlined in chapter seven highlight that the techniques suggested here must be used with caution, but at the same time their simplicity and low demand for input variables are expected to prove strong advantages. It is concluded in section 8.5 that while they do not represent replacements for existing analytical methodologies, they are capable of bolstering the information with which quarantine policies are formulated.

8.2 The Aggregate Model

Traditionally, economic models used in the analysis of quarantine measures have centred on estimating the expected damage resulting from a pest incursion (e.g. McKelvie (1991); McKelvie et al (1994)). This has entailed investigations of the likely loss of producer surplus, making them biased towards the production side. Those that have also taken account of consumer surplus effects (e.g. Hinchy and Low (1990); Hafi *et al* (1994)) have focused on a move from a closed economy to a quarantine-restricted economy, with no mention of a free trade scenario. However, an appropriate modelling technique must acknowledge the fact that both a quarantine-restricted and closed economy scenario impose costs on consumers since their welfare is maximised under free trade. Furthermore, the expected damage relating to a pest is not zero in a closed economy situation since the notion of 'zero risk' is, to all intents and purposes, unachievable.

The partial equilibrium model presented in James and Anderson (1998) represents a more suitable framework to use in the examination of quarantine strategies than previously demonstrated. It is a straightforward comparative static, partial equilibrium trade model using the three scenarios of a closed economy, quarantine-restricted trade and free trade to gauge the social welfare implications of imposing SPS measures on imported goods. The model's use as an analytical tool is demonstrated in chapter three where it is applied to two interstate quarantine situations concerning mangoes and tomatoes. These examples serve to illustrate that the 'net' welfare implications of trade restrictions are conceptually ambiguous when consumer surplus is taken into account.

Unlike conventional assessments, the approach used in the case studies is to focus on consumer surplus losses rather than expected producer surplus gains. Therefore, the need for subjective information concerning the likelihood of pest entry and establishment, incursions scenarios and average variable cost increments are avoided. Instead, the loss of consumer surplus brought about by the inflationary effects of quarantine protocols is calculated using readily available (and objective) price and quantity data. This estimate is then used to determine a critical level of expected damage exactly offsetting the loss in consumer surplus. In the case of mangoes this was estimated to be in the order of $56,000 (or 9.5 per cent of the current total value of the industry), while in the case of tomatoes it was estimated at around $785,000 (or 12.8 per cent of industry value). Hence, for interstate quarantine strategies to have no net welfare effect, the damage to domestic producers they are required to avoid is $56,000 for the mango industry and $785,000 for the relatively large tomato industry.

These findings suggest that the size of an industry has some bearing on the economic justification of quarantine protection. For the large tomato industry, small variations in price exert a sizeable impact on consumers, whilst for a small industry like mangoes consumer concerns are less significant. Therefore, using the aggregate model it is somewhat easier to justify protection for smaller industries. This is where results need to be compared with conventional expected damage assessments so that the likelihood of avoiding damage of a suitable magnitude can be determined. The critical level of expected damage identified using the aggregate model provides a means of calibrating these assessments, gearing them towards the idea that consumers also face costs and benefits from quarantine strategies. A quarantine assessment utilising this information will form a powerful tool with which quarantine policies can be designed to reflect the community's interest, and not just a proportion of it.

8.3 The Spatial Model

Due to the vast area and range of climatic conditions characterising Australia it is often the case that agricultural industries are fragmented into different areas, each with a unique set of production characteristics. The same is true of WA. This makes it difficult in many cases to come up with a set of aggregated data that is truly representative of all component growing areas of an industry. For this reason, chapter four puts forward a spatial model that compensates for the shortcomings of the aggregate model by taking account of variations in production costs in different regions. This is applied to the mango and tomato examples to determine the regional impacts of interstate quarantine measures.

At the core of the spatial model are regional production costs that are, to a large extent, dictated by environmental factors. Regions with high production costs have a lower capacity to cope with increased levels of competition brought about by a relaxation of quarantine regulations. If the market price of a product falls below the minimum value of average variable costs in a producing region, then profit-maximising producers in that region will minimise losses by exiting the market. Conversely, regions with relatively low production costs have a greater capacity to survive in the face of competition. The closed economy, quarantine-restricted and free trade scenarios all depict different degrees of competition. It follows that by looking at the regional cost structure of an industry the effects of quarantine strategies can be seen in more detail than is possible with the aggregate model.

The mango industry has two main growing areas, the Kimberley and Central regions. Together, these account for over 90 per cent of total mango production in WA. Despite differences in production methods, both these areas are characterised by similar average variable production costs under the closed economy, quarantine-restricted and free trade scenarios. For this reason the results obtained using the spatial model are quite similar to those of the aggregate model. In the case of the mango industry moving from a closed state to one of quarantine-restricted competition, the percentage decline in aggregate profit predicted by the spatial model is 31 per cent for the central region and 32 per cent for the Kimberley region. Hence, the aggregate model results are representative of the industry despite the omission of regional data.

In contrast, the tomato industry is made up of three growing areas with quite different production costs, the Central, Swan Coastal Plain and South West regions. The Central region has high production costs, the South West low production costs, and the Swan Coastal Plain has average production costs. The spatial model predicts that in the event that the industry moves from a closed state to a quarantine-restricted trade state, the percentage decline in aggregate profit will be around 37 per cent for the Central region, 20 per cent for the Swan Coastal Plain region, and 17 per cent for the South West Region. Under these circumstances, the aggregate model predicts that total industry profit will fall by around 29 per cent. So, profit falls more significantly in the high cost production region (Central) than suggested by the aggregate model, while profit falls to a much lesser extent in the low production cost region (South West).

These results tend to suggest that an aggregated, industry-wide approach to modelling the effects of quarantine measures may be inappropriate where there are significant variations in production costs between regions. Where costs are comparable across component growing areas, the aggregate model can be relied upon to deliver results that are representative of producer welfare changes resulting from quarantine decisions. Therefore, in these circumstances the relatively data-intensive spatial approach adds little to an analysis. On the other hand, where component growing regions exhibit considerably different growing costs, the results of the aggregate model may not provide a true indication of the producer welfare effects caused by different quarantine strategies. Under these circumstances, it is recommended that a spatial analysis be carried out to bolster an aggregated analysis.

8.4 Model Application

A great deal of interest surrounds the specification of the ALOP defining the level of protection a trading entity wishes to achieve when importing products from elsewhere. No country or State has yet articulated their ALOP since the concept is not clearly defined in the SPS Agreement. The reason for this ambiguity lies in the workings of the risk assessment process itself because threats are assessed on the basis of 'scientifically plausible assumptions', and since decisions of what is plausible depend on individual assessors it is difficult to reach an international consensus on what constitutes an ALOP. Nevertheless, each and every trading region applies an ALOP either consciously or unconsciously, and sets quarantine measures in place to reflect it.

Intuitively, Australia can be said to have a high ALOP since it has an intricate network of quarantine rules and regulations governing the movement of goods across its borders. The same can be said of WA (e.g. WAQIS, 1999). Since the partial equilibrium models of chapters three and four are capable of identifying a critical level of expected damage (ΔED) required to offset losses in consumer surplus brought about by quarantine-induced price inflation, they are also able to derive the level of expected damage corresponding to the ALOP (ED_{ALOP}). This is simply a matter of calculating the gains from trade under a quarantine-restricted trade scenario. Assuming quarantine policies are only put in place up to the point where import risk becomes socially acceptable, the level of expected damage required to offset forfeited gains from trade at this point represent the ED_{ALOP}.

The conceptual framework developed in Snape and Orden (2001) can be used to show how this idea can be applied to practical examples, and is presented in chapter five. This utilises the concept of iso-risk, and presents the trade off between import risk reduction (or expected damage abatement) versus the gains from trade. It also allows the ALOP to be clearly specified, and goods to be assessed as either representing a level of risk above or below this level. This method of representing the effects of quarantine policies on social welfare, illustrated in Figure 5.1, is a concise method communicating the implications of trade restrictions on an economy, and can be used to good effect in economic analyses.

In chapter six this model is used in conjunction with the results of the aggregate model of chapter three to indicate the ED_{ALOP} relevant to WA when applying interstate SPS measures. Using this approach the value of expected damage for produce entering the State free of quarantine treatments (ED_f) is estimated at around $188,000 for mangoes and $1,855,000 for tomatoes. After satisfying all quarantine protocols currently governing the movement of produce across the WA border the maximum socially acceptable level of expected damage (or the ED_{ALOP}) is approximately $132,000

(22.5 per cent of post-quarantine producer surplus) for mangoes and \$1,070,000 (17.5 per cent of post-quarantine producer surplus) for tomatoes[74].

This suggests an inconsistency in the way quarantine measures are implemented against horticultural products entering WA from the eastern States of Australia. The larger industry, tomatoes, appears to receive a greater amount of protection. This is an interesting result in light of the findings of chapter three in which it is asserted larger industries are more difficult to justify protection for since consumer surplus is relatively significant. Hence, price variations cause a greater effect on consumer welfare than in the case of smaller industries. However, the differences in quarantine protection between the mango and tomato industries are to be expected since consumer concerns have largely been ignored when implementing quarantine regulations. The results of chapter six therefore present information of importance to policy-makers attempting to act in the public interest, and provide a useful supplement to traditional assessments of expected damage.

As a consequence of the simplicity of the partial equilibrium framework used to calculate the ED_{ALOP} on the basis of forfeited gains from trade, there are a number of areas where information has been omitted. These problems are identified and discussed in chapter seven, and are classified under three groups. The first involves external economies produced by quarantine due to pest non-host specificity and flow-on effects to industries using affected goods as inputs into their production process. These are not accounted for in the model, but may be incorporated through the use of multiplier information (e.g. Islam and Johnson, 1997). The second is also an example of an external economy, and concerns environmental damage that may result from pest

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[74] Note $\Delta ED = ED_f - ED_{ALOP}$.

incursions. Expressing values for ecological damage in an accurate and cost-effective manner is generally not feasible, and must be overcome using qualitative information. Finally, there are dynamic issues that are not accounted for in the static models used, such as strategic behaviour on the part of affected producers (and consumers) in the face of pest outbreaks. These are also difficult to incorporate without the use of complex, data-intensive methodologies requiring subjective parameter estimates. Future research effort may be directed at addressing these problems if the techniques suggested are to be formally incorporated into the import risk assessment process.

8.5 Conclusions

This thesis presents an alternative way of examining the economic impacts of quarantine policies. Rather than estimating likely damage to domestic host industries in the event of an exotic pest incursion and combining it with an estimated risk of entry and establishment, the methodology presented here places emphasis on the social welfare implications of guarding against these incursions. Given that quarantine measures restrict trade and inflate prices means that the resultant consumer welfare loss is relatively easy to measure using price and quantity data. The aggregate and spatial models presented provide a simple means of estimating the likely welfare losses to trade in a range of industry situations. Although generally applicable to issues of international trade, two commodities traded interstate in Australia are used to demonstrate practical applications of these models, mangoes and tomatoes. An assessment of the quarantine restrictions on the interstate movement of these goods into WA reveals that the critical level of expected damage required to offset forfeited gains from trade are higher for tomatoes that for mangoes.

Knowing how much consumer surplus regulatory authorities are prepared to sacrifice in the interests of border protection provides an estimate of the maximum amount of damage they perceive to be socially acceptable. Using the critical level of expected damage estimated using the aggregate model it is therefore possible to comment on the ALOP being exercised when quarantine strategies for specific goods are designed and implemented. In doing so however, it is important that the shortfalls of the partial equilibrium analytical models are acknowledged and suitable steps taken to ensure the findings expressed are an appropriate representation of the facts surrounding a specific quarantine issue. In view of the ambiguity surrounding ALOP articulation, this work provides an important appendage to traditional damage assessments that may one day facilitate the use of a clear and objective means of assessing market access requests.

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