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ABARE CONFERENCE PAPER 99.5

Using a decision theoretic approach to choose among alternative import protocols for an import competing commodity

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Combined 43rd Annual Australian and 6th Annual New Zealand
Agricultural and Resource Economics Society Conference
Christchurch, New Zealand, 20–22 January 1999

Preconference workshop, 'Border Security and Risk Analysis',
Lincoln University, Christchurch, 19 January 1999

The global push toward free trade and the consequent rise in volume of imports from a wider range of countries incurs the likelihood of introducing unwanted pathogens. Given that a zero-risk quarantine policy is not possible, there are tradeoffs between the gains from international trade and the potential costs to society of disease incursions. The aim in this paper is to demonstrate a means for choosing among alternative import protocols through an economic model.

The economic modeling approach applied to a stylised set of import protocols was a two step process. First, the gains and losses to consumers and producers, including costs of disease, were estimated for each import protocol. In the second step, three decision rules — minimax, minimin and minimax regret — were applied to a cost matrix to determine the most efficient import protocol.

ABARE project 1589

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Introduction

Australia is a member of the World Trade Organisation (WTO) and a signatory to the Agreement on the Application of Sanitary and Phyto-sanitary Provisions (SPS agreement) and the Agreement on Technical Barriers to Trade. Under the SPS agreement, each country has a sovereign right to determine its appropriate level of protection. The clauses of the agreement put heavy emphasis on the scientific assessment of the risk of disease introduction when choosing an import measure. This course of regulatory decision making differs from the economic paradigm that selects the appropriate level of protection using cost–benefit analysis (Roberts 1998).

Implementing a quarantine policy to minimise the costs of pest and disease incursions entails a degree of restriction on imports that are potentially contaminated. Restricting imports lowers competition faced by the import competing industries and may result in increased costs for domestic consumers. In effect, the welfare of consumers is reduced because of their limited access to cheaper imported substitutes.

This paper illustrates the use of economic models to choose among alternative import protocols designed to minimise the risk of disease. This paper is in three parts. First, the economic impacts of disease are discussed. Second, a theoretical model showing the economic effects of allowing imports potentially carrying disease is presented. Finally, hypothetical import protocols under three different disease states are analysed using decision theory. This analysis draws on a previous ABARE study of quarantine issues pertaining to chicken meat imports (Hafi et al. 1994). In that study, the trade gains and cost of disease were estimated for several import protocols and the critical probability concept was used to derive a breakeven level of disease risk.

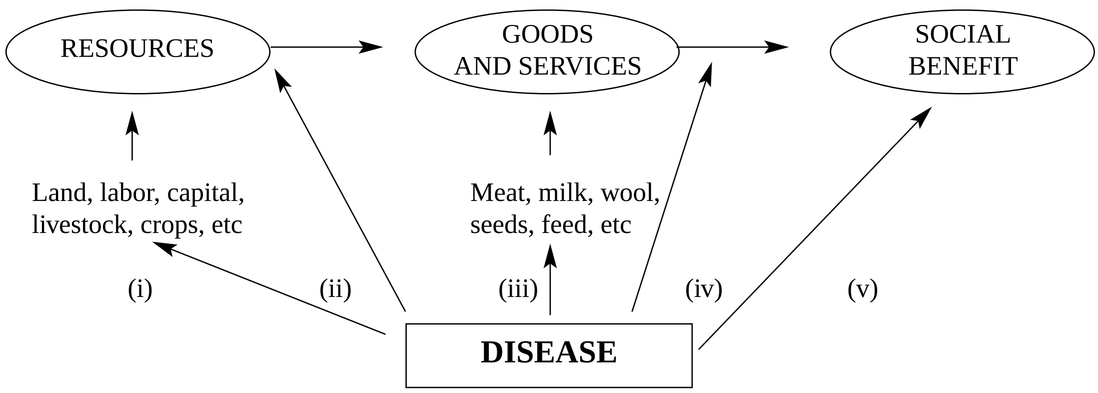
The modeling approach adopted in this paper differs from the previous ABARE study in several ways. First, the economic assessment of chicken meat imports is purely for illustrative purposes. Second, the choice of the import protocol is done within a decision theoretic framework. This means that there is an explicit criterion for each decision rule. Third, consistent with decision making under uncertainty, the decision rules used in this paper assume that information on probabilities required by an expected utility analysis of alternative import protocols is not available. Finally, the base used in undertaking the economic assessment is the free trade regime. An advantage of using this base is that the domestic output at risk of being damaged by a disease incursion is the most efficient output.

Economic impacts of disease

An overall perspective of how disease affects different economic activities is shown in figure 1 (adapted from McInerney 1996). As an economic concept disease is a negative influence on value creating processes that are based on using livestock, crops, fish and forestry as economic resources. The economic impact of disease encompasses more than the direct monetary cost of disease, usually deaths and output or quality reductions, experienced in the production process. The SPS agreement defines which economic factors are relevant when a country is assessing its appropriate level of protection. These include loss of production or reduction in sales, cost of establishment or spread of a pest or disease, the costs of control or eradication and the relative cost effectiveness of alternative approaches to limiting risks (Article 5(3), SPS agreement, World Trade Organisation 1995).

There is consensus that the agreement specifically excludes reductions in producer surplus due to competitive forces unrelated to disease. However, there is no explicit reference in the agreement to the role of benefits from trade in determining the appropriate level of protection although their inclusion would favor freer trade (James and Anderson 1998).

Figure 1: **Economic impacts of disease**



Disease impacts can be manifested in the following:

(i) Damage of primary resources, like death of livestock or abandonment of land resulting from the presence of spores of certain diseases.

(ii) Reduced resource productivity and hence lower efficiency of production processes (for example, lower feed quality would result in lower feed conversion factors and reduced rates of weight gain in animals).

(iii) Declines in both quantity and quality of output (for example, lower milk yield and/or protein content).

(iv) Diminished product suitability for further processing or increased costs in the distribution chain (for example, drug residues and inspection costs for meat products).

(v) Direct effect of disease on human health.

Economic modeling of the effects from imports potentially carrying disease

Figure 2 is a theoretical model showing the economic effects arising from allowing imports potentially carrying disease. In the absence of imports, the domestic market equilibrium for an import competing commodity would be at quantity QD_1 and price P_d. With the advent of imports, domestic prices would fall to the landed import price P_m causing domestic production to contract by the amount QD_1 less QD_2. However, total supply, consisting of domestic production and imports, would expand to *QT*. As a result, consumer benefits would increase by an amount represented by P_dEFP_m because of lower prices and increased consumption. Domestic producers would forgo income following the decrease in prices received. P_dEHP_m gives the producer loss. The net gain from free trade is *EFH*.

The cost of a disease outbreak is represented by a shift in the domestic supply curve to *S*'. Disease costs to the domestic industry are associated with declines in production (the difference between QD_2 and QD_3) and the cost of disease control and eradication. The loss to domestic producers from the disease outbreak is the area *OIH* while the net gain from trade is *EFH*. The net gain from trade (*EFH*) will likely exceed the disease cost (*OIH*), the higher is the domestic price relative to the world price, the higher the price response of producers and consumers below point *E*, the lower is the likelihood of disease incursion and the smaller are losses from the disease.

Figure 2: **Impacts of disease-contaminated imports on the domestic market**

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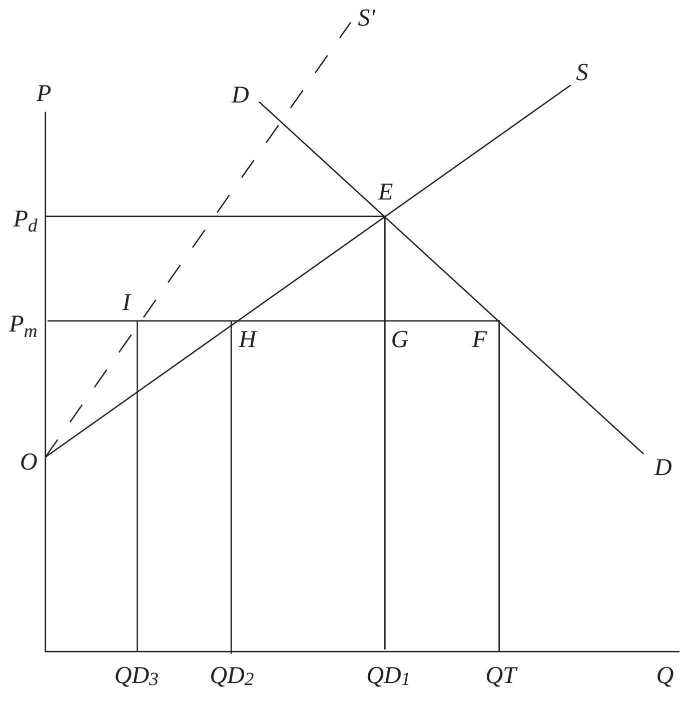


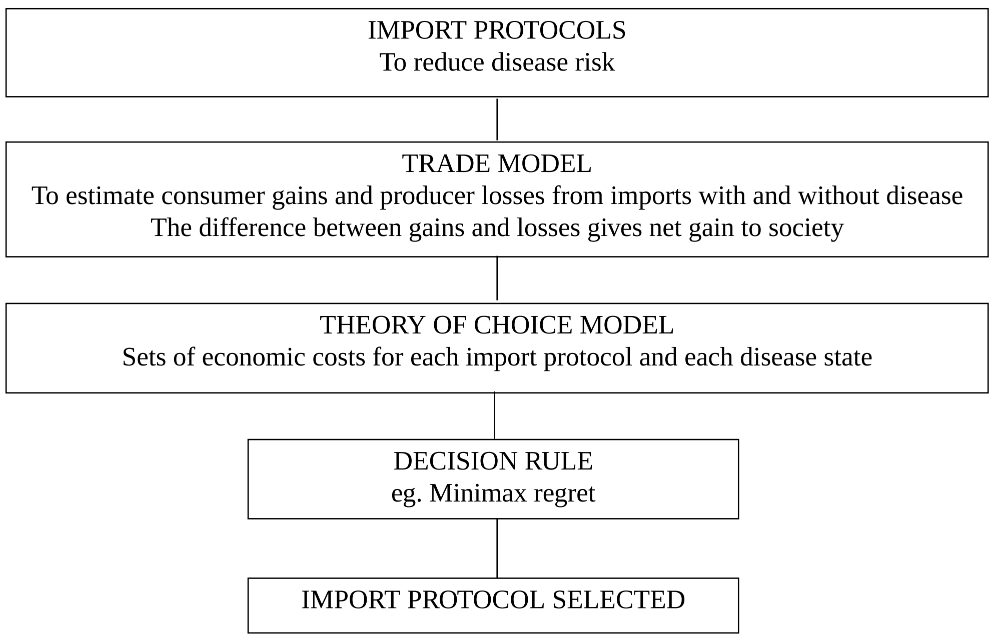
An illustrative economic assessment of chicken meat import protocols

The Australian poultry industry is concentrated in New South Wales and Victoria and is oriented almost exclusively to domestic consumption requirements. Imports, apart from cooked uncanned meat from New Zealand, were not permitted under previous quarantine laws. However, in response to longstanding requests from the United States, Denmark and Thailand, AQIS recently completed an import risk assessment of cooked chicken meat from those countries. Conditions for the import of cooked chicken meat from those countries were adopted in late 1997. Australian exports of chicken meat amount to only a small proportion of domestic production. Total poultry meat production was estimated to be 557 000 tonnes in 1997, with a gross retail value of around $2 billion (ABARE 1998; Australian Chicken Meat Federation 1998).

Under new WTO provisions, several countries have requested permission to export cooked and uncooked chicken meat to Australia. The possibility of importing exotic disease agents into Australia and the effect this would have on poultry production poses a major threat to the industry. Moreover, the import of chicken products could have a significant economic impact on the Australian industry. However, by not importing chicken meat, consumer gains from higher availability and lower prices are forgone. The stylised model presented in this paper illustrates an assessment of the potential consumer gains from trade against the cost to society from disease incursion.

The economic modeling approach adopted is a two-step process (figure 3).

Figure 3: **Modeling framework to facilitate decisions on imports with potential disease risk**



Trade modeling

First, the gains to consumers and losses to producers in the absence of disease were obtained for each level of chicken meat imports arising from a given import protocol. These trade effects were obtained from Hafi, Reynolds and Oliver (1994). Using a perfectly competitive trade model, they estimated the trade effects and the cost of introducing Newcastle disease at the national level through imports. Their results at each import level are given in table 1. Trade gains are highest at an import level of 100 000 tonnes and lowest at an import level of 5000 tonnes in the short run.

Table 1: **Apparent net gain and cost of introducing Newcastle disease with imports of chicken meat** First year results, in 1993 dollars

Annual imports	Consumer gain	Producer loss	Net gain	Disease cost
	$m	$m	$m	$m
100 000 tonnes	155.82	139.84	15.98	29
40 000 tonnes	61.95	59.33	2.62	34
20 000 tonnes	30.91	30.25	0.66	35
10 000 tonnes	15.44	15.27	0.17	36
5 000 tonnes	7.72	7.67	0.05	37

They used a 15 per cent loss in broiler production from Newcastle disease to estimate the cost of the disease. As given in table 1, the cost of introducing the Newcastle disease ranged from $29 to $37 million, depending on the level of domestic production. Lower levels of imports would lead to less competition in the domestic market, thereby leading to higher domestic production. This would result in a larger domestic output exposed to disease outbreak. If this occurred, the cost of disease would rise relative to a more open trade regime.

Choice modeling

In the second step of the modeling process, a cost matrix using information on the cost of disease damage and forgone benefits from trade under each protocol was constructed. In estimating the forgone benefits from trade and establishing the base level of disease cost, the base used was the free trade regime. This was selected as the base because, in the absence of disease incursion and protection accorded to domestic industries, competition in the domestic market through free trade would ensure that domestic producers are most efficient. Hence, the domestic output at risk to the disease outbreak is the most efficient level of production within the available resources. Each row represented a particular import protocol or strategy while each column represented a particular state of disease damage. Each cell entry in the matrix is the sum of the forgone net gain from trade and the cost of disease.

An important component of the second step is the application of decision rules to the cost matrix to select the most efficient import protocol. Each decision rule reflects the uncertainty arising from disease incursions, forgone trade gains and the attitude of the decision maker toward taking chances.

An illustration of import decision rules for selecting chicken meat import protocols

Decision modeling

Under conditions of uncertainty, relevant probabilities for biological or economic risk are often unknown or ambiguous because of the scarcity of observation of events and of information on underlying causes. In the absence of these probabilities, an alternative framework is required to assess the costs resulting from different protocols or strategies and to facilitate the choice among policy options involving different social values. Decision theory suggests a natural criterion for selecting a protocol that would maximise social welfare (Harsanyi 1992).

Decision theory can be applied to assess the range of import protocols designed to reduce the likelihood of disease introduction and consequently the cost of disease to domestic producers. An import protocol could be a demand by the importing country for the exporting country to meet certain conditions before its products are allowed entry, such as cooking meat at a certain temperature or providing certification that products are sourced from disease-free areas.

Since the probabilities of disease introduction under different protocols are unknown, and the likely extent of damage from a disease incursion is also uncertain, decision models appear to be the relevant and appropriate analytic option to evaluate these protocols (Baumol 1987, p. 458).

In constructing the cost matrix required by decision theory, three assumptions were made in this paper. First, each level of imports is assumed to result from a specific import protocol aimed at reducing the likelihood of disease introduction and therefore the corresponding disease costs. With no intervention to curb the threat from disease, imports are assumed to be 100 000 tonnes. This is assumed to approximate the free-trade level. Under this protocol, it is assumed that a disease incursion is almost certain every year. Consequently, the actual cost after disease outbreak is the expected cost of disease under a free trade regime.

Second, for illustrative purposes and analytical simplicity, the reduction in the cost of the disease under a particular protocol is assumed to be proportional to the reduction in imports. Hence, relative to free trade, the expected costs of disease are 95, 90, 80 and

60 per cent lower when import levels are 5000, 10 000, 20 000 and 40 000 tonnes, respectively.

Third, to allow for uncertainty in disease losses and its cost, three different states of disease infestation (low, medium and high) were used in this study. The medium case in this study refers to a trade regime that allows 100 000 tonnes of annual imports and results in a cost of disease amounting to $29 million. This figure was estimated by Hafi et al. (1994). The corresponding costs of disease for the low and high cases (that is, $14.5 and $43.5 million respectively) were based on the assumption that these cases are 50 per cent below and above the medium case.

Decision rules

Three decision rules are considered in this section. These are the *minimax*, the *minimin* and the *minimax regret* rules. The aim of these rules is to provide a basis for selecting the most efficient import protocol. This refers to the import protocol that yields the lowest cost in terms of forgone net gains from trade plus the cost of the disease in the context of the decision rule being adopted.

The minimax criterion is the most conservative among the three decision rules. Under this criterion, the decision maker determines the worst outcome that could occur for each import protocol and selects the protocol that yields the least unfavorable of these outcomes. In contrast, the minimin criterion suits the decision maker willing to bear the most risks. Under this criterion, the decision maker chooses the protocol yielding the lowest cost regardless of the risks arising from disease outbreaks.

The minimax regret criterion focuses on the opportunity cost to the decision maker of choosing an incorrect protocol. For example, an incorrect protocol is the implementation of a total import ban when the risk of disease from imports is minimal. In this case, a major component of the opportunity cost is the forgone net gains from trade. Hence, the aim of the minimax regret rule is to minimise the cost of mistakes (regrets).

To implement these decision rules, a matrix representing the expected cost of each protocol for each of the disease states and in the absence of the disease is required. In table 2, there are five import protocols resulting in five import levels and three states of disease damage (low, medium and high). Entries in column 2–4 are the expected costs under each protocol and each state of damage. For example, the protocol limiting imports to 40 000 tonnes is assumed to reduce the cost of disease by 60 per cent relative to free trade. Hence, the expected disease costs of this protocol for low, medium and high state of disease damage are $5.8 million, $11.6 million and $17.4 million respectively.

Table 2: **Disease costs under five different chicken meat import protocols**

Annual imports	Expected cost of disease under different protocols – State of damage – *Low (7.5% loss)*	*Medium (15% loss)*	*High (22.5% loss)*	Reductions in disease costs due to import protocols
	$m	$m	$m	%
100 000 tonnes	14.50	29.00	43.50	0
40 000 tonnes	5.80	11.60	17.40	60
20 000 tonnes	2.90	5.80	8.70	80
10 000 tonnes	1.45	2.90	4.35	90
5 000 tonnes	0.73	1.45	2.18	95

To construct the cost matrix, forgone benefits from trade at each level of imports are included in table 3. The second column of table 3 indicates the forgone benefits from trade in the absence of disease. The entries in columns 3–5 are the sum of the expected cost of the disease reported in table 2 and the forgone net gains from trade. For example, the entry for 40 000 tonnes under low damage is $5.8 million plus $13.4 million equals $19.2 million.

It is assumed that maximum gains from free trade would be fully realised at an import level of 100 000 tonnes. Forgone trade gains arising from lower imports under each of the remaining four protocols are given by the difference between net benefits arising from imports of 100 000 tonnes and those from lower imports under each protocol. For example, the forgone trade gain at 40 000 tonnes is $15.98 million less $2.62 million (from table 1) equals $13.4 million.

Once the entries to the cost matrix (see table 3) are estimated, the decision rules can be applied to select the most efficient import protocol. Risk-averse decision makers using the

Table 3: **Cost matrix of alternative import protocols**

Import protocol Scenarios	Forgone free trade gains	Expected cost of disease – State of damage – *Low*	*Medium*	*High*
	$m	$m	$m	$m
100 000 tonnes	0.00	14.50	29.00	**43.50**
40 000 tonnes	13.36	19.20	25.00	**30.80**
20 000 tonnes	15.32	18.20	21.10	**24.00**
10 000 tonnes	15.81	17.25	18.70	**20.15**
5 000 tonnes	15.93	16.63	17.35	**18.08**

minimax criterion would minimise the worst outcomes expected from a disease outbreak. They would rank the import protocols according to their maximum costs (bold figures) and select the import protocol with the lowest cost. This is 5000 tonnes with a cost of $18.08 million.

For decision makers willing to accept risks and adopting the minimin criterion, they would select the protocol with the lowest cost, expecting that no disease would occur. For these individuals, the chosen protocol is 100 000 tonnes with an expected cost of disease of zero. Hence, individuals strongly supporting the free-trade protocol view the possibility of reaping the maximum free trade gain as worth more than the risks from disease outbreaks and its consequent costs.

The last decision rule to be considered is the minimax regret criterion (table 4). Entries in table 4 are deviations from the least cost option for each state of disease infestation. This is the amount by which society would be worse off when choosing an option over the least cost one. For example, the lowest cost for the low damage state is $14.5 million (table 3). If the decision maker implemented the 40 000 tonne protocol and the disease damage is low, the cost of the error is $19.2 million less $14.5 million equals $4.7 million.

The second step in applying the minimax regret rule requires analysing each import protocol for the largest cost of committing mistakes (regret). Hence, for 100 000 tonnes, the largest regret is $25.43 million. The other largest regrets for each import protocol are in bold print. Finally, the decision maker selects the import protocol with the smallest bold printed regret. This is 40 000 tonnes with a regret of $13.4 million.

The minimax regret decision making process makes full use of information on disease outbreaks and trade gains. In this respect, it has an advantage relative to minimax and minimin decision rules. Also, in this particular analysis, it avoids providing extreme solutions such as the free trade position (that is, having no quarantine restrictions) or imposing a conservative quarantine regime (that is, severe import restriction).

Table 4: **Regret matrix for the different import protocols and disease states**

Import protocol scenario	**Regret from lost trade gains**	**Regret from disease state**		
		Low	***Medium***	***High***
	$m	$m	$m	$m
100 000 tonnes	0.00	0.00	11.65	**25.43**
40 000 tonnes	**13.36**	4.70	7.65	12.73
20 000 tonnes	**15.32**	3.70	3.75	5.93
10 000 tonnes	**15.81**	2.75	1.35	2.08
5 000 tonnes	**15.93**	2.13	0.00	0.00

It should be noted that the previous results arising from applying the decision rules depended critically on the type of information available for estimating the different entries in the cost matrix. A subset of this information includes data on supply and demand parameters, cost of disease, effectiveness of disease protocols and extent of damage to the domestic production. Hence, the previous import protocols selected under the three decision rules must be accepted only within the confines of the given cost matrix in this paper and purely for illustrative purposes.

Conclusions

Implementing a quarantine related import protocol involves tradeoffs between gains from trade and the potential costs of disease outbreak. In this paper, the economic assessment of these tradeoffs is illustrated through a two step modeling process. The two steps of the prototype model are:

- estimating the economic impacts of the trade regime and disease outbreaks on domestic consumers and producers through a trade model; and
- applying a decision rule to the costs corresponding to a set of import protocols and to a set of disease outbreak events to determine the most efficient import protocol.

Each decision rule represents an analytical tool which a decision maker can use to select a given import protocol to address the risk of disease incursions. The type of strategy selected depends on the willingness to take chances. Highly risk-averse decision makers, using the minimax decision rule, would select the most conservative import protocol. Risk-taking decision makers, applying the minimin decision rule, would prefer the free-trade position.

Decision makers who wish to minimise the cost of incorrect decisions (regrets) would select an import protocol that minimises the opportunity cost (disease damage cost plus the cost of forgone trade) of disease incursions.

There are several merits in adopting the modeling approach in this paper. First, it highlights the tradeoffs between trade gains and disease cost involved in implementing quarantine related import protocols. Second, the decision rule component is robust enough to represent alternative attitudes of the decision maker toward taking chances. Finally, the information requirements of the modeling framework emphasise the importance of interdisciplinary cooperation in constructing the elements of the cost matrix.

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