Economic effects on Australian southern bluefin tuna farming of a quarantine ban on imported pilchards
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ABARE report to the Fisheries Resources Research Fund

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PILCHARD IMPORT BAN

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1. Introduction

The southern bluefin tuna farming industry in Australia has expanded rapidly since production commenced in 1991. In 1995-96 the value of farmed tuna production reached $39.9 million (Brown, Van Landeghem and Schuele 1997). Tuna farmers fatten juveniles and export grown tuna to Japan’s sashimi market. Pilchards are the most cost effective source of feed for tuna farming at the moment — so farmed tuna are fed mainly on pilchards. Currently, around 50 per cent of the pilchards used by the tuna farming industry are sourced from imports.

The purpose in this report is to estimate some of the key economic effects on tuna farming and related activities of a potential quarantine ban on uncooked pilchard imports. The background to this report is the episode between March and June 1995 when large scale pilchard deaths occurred over more than 6000 kilometres off the coast of Australia (Department of Primary Industries and Energy 1996). Widespread pilchard deaths were first reported in the Great Australian Bight off South Australia, then spread east and west to reach waters off Noosa in Queensland and Geraldton in Western Australia respectively. Pilchard deaths were also reported off the east coast of the North Island of New Zealand.

The rate of spread of the pilchard deaths in relation to the pilchard migration at prevailing currents suggested that disease may have been involved. Through the Consultative Committee on Exotic Animal Disease (CCEAD), a Pilchard Mortality Task Force was established on 10 May 1995 to investigate the cause of the pilchard deaths. A chief concern was that disease may have been introduced into Australia. Two possible disease pathways to the aquatic environment are the use of imported frozen pilchards as feed for tuna farmed in sea cages and their use as bait in longline tuna fishing, recreational fishing and the rock lobster industry. Pilchards are also used in petfood and as a very minor source of food for human consumption, but the pathway to the aquatic environment is far less direct in these cases.

Three possible scenarios for the pilchard deaths and the spread of the deaths were identified in the interim report of the Pilchard Mortality Task Force — activation (by environmental factors) of latent infections already present in the pilchard population; damage by phytoplankton (although these were not present in all kill sites in Western Australia); and the introduction of a pathogenic organism in imported pilchards used as feed in tuna farming or for bait (Department of Primary Industries and Energy 1995).
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Pilchards are a relatively short lived fish with a life expectancy of eight years, and deaths are commonly associated with annual variations in water temperature. A particularly cold water current was present off the coast in the location of the pilchard deaths. However, more recently, Griffin (1997) and Whittington et al. (1997) concluded that the possibility of a disease having been newly introduced into Australian waters could not be rejected. The final report of the Pilchard Mortality Task Force is yet to be released.

Concurrent to the early work of the Pilchard Mortality Task Force, the Australian Quarantine and Inspection Service (AQIS) was also inquiring into salmon import risks. Uncooked salmon product imports have been under quarantine ban since 1975, to protect the Australian industry from imported disease. In January 1994, Canada requested that Australia review the ban. Australia, as a member of the World Trade Organisation, must ensure that quarantine decisions are scientifically based on disease risks. It was recommended from the scientific assessment in the final report that AQIS maintain the import ban on uncooked salmon product from North America (Department of Primary Industries and Energy 1996).

In June 1995 the National Task Force on Imported Fish and Fish Products was established to undertake a broad review of the economic and environmental effects associated with the aquatic use of imported fish and fish products. Both the pilchard deaths and the salmon inquiry had highlighted concerns about the effectiveness and efficiency of existing policies and protocols in the management of aquatic import risks. Many Australian fisheries and aquaculture operations use imported aquatic products as inputs in production. Currently, most marine products imported for feed or bait are not subject to quarantine restrictions.

The National Task Force soon had available the findings from the Bureau of Resource Sciences' research on aquatic animal quarantine. It was noted that a variety of disease incursions occurred in the Australian fisheries sector during the 1980s and 1990s (Humphrey 1995). It was concluded that the use of uncooked aquatic products has the potential to introduce exotic disease (Nunn 1995). The report of the National Task Force was published in December 1996 (National Task Force on Imported Fish and Fish Products 1996).

The current study documents and extends ABARE research (undertaken for the National Task Force on Imported Fish and Fish Products) on the economic effects on tuna farming of a potential quarantine ban on imported pilchards. If a quarantine ban is to be imposed on pilchards because there is the risk of damage to the aquatic environment from imported disease, the costs of removing this disease risk will include the direct costs to tuna farming from
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using a less cost effective feed source. However, to assess the economic merits of a quarantine ban on pilchard imports, these disease risk control costs need to be balanced with rigorous scientific and economic research on the potential benefits of the costs avoided by adopting disease mitigation strategies. Such an analysis, while beyond the scope of this study, may well be justified.

In principle, tuna farming and other aquaculture industries offer the potential to enhance the ecologically sustainable development of fishery resources (Anderson 1985). However, this outcome requires careful management of the risks of environmental spillover effects. Pilchards are a source of feed for both wild tuna stock and farmed tuna, for example. It is conceivable that any potential damage costs associated with the spread of an imported disease through tuna aquaculture to wild pilchards could also have implications for wild tuna. The impact of the widespread pilchard deaths in 1995 on the wild pilchard and tuna stocks has not yet been fully assessed.

There needs to be some insurance that using a quarantine ban to control specific disease will reduce environmental risks and not compound them. Disease risk may be increased, for example, when aquaculture substitutes the banned feed product with another uncooked imported fish product that has an unknown risk. Facilitating research, development and adoption of cost competitive manufactured feeds for aquaculture could be a promising means of managing feed based environmental risks. An import ban may be warranted on the basis of a full risk weighted cost–benefit assessment, but it may be relatively more cost effective to impose a partial import ban (provided the ban could be enforced at low cost) and this option should be considered. A partial quarantine is an import ban that excludes only those uses where the pathway for disease transmission is assessed to be significant.
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2. Australian southern bluefin tuna farming

Southern bluefin tuna fishery
The southern bluefin tuna fishery comprises a single pelagic stock (McLoughlin, Wallner and Staples 1997). The tuna are slow growing, with a lifespan of forty years. Australia and Japan commenced fishing for southern bluefin tuna in Australian waters in the 1950s. Using longline fishing techniques, off Australia and more widely in the southern oceans, Japanese fishers have always targeted the highly priced adult pelagic fish for sashimi. Before 1990, Australian operators mainly caught lower priced juvenile schooling tuna for canning, using surface fishing techniques (pole and line and purse seine). However, there has been considerable technical change in Australia southern bluefin resource use in recent years.

The Australian catch reached a record 21 500 tonnes in 1982. However, at the same time, there were heightened scientific and economic concerns that the southern bluefin tuna fishery was being overexploited (Geen and Nayar 1989; Campbell, Battaglene and Brown 1996; McLoughlin, Wallner and Staples 1997). In response, in 1983-84, Australia, Japan and New Zealand agreed to individually limit their total global allowable catch of southern bluefin tuna.

In 1994, the tripartite agreement was formalised in the Convention for the Conservation of Southern Bluefin Tuna (CCSBT). Australian catch quotas were reduced by 75 per cent between 1983-84 and 1989-90, from 21 000 tonnes to 5265 tonnes (Campbell, Battaglene and Brown 1996). The catch quota has not been altered from the 1989-90 level. Australian scientific evidence suggests that catch quotas will need to remain constant until at least 2006 to rebuild the spawning biomass to the 1980 level (McLoughlin et al. 1997). The Australian catch is managed under an individual tradable quota scheme.

Each nation’s quota limit under the CCSBT applies to the tonnage of fish caught; there are no constraints on the mix of juvenile and adult fish which may be caught. (The same conditions applied under the earlier tripartite arrangements.) Other things being equal, such a management policy is likely to have increased the profitability of longline fishing in Australia because the quota price is the same for juvenile and adult fish and equals the maximum effective value that can be earned in both uses. This incentive, reinforced by concerns about the sustainability of the fishery, is likely to have fostered research and
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development into tuna aquaculture. Tuna farming could generate the opportunity to add value to the juvenile tuna quota.

Consistent with these economic incentives, the first experimental farm was established in Port Lincoln in 1990. This involved growing out in a sea pen fifty juvenile tuna that had been caught in the Great Australian Bight (O'Sullivan 1996). Funds were provided to further pursue experimental tuna farming as part of a 1991–93 joint venture agreement between the Australian and Japanese governments, and to train Australian tuna fishers in Japan's longline fishing techniques (Lal, Haque and Battaglene 1994). Successful trials eventually led to the development of several tuna farms in South Australia, the location of which is indicated in figure A.

In 1995-96 the total Australian catch quota was 5265 tonnes, compared with an annual total catch of 5146 tonnes. By 1995-96, 65 per cent of the total Australian catch was used for tuna farming and 7 per cent was used for domestically operated longlining, compared with 0 per cent and 0.3 per cent respectively in 1990-91 (Ward et al. 1997). It is projected that tuna farming over the medium
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term (to 2006) could increase its share of the total allowable catch to 80 per cent (4212 tonnes), with domestic longlining accounting for the remaining share. After 2006, it is possible that the total allowable Australian catch may be increased if the bluefin tuna spawning mass has returned to the 1980 level.

Southern bluefin tuna farming in Australia

Australia's commercial tuna farm industry, located at Port Lincoln, comprised twelve 20 hectare farms and employed 535 full time workers in 1996 (O'Sullivan 1996; B. Jeffriess, President, Tuna Boat Owners Association of Australia, personal communication, March 1996). Compared with longline tuna fishing, a key potential advantage of successful tuna farming, and of successful aquaculture ventures more generally, is the ability to control output risks and thereby reduce income risk. Notably, there may still be significant output risks in the learning phase of the development of a new aquaculture industry — for example, 75 per cent of the tuna held in cages in South Australia died during a storm in 1996 (Clarke 1996).

Profits in tuna farming are earned by producing high value tuna for Japan's sashimi market. Production increased from 97 tonnes in 1991-92 to 2013 tonnes in 1995-96 (Brown et al. 1997). Over the same period, the value of production from the tuna farms increased from $1.8 million to around $40 million. Possibly in an effort to manage environmental risks, the number and maximum size of tuna farms are controlled by the South Australian government through site licensing.

In southern bluefin tuna farming, juvenile tuna weighing about 20 kilograms are captured, put in sea pontoon cages, and grown out to an average weight of 30 kilograms when they are killed, gilled and gutted, chilled and air freighted to Japan (Brown et al. 1997). Juvenile fish are caught from December to May off the South Australian coast, using mainly purse seine techniques (O'Sullivan 1996). A typical fishing trip takes three to four weeks to complete over a distance of around 200 kilometres. Fish are either caught by tuna farmers directly or purchased under subcontract.

Farmed tuna are sold to Japan throughout the year but sales are concentrated in August, when competition from northern bluefin tuna imports is low (Brown et al. 1997). Tuna grow-out takes between four and nine months (O'Sullivan 1996). Fat content, size and the redness of the tuna meat are positively related to the price received for sashimi in Japan. Tuna fish farmed in summer put on weight more rapidly but produce less fat and have weaker flesh colour than those farmed in winter. Over the long term, it is expected that profit opportu-
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nities in tuna farming will reduce the seasonality of bluefin tuna prices (in real terms) in Japan.

In the 1997 season, almost 25 per cent of tuna farming revenues is assumed to have been paid in feed costs and another 25 per cent is assumed to have been paid for juvenile tuna stocks. Tuna can be fed a cocktail of fish species, including pilchards, jack mackerel and squid, but frozen pilchards are the least cost source of feed and are the main feed used (National Task Force on Imported Fish and Fish Products 1996). In the 1997 season, it is estimated that about 29,000 tonnes of pilchards were used on tuna farms, around half of which were imported. Notably, the South Australian Research and Development Institute aims to produce a commercially viable manufactured tuna feed by 1999 (S. Clark, Senior Research Scientist, South Australian Research and Development Institute, personal communication, February 1996). The nutritional quality of manufactured feed can be tailor made and labour use may be reduced through the use of automated pellet release feeders.

Australian pilchard fisheries

Apart from use as feed in tuna farms, pilchards are sold for petfood manufacture, fish bait and, in either fresh or canned form, human consumption. Operating pilchard fisheries are located in Western Australia, South Australia and Victoria (National Task Force on Imported Fish and Fish Products 1996). Those in most of Western Australia and in South Australia are managed under a total annual allowable catch limit for particular fishing zones. In Victoria, a combination of limited entry and input controls are used to manage the fishery.

The Australian pilchards industry is estimated to have caught 15,500 tonnes of pilchards in 1995-96 — 9710 tonnes in Western Australia, 2343 tonnes in Victoria (ABARE 1996) and an assumed 3447 tonnes in South Australia (close to the state's total allowable catch of 3500 tonnes for 1996) (National Task Force on Imported Fish and Fish Products 1996).
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3. Modelling the economic impact of a pilchard import ban

Some economic implications
The objective in this report is to quantitatively illustrate key economic effects on tuna farming of an import ban on pilchards. A mathematical programming model has been constructed for this purpose. The introduction of a quarantine ban on pilchard imports to Australia will have an impact on the southern bluefin tuna farming industry and on other users of pilchards.

The impact of a quarantine restriction on tuna farming will depend on:

- the price of domestically caught pilchards;
- the prices of substitutes to pilchards, such as jack mackerel, squid or, when available, manufactured feed pellets;
- the feed requirement per tonne of southern bluefin tuna harvested for each of these substitutes;
- the impact of each substitute on non-feed operating costs; and
- the impact of alternative feed mixes on the quality and, hence, prices received for tuna.

The most important and currently measurable of these effects are incorporated in the simulation model. Notably, alternative feeds to pilchards are assumed to be perfect substitutes in the modelling exercise, so no allowance has been made for the last three items above. Differences between the feeds, in terms of each of these responses, could be readily incorporated into the model if data were available to indicate the likely direction and magnitude of the effects for the alternative feeds. Thus, for example, operating costs are likely to increase with greater use of jack mackerel because this fish needs to be cut into portions for use as tuna feed, although the magnitude of the cost increase is unknown.

However, the qualitative effects of any differences in these responses are clear. Other things being equal, the effective cost of feed is positively related to the quantity of feed required per tonne of tuna output and to any other increased operating cost impact, and negatively related to any tuna quality improvement which results in a positive tuna price impact.
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In the modelling exercise, domestic and imported pilchards are also assumed to be perfect substitutes. Importantly, the introduction of a quarantine ban on imported pilchard (currently priced around $870 a tonne) will result in an increase in the price of domestically caught pilchards as domestic industries and consumers compete for the reduced total supply of pilchards. Domestic production of pilchards may increase, although the extent of the increase will be effectively limited by pilchard quotas and the size of the pilchard fish stock.

The magnitude of the pilchard price increase will be influenced by the responsiveness of industries and consumers in reducing their use of pilchards as the pilchard price increases. If there are alternative fish species, for example, that are relatively close substitutes for pilchards as petfood or fish bait or in human consumption, and that are relatively competitively priced, these end users of pilchards will switch into the alternative products even for a relatively small increase in the relative price of pilchards. In this case, an increased share of domestic production of pilchards will be available for the tuna farming industry. However, the costs of the tuna farming industry will still increase.

If the closest feed substitute to pilchards in the tuna farming industry is jack mackerel, which costs about $1350 a tonne (55 per cent above the defined pilchard import price), or squid which costs about $1850 a tonne (113 per cent above the defined pilchard import price), the industry may be willing to pay up to this price for domestic pilchards to minimise feed costs, provided tuna farming is still profitable for this new level of feed costs. While tuna farm costs will still increase, this may not affect the optimal level of operations of tuna farming. However, for the above possible range of substitute prices for pilchards as tuna feed, it may be uneconomic to use these feeds in tuna farming over the long term. In this case, tuna farming output will need to be constrained to a level at which only domestic pilchard supplies are used.

Simulation model

A dynamic nonlinear model is used to simulated the main industry activities in tuna farming and related activities each year from 1997 to 2020. All markets in the model are assumed to be competitive. A detailed algebraic description of the model is provided in appendix A, in which parameter values are also outlined.

Three activities are represented in the model: tuna farming, domestic pilchard fishing and consumption of pilchards outside tuna farming. Imported and domestic pilchards are assumed to be perfect substitutes in all uses, and it is further assumed that available substitutes to pilchards as tuna feed are also perfect substitutes. In particular, domestic and imported pilchards are
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indistinguishable to users and command the same price except in the presence of an import ban when the import price is undefined.

The domestic price of pilchards is competitively determined in the model to balance the total available supply with the total domestic demand. Potential users of pilchards outside tuna farming, principally the petfood industry, base their consumption on a negatively sloped log linear demand curve: the higher the pilchard price, the lower the demand for pilchards. Tuna farmers choose the least cost source of feed for tuna, which is a choice between pilchards and alternative feed.

Domestic pilchard fishing is also modelled simply. Pilchard fishers are assumed to be competitive and act as profit maximisers. The domestic pilchard fisheries industry is assumed to choose a total annual harvest which maximises profits subject to a total allowable catch limit. The marginal cost of fishing effort is exogenously projected and is assumed to be constant, as is the total allowable pilchard catch. Thus, for simplicity, overcrowding leading to profit dissipation is not modelled here. Increased demand for pilchards could increase fishing costs without increasing profits to the extent that the existing management regimes define less than perfect private property rights to the use of the pilchard fisheries.

In the model, tuna farmers produce farmed tuna by growing out juvenile tuna each year. In each period, there are three constraints limiting farmed tuna output — equipment capacity, an exogenously projected quota on the juvenile tuna catch and a feed constraint (which describes the proportion of feed required to grow-out the juvenile tuna).

The tuna farming industry is competitive and in each period chooses the level of production, the level of investment in equipment capacity, and the levels of variable inputs to maximise the present value sum of current and future profits. Annual industry profit is gross revenue less operating cost less juvenile tuna and feed cost. The ex farm liveweight price of tuna is exogenously projected. Operating costs for energy, material and labour are assumed to be proportional to output, and unit operating costs are assumed to be constant. The marginal cost of juvenile tuna is exogenously projected and is assumed to be constant.

Scenarios and research method

The simulation model is used to construct a baseline forecast of industry activities in tuna farming and related activities for the years 1997–2020. It is assumed in this baseline forecast that pilchards are the least cost source of feed and, for simplicity, that domestic and imported pilchards are the only feed used in tuna.
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farming. That is, there is no pilchard import ban in the baseline forecast and the small amounts of jack mackerel and squid currently used as feed in the industry are ignored. The domestic price of pilchards is assumed to be identical to the import price (an estimated $870 a tonne in early 1997).

- Two alternative scenarios in which pilchard imports are banned from 1998 are specified in the simulation study. These alternative scenarios are distinguished by the price assumed for the feed substitute to pilchards in tuna farming.

  - **Alternative scenario 1** – price assumed for the feed substitute to pilchards in tuna farming is $1350 a tonne, which is assumed to be indicative of the price of jack mackerel.

  - **Alternative scenario 2** – price assumed for the feed substitute to pilchards in tuna farming is $1850 a tonne, assumed to be indicative of the price of squid.

All prices and costs in the model are expressed in 1997 constant dollars. These alternative scenarios are compared with the baseline forecast.

The simulation model results are used to derive indicators of the direct economic welfare derived from tuna farming and related activities in the various scenarios. The formulas for these measures are outlined in appendix A. Briefly, the total economic welfare measure is the sum of the welfare measures from production and consumption activities.

- Economic profits are associated with growing out juvenile tuna on farms and with harvesting the domestic pilchard wild catch. In each industry, the net present value of profit represents the discounted sum of the economic profit derived over the simulation period, 1997–2020.

- A net consumer surplus is attributed to consumers who use pilchards outside tuna farming. The annual net consumer surplus is the difference between what consumers are willing to pay for pilchards less what they actually pay. The welfare measure for consumers over the simulation period is the discounted sum of the annual net consumer surpluses.

As outlined in appendix A, the annual economic profit from domestic pilchard fishing exactly equals the resource rent to the wild catch. For tuna farming, the present value of economic profits equals the discounted sum of resource rents to the wild juvenile tuna catch plus a lump sum payment which represents the net value of tuna farm capital assets held by the industry over the simulation period. The net capacity asset value equals the asset value of the capacity inher-
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...ited in the opening projection period less the discounted value of capacity remaining in the closing period — or more correctly, the opening value inherited by the industry one period later.
4. Simulation results

The main simulation results are given in table 1 and figure B for the projection period 1997–2020. The simulation results are reported for the three scenarios in absolute terms. The results for alternative scenarios 1 and 2 are also reported as annual percentage deviations from the baseline scenario.

Baseline scenario

Pilchards — the domestic and the imported perfect substitute — are the least cost source of tuna feed in the baseline scenario. Thus, the domestic price of pilchards equals the constant import price (in 1997 dollars) of $870 a tonne (figure B[a]) and the pilchard share in tuna feed is unity (figure B[f]). Given that the allowable catch of domestic pilchards is assumed to be limited, and that the demand for pilchards far exceeds domestic supply in every year, domestic pilchard fishers earn an annual resource rent (which is the difference between the gross value of the fish catch and harvesting costs). The annual resource rental price to domestic pilchards is a constant $110 a tonne in the baseline scenario (figure B[c]). This is the unit price ($870 a tonne) less the marginal cost of the harvest ($760 a tonne).

The cost of pilchards as tuna feed is sufficiently low to support resource rents from the harvesting of juvenile tuna from the wild for grow-out (figure B[d]). It is assumed that the annual resource rent associated with the juvenile tuna catch for farming accrues to farmers. The annual resource rent is the gross value of the juvenile tuna fish catch less the cost of the effort used in fishing. In the long run, the annual resource rental price to juvenile tuna for farming is around $8262 a tonne: this is the maximum value that tuna farming is projected to add to the juvenile tuna quota.

Tuna farm production is fully determined from the allowable juvenile tuna catch in all projection periods of the baseline scenario. Between 1997 and 2006, the available annual juvenile tuna catch for grow-out is assumed to increase by 4.2 per cent a year from 2900 tonnes, and to stabilise at 4212 tonnes. Consequently, the annual growth in tuna farm output is also 4.2 per cent between 1997 and 2006, and 0 per cent thereafter (figure B[e]). The optimal level of tuna farming in the baseline scenario involves annual tuna production of 5686 tonnes over the medium to long term, compared with 3915 tonnes in 1997.
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Main simulation results

<table>
<thead>
<tr>
<th>Results</th>
<th>Unit</th>
<th>1997</th>
<th>1998</th>
<th>2006</th>
<th>2010</th>
<th>2020</th>
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<tbody>
<tr>
<td>Baseline scenario - no ban on pilchard imports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilchard price</td>
<td>$/t</td>
<td>870</td>
<td>870</td>
<td>870</td>
<td>870</td>
<td></td>
</tr>
<tr>
<td>Farmed tuna output</td>
<td>t</td>
<td>3,915</td>
<td>4,081</td>
<td>5,686</td>
<td>5,686</td>
<td>5,686</td>
</tr>
<tr>
<td>Pilchard feed use in tuna farming</td>
<td>t</td>
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<td>30,228</td>
<td>42,120</td>
<td>42,120</td>
<td>42,120</td>
</tr>
<tr>
<td>Non-pilchard feed use in tuna farming</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other domestic use of pilchards</td>
<td>t</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Pilchard imports</td>
<td>t</td>
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<td>32,728</td>
<td>44,620</td>
<td>44,620</td>
<td>44,620</td>
</tr>
<tr>
<td>Domestic pilchard catch</td>
<td>t</td>
<td>15,500</td>
<td>15,500</td>
<td>15,500</td>
<td>15,500</td>
<td>15,500</td>
</tr>
</tbody>
</table>

Scenario 1 - pilchard import ban, other feed price $1350/t

| Pilchard price | $/t | 870  | 1,350 | 1,350 | 1,350 | 1,350 |
| Farmed tuna output | t   | 3,915 | 4,081 | 5,686 | 5,686 | 5,686 |
| Pilchard feed use in tuna farming | t   | 29,000 | 13,499 | 13,499 | 13,499 | 13,499 |
| Non-pilchard feed use in tuna farming | t   | 0    | 16,729 | 28,621 | 28,621 | 28,621 |
| Other domestic use of pilchards | t   | 18,000 | 2,001 | 2,001 | 2,001 | 2,001 |
| Pilchard imports | t   | 31,500 | 0    | 0    | 0    | 0    |
| Domestic pilchard catch | t   | 15,500 | 15,500 | 15,500 | 15,500 | 15,500 |

Scenario 2 - pilchard import ban, other feed price $1850/t

| Pilchard price | $/t | 870  | 1,744 | 1,744 | 1,696 | 1,696 |
| Farmed tuna output | t   | 3,915 | 2,017 | 2,017 | 2,006 | 2,006 |
| Pilchard feed use in tuna farming | t   | 29,000 | 14,944 | 14,944 | 14,861 | 14,861 |
| Non-pilchard feed use in tuna farming | t   | 0    | 0    | 0    | 0    | 0    |
| Other domestic use of pilchards | t   | 18,000 | 556  | 556  | 639  | 639  |
| Pilchard imports | t   | 31,500 | 0    | 0    | 0    | 0    |
| Domestic pilchard catch | t   | 15,500 | 15,500 | 15,500 | 15,500 | 15,500 |

Percentage change from baseline scenario

Scenario 1 - pilchard import ban, other feed price $1350/t

| Pilchard price | %   | 0.0  | 55.2 | 55.2 | 55.2 | 55.2 |
| Farmed tuna output | %   | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |
| Pilchard feed use in tuna farming | %   | 0.0  | -55.3 | -68.0 | -68.0 | -68.0 |
| Non-pilchard feed use in tuna farming | %   | na  | na  | na  | na  | na  |
| Other domestic use of pilchards | %   | 0.0  | -8.9 | -88.9 | -88.9 | -88.9 |
| Pilchard imports | %   | 0.0  | -100.0 | -100.0 | -100.0 | -100.0 |
| Domestic pilchard catch | %   | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |

Scenario 2 - pilchard import ban, other feed price $1850/t

| Pilchard price | %   | 0.0  | 100.4 | 100.4 | 95.0  | 95.0  |
| Farmed tuna output | %   | 0.0  | -50.6 | -64.5 | -64.7 | -64.7 |
| Pilchard feed use in tuna farming | %   | 0.0  | -50.6 | -64.5 | -64.7 | -64.7 |
| Non-pilchard feed use in tuna farming | %   | na  | na  | na  | na  | na  |
| Other domestic use of pilchards | %   | 0.0  | -96.9 | -96.9 | -96.5 | -96.5 |
| Pilchard imports | %   | 0.0  | -100.0 | -100.0 | -100.0 | -100.0 |
| Domestic pilchard catch | %   | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  |

a All prices are in 1997 dollars. na Not applicable.
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Tuna farm capacity, and thus net investment, matches the expansion in the allowable juvenile tuna catch for farming. Gross investment covers both net investment and the replacement of worn out capacity. Profits from tuna farming are initially insufficient to provide an annual return to capacity in 1997 (figure B[b]). In that year, the capacity of 4200 tonnes is fully determined from past activities and is more than that required to support the maximum juvenile tuna catch. However, the strong projected improvement in the industry's future profitability means that a normal rate of return to capital may be earned from 1998.

In the baseline scenario, growth in pilchard use in tuna farming matches growth in farmed tuna output. Pilchard use in tuna farming increases from 29 000 tonnes in 1997 to 42 120 tonnes by 2006 (figure B[g]). At a constant price of $870 a tonne (in 1997 dollars), domestic use of pilchards outside tuna farming is a constant 18 000 tonnes from 1997 (figure B[h]). A constant log-linear demand function is assumed, with a price elasticity of demand of -5 and a
PILCHARD IMPORT BAN

scale term of 8.97. Summing the two sources of demand, the total projected domestic use of pilchards is 60 120 tonnes in 2006, compared with 47 000 tonnes in 1997. Given that it is assumed that the domestic pilchard catch is limited to a constant annual quota of 15 500 tonnes, pilchard imports increase to 44 620 tonnes by 2006, compared with 31 500 tonnes in 1997.

Alternative scenario 1

In scenario 1, the tuna feed substitute for pilchards is jack mackerel, assumed to be available at a constant price of $1350 a tonne (in 1997 dollars) — about 55 per cent higher than the pilchard price in the baseline forecast. Pilchard imports are banned in this scenario, and the price of domestic pilchards immediately rises to the price of jack mackerel in 1998 and stays there (figure B[a]). The long run annual resource rental price to the wild pilchard stock increases commensurately to $590 a tonne. Tuna farm output can be supported at base-

Key simulation results (continued)

(e) Farmed tuna output

(f) Pilchard share in tuna feed

(g) Pilchard use in tuna farming

(h) Other uses of pilchards
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line levels in this scenario (figure B[e]), but the value of resource rents to juvenile tuna is markedly reduced (figure B[d]). In particular, the long run annual resource rental price to the juvenile tuna farming stock is projected to be $3462 a tonne.

Compared with the baseline scenario, in which the pilchard share of the tuna feed mix is 100 per cent, the share drops to 45 per cent in 1998 and further to a maintainable level of 32 per cent by 2006 (figure B[f]).

Given a $480 a tonne increase in the pilchard price, the use of pilchards outside tuna farming contracts immediately to an annual level of 2001 tonnes in 1998, around 89 per cent below the baseline level (figure B[h]). The residual domestic supply of pilchards of around 13 499 tonnes is used in tuna farming from 1998. Growth in tuna feed requirements is met by jack mackerel, which supplies 16 729 tonnes in 1998 and 28 621 tonnes in 2006 when activity stabilises.

Alternative scenario 2

In scenario 2, the tuna feed substitute for pilchards is assumed to be squid, available at $1850 a tonne (in 1997 dollars) — more than double the pilchard price in the baseline forecast (figure B[a]). By contrast with alternative scenario 1, the substitute price for pilchards in this simulation exceeds the maximum price which tuna farmers could pay for feed and still remain profitable. The only alternative which ensures the long run viability of the industry in this scenario is to use domestic pilchards as tuna feed. However, the tuna farm industry is required to contract markedly to achieve this simulated outcome (figure B[e]). No resource rents are generated from the juvenile tuna harvest in this case (figure B[d]). Over the long term, the industry earns a normal rate of return to capital (figure B[b]) but does not add value to the juvenile tuna quota under the simulated import ban in this scenario.

The simulated adjustment phase under the pilchard import ban is short and sharp for tuna farming industry activity. Annual tuna farm production is simulated to fall sharply from 3915 tonnes in 1997 to 2017 tonnes in 1998, almost reaching a maintainable long run level of production (figure B[e]). Nevertheless, the tuna farm adjustment process to the import ban is characterised by excess capacity such that a normal rate of return to capital is not earned until 2009 (figure B[b]). Output from the tuna farm industry is 51 per cent lower than the baseline potential in 1998, and 65 per cent below baseline when activity stabilises in 2011.
PILCHARD IMPORT BAN

A large and sustained increase in the resource rents earned to domestic pilchard fishers is simulated under the import ban in scenario 2 (figure B[c]). In particular, the long run annual resource rental price to pilchard fishers is around $936 a tonne — a direct consequence of the increased prices received for domestic pilchards (figure B[a]). In 1998, a sharp increase in the price of domestic pilchards — a rise of around $874 a tonne — to a level of $1744 a tonne is required to ration the limited domestic pilchard supply between tuna farmers and other users. The long term maintainable price of domestic pilchards is $1696 a tonne. Almost all of the available catch is diverted to tuna farming because the demand by tuna farmers is less price responsive than the demand by other pilchard users (figures B[f-h]). Overall, the simulated long term use of pilchards outside tuna farming is 639 tonnes — around 97 per cent below the baseline level — while the simulated long term use of pilchards in tuna farming is 14861 tonnes — around 65 per cent below the baseline level.

Simulated net present value measures of economic welfare

Indicators of the direct economic welfare derived from tuna farming and related activities in the various scenarios are given in table 2. In the baseline scenario,

<table>
<thead>
<tr>
<th>Simulated net present value measures of economic welfare</th>
<th>Unit</th>
<th>Baseline scenario</th>
<th>Alternative scenario 1</th>
<th>Alternative scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuna farmers’ profit</td>
<td>$m</td>
<td>358</td>
<td>169</td>
<td>27</td>
</tr>
<tr>
<td>Share of total economic welfare</td>
<td>%</td>
<td>35</td>
<td>49</td>
<td>11</td>
</tr>
<tr>
<td>Deviation from baseline</td>
<td>%</td>
<td>–</td>
<td>–53</td>
<td>–93</td>
</tr>
<tr>
<td>Juvenile tuna resource rents</td>
<td>$m</td>
<td>350</td>
<td>162</td>
<td>25</td>
</tr>
<tr>
<td>Share of total economic welfare</td>
<td>%</td>
<td>34</td>
<td>47</td>
<td>11</td>
</tr>
<tr>
<td>Deviation from baseline</td>
<td>%</td>
<td>–</td>
<td>–54</td>
<td>–93</td>
</tr>
<tr>
<td>Net capacity asset value</td>
<td>$m</td>
<td>7</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Share of total economic welfare</td>
<td>%</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Deviation from baseline</td>
<td>%</td>
<td>–</td>
<td>0</td>
<td>–83</td>
</tr>
<tr>
<td>Pilchard fishers’ profit/resource rents</td>
<td>$m</td>
<td>19</td>
<td>97</td>
<td>158</td>
</tr>
<tr>
<td>Share of total economic welfare</td>
<td>%</td>
<td>2</td>
<td>28</td>
<td>66</td>
</tr>
<tr>
<td>Deviation from baseline</td>
<td>%</td>
<td>–</td>
<td>398</td>
<td>712</td>
</tr>
<tr>
<td>Other pilchard users’ consumer surplus</td>
<td>$m</td>
<td>639</td>
<td>76</td>
<td>56</td>
</tr>
<tr>
<td>Share of total economic welfare</td>
<td>%</td>
<td>63</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td>Deviation from baseline</td>
<td>%</td>
<td>–</td>
<td>–88</td>
<td>–91</td>
</tr>
<tr>
<td>Total economic welfare</td>
<td>$m</td>
<td>1 016</td>
<td>342</td>
<td>240</td>
</tr>
<tr>
<td>Deviation from baseline</td>
<td>%</td>
<td>–</td>
<td>–66</td>
<td>–76</td>
</tr>
</tbody>
</table>

*Net present value in constant 1997 dollars for the period 1997-2020.*
in which pilchards may be imported, the total economic welfare derived from
tuna farming, pilchard fishing and pilchard consumption is valued at $1016
million over the simulation period 1997-2020. Profit derived from tuna farming
contributes 35 per cent to this simulated net benefit, profit derived from
domestic pilchard fishing accounts for 2 per cent, and the net benefit to pilchard
consumers outside tuna farming is 63 per cent of the total.

The total economic welfare derived from tuna farming and related activities is
always simulated to be reduced as a result of the imposition of a pilchard import
ban when available tuna feed substitutes to pilchards are more costly. The
smallest projected direct loss in economic welfare is $675 million (66 per cent)
of the baseline value if the price of substitute feed is $480 a tonne (or 55 per
cent) above the world price of pilchards, as in scenario 1. The largest direct
loss in economic welfare is $776 million (76 per cent) of the baseline value if
the price of substitute feed is $980 a tonne (or 113 per cent) above the world
price of pilchards, as in scenario 2. In this latter case, domestic pilchards are
the only economic source of tuna feed available at a simulated long run price
around $826 a tonne above the world price of imports.

As expected, tuna farmers and other pilchard users are always simulated to be
adversely affected by an import ban on pilchards, the least cost source of tuna
feed currently available. Conversely, domestic pilchard fishers are always sim-
ulated to gain from an increase in the price of alternative tuna feed to pilchards
— to the extent that the domestic price of pilchards increases. However, this
simulated welfare gain to pilchard fishers is less than the simulated losses to
pilchard users. In scenario 1 and relative to baseline, the simulated net present
value of pilchard fishers profit increases by $77 million (28 per cent), while
the simulated loss to tuna farmers is $189 million (53 per cent) and that to other
pilchard consumers is $563 million (88 per cent). In scenario 2, as a result of
the pilchard import ban, it is simulated that pilchard fishers gain $138 million,
that tuna farmers lose $331 million, and that other pilchard consumers lose
$583 million relative to baseline.
5. Conclusion

A mathematical programming model was used in this report to simulate the direct effects on the Australian southern bluefin tuna farming industry, other domestic pilchard users and the domestic pilchard fisheries industry of imposing an import ban on pilchards. The economic effects were generated by comparing the model results from a baseline scenario in which pilchard imports are not banned with alternative scenarios in which pilchard imports are banned.

The analysis in this study is based on several assumptions, the most important being that tuna feed alternatives to pilchards are perfect substitutes. The costs of the import ban under this assumption are simulated to be large for tuna farmers and all other users of pilchards. The findings for tuna farming are consistent with the principle that pilchards are currently the least cost source of tuna feed in the profit maximising tuna farming industry.

In the baseline scenario, the discounted sum of annual profits from tuna farming is projected to be $358 million (in 1997 dollars) between 1997 and 2020. The least cost source of tuna feed is pilchards, priced at $870 a tonne in the baseline scenario when pilchard imports are not banned. Output in tuna farming is projected to increase from 3915 tonnes in 1997 to a long run sustainable level of 5686 tonnes in 2006 under baseline conditions. Given profit maximising conditions, this output path reflects an assumed 4.2 per cent annual increase in the juvenile tuna quota available for farming between 1997 and 2006, with a constant quota assumed thereafter.

The growth in tuna farm feed matches the growth in tuna farm output. Assuming that the supply of domestic pilchards is fixed over the projection period, all growth in tuna feed requirements is simulated to be met by imports. Pilchard imports increase from 31,500 tonnes to 42,120 tonnes in the baseline scenario.

Given a pilchard import ban, the discounted sum of profits from tuna farming could be reduced to a projected $169 million (a projected loss of $189 million) between 1997 and 2020 if the price of the least cost substitute to pilchards for tuna feed is $1350 a tonne (the assumed price of jack mackerel). At this price, the long run sustainable output rate for tuna farming is still simulated to be 5686 tonnes. If the least cost substitute price increased to $1850 a tonne (the assumed price for squid) under a pilchard import ban, the tuna farming industry could contract markedly, with projected output falling from 3715 tonnes in 1997 to a long run sustainable level of 2006 tonnes. In this case, the
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net present value of profits in tuna farming could be reduced further to $26.6
million between 1997 and 2020.

Resource rents to domestic pilchard fishers are simulated to increase markedly
under the pilchard import ban when the price of the least cost substitute to
pilchards exceeds the price of imported pilchards of around $870 a tonne. If
the least cost substitute to pilchards is jack mackerel under a pilchard import
ban, for example, the net present value of profits to pilchard fishers between
1997 and 2020 could increase from $19 million in the baseline scenario to $97
million when the domestic pilchard supply is subject to a constant allowable
catch. This finding highlights a potential pressure to increase pilchard fisher
costs without increasing profits when demand increases and overcrowding
results if property rights to the resource are less than perfectly defined.

The above assessment could change for the tuna farming industry if there are
other internal costs or risks from the use of imported pilchards in addition to
the direct costs of purchase. To the extent that there is any risk that the Aus-
tralian government may impose an import ban on pilchards, for example, the
cost of risk to profits may be reduced by diversifying the source of tuna feed
away from pilchards. In this sense, there may be some potential overreliance
of the industry on imported pilchards in the absence of a proven long term cost
effective substitute to pilchards as tuna feed. It is possible that the develop-
ment of a commercially viable manufactured tuna feed may reduce both envi-
ronmental and economic risks.

The South Australian Research and Development Institute is coordinating
research to develop a manufactured feed for farmed tuna. The adoption of the
feed in tuna farming will depend on a cost–benefit assessment. Assuming per-
fect feed substitutes, and in the absence of a pilchard import ban, tuna farmers
could be indifferent about purchasing the manufactured feed instead of imported
pilchards if the price of manufactured feed is $870 a tonne. At this price, the
import ban may have no effect on the profitability of tuna farming, or on the
economic welfare of pilchard fishers or on other domestic users of pilchards.

At a manufactured feed price greater than $760 a tonne (the assumed unit cost
of harvesting domestic pilchards) but less than $870 a tonne, tuna farmers could
replace imported pilchards with manufactured feed under the perfect substi-
tutes assumption. At a still lower price, tuna farmers could solely use manu-
factured feed on tuna farms. In both cases, the price of domestic pilchards
could drop to the price of manufactured feed.

In the model framework used in this study, the technical advance in manufac-
tured feed could increase profits in tuna farming and increase the economic
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welfare of other users of pilchards. Although it could decrease the resource rents earned by pilchard fishers domestically, the total economic welfare of tuna farmers and related industries could be increased.

However, based on the simulation model, if the price of manufactured feed exceeds $870 a tonne, the feed could only be adopted under a pilchard import ban. In this case, tuna farmers could be indifferent about purchasing jack mackerel or manufactured feed if the price of manufactured feed is $1350 a tonne. The maximum share of manufactured feed in tuna farming is projected to be 68 per cent by 2006 under this condition. If manufactured feed is priced below $1350 a tonne but greater than $870 a tonne, the maximum share could be greater still. In both cases, the price of domestic pilchards under an import ban, could rise to the price of manufactured feed.

In summary, if the minimum price for the tuna feed substitute to pilchards is greater than the pilchard import price of $870 a tonne, tuna farmers and other pilchard users are projected to be worse off under a pilchard import ban. Although pilchard fishers are projected to be better off, the total economic welfare of tuna farmers and related industries could be reduced.
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Appendix A: Primal dual model of Australian tuna farming

The model used to simulate some key potential impacts on Australian tuna farming of a ban on imported pilchards is outlined in this appendix. A list of model sets and variables is given below, followed by a presentation of the model parameters and baseline scenario values. Parameters are ABARE assumptions which are largely based on updates of Lal, Haque and Battaglene (1994). Model equations are given in section 3, and welfare measures are noted in section 4. The model was solved using the GAMS-MINOS software. In general, the GAMS code is reproduced in upper case below. Explanatory notes are also provided in the boxes.

1. Model sets and variables

Sets

T
Annual time periods (1997–2020)

TF(T)
First time period (1997)

TL(T)
Last time period (2020)

TM(T)
Most time periods (1998–2020)

Variables

XPT(T)
Tuna farm use of pilchards

XOF(T)
Tuna farm use of other feed

XPO(T)
Other domestic use of pilchards

QTF(T)
Production of farmed tuna

QPD(T)
Domestic harvest of pilchards

QPM(T)
Volume of imported pilchards

I(T)
Gross investment in capacity of tuna farming

K(T)
Capacity of tuna farming

LPK(T)
Present value price of tuna farm capacity

LCFD(T)
Present value unit cost of tuna feed in potential tuna output equivalent

LPPD(T)
Present value price of domestic pilchards
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\( LRK(T) \) Present value annual unit rental to tuna farm capacity

\( LRPM(T) \) Present value unit quota rental on pilchard imports

\( LRPD(T) \) Present value unit quota rental on domestic pilchard catch

\( LRJV(T) \) Present value unit quota rental on domestic juvenile tuna catch

\( OBJ \) Objective function value

Positive variables: \( XPT, XOF, XPO, QTF, QPD, QPM, I, K, LPK, LCFD, LPPD, LRK, LRPM, LRPD, LRJV \).

---

Note

All prices and costs are in 1997 $'000 a tonne and volumes are in '000 tonnes. Present values are constant values which are discounted to 1997. Producer prices for fish are measured in live weight equivalent.

2. Model parameters and values

Scalars

\( MB \) Binary variable is 1 under import ban scenario (0)

\( DRATE \) Discount rate fraction (0.08)

\( DEP \) Tuna farm capacity depreciation fraction (0.06)

\( ED \) Price elasticity of other domestic demand for pilchards (-5)

\( AXPO \) Scale term in other domestic demand curve for pilchards (8.97)

\( PT \) World price of tuna (27.14)

\( PPM \) World price of imported pilchards (0.87)

\( POF \) Price of other tuna feed (1.35)

\( KB \) 1997 tuna farm capacity (4.2)

\( ATF \) Tuna farm unit operating cost (10.2)

\( BTF \) Tuna farm unit investment cost in capacity (2.5)

\( CTF \) Tuna farm adjustment cost parameter for capacity expansion (0.5)

\( MCJ \) Unit cost of juvenile tuna (5.43)

\( MCP \) Unit cost of domestic pilchards (0.76)
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**GRFAC**  Projected constant growth of juvenile tuna, 1998–2006 fraction (0.042)

**FDX1**  Potential tuna farm output to feed input proportion (0.15)

**MORT**  On-farm mortality rate of tuna fraction (0.10)

**G2**  Fed potential tuna farm output per farmed tuna output equivalent

**WTINC**  Potential weight increase of a tuna from feed fraction (0.5)

**G1**  Juvenile input per farmed tuna output equivalent

\[
G2 = \frac{1}{1 - MORT} \\
G1 = \frac{G2}{1 + WTINC}
\]

**Note**

- The price shown for other (non-pilchard) feed for tuna is the price of jack mackerel. In scenario 2, the substitute feed is squid, available at a price of $1.85 a kilogram.

- In 1997 an estimated 18 000 tonnes of pilchards were consumed in other domestic uses outside tuna farming — primarily in petfood manufacture. The scale term in the demand curve for other (non-tuna farming) domestic demand for pilchards was calibrated to this quantity and an import parity price of $870 a tonne.

- The volume of the juvenile tuna biomass for farm grow-out is \( G1 \cdot QTF \) and the potential volume of tuna which must be fed is \( G2 \cdot QTF \). The juvenile to adult farmed fish has a potential weight increase of \( WTINC \) when fed \( FDX1 \) tonnes of feed. The actual farmed tuna output is the potential output adjusted for fish mortality.

Parameter \( DR(T) \), discount rate factor:

\[
DR(T) = \frac{1}{(1 + DRATE)^{ORD(T)} - 1)}
\]

Parameter \( QPMBAR(T) \), import constraint on pilchards:

\[
QPMBAR(T) = 10000 \\
QPMBAR(TM)\$MB = 0
\]
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*Note*
The pilchard import quota constraint will not bind in the baseline scenario given a high enough quota on the volume. The import ban is binding in alternative scenarios. A $ sign means only if.

Parameter $QJVBAR(T)$, quota on domestic juvenile tuna catch for tuna farms:

$$QJVBAR(TF) = 2.9$$

$$LOOP(T$$(ORD(T) LE 9), QJVBAR(T+1) = QJVBAR(T)*(1 + GRFAC))$$

*Note*
It is assumed that the total allowable juvenile tuna catch for farming increases at the rate GRFAC between 1997 and 2006 and is constant thereafter. This means tuna farms may take an increasing share of the constant Australian tuna quota over this period. The share is assumed to reach maximally 80 per cent by 2006.

Parameter $QPDBAR(T)$, quota on domestic pilchard catch:

$$QPDBAR(T) = 15.5$$

3. Model equations

$ZPP$, zero pure profit objective function:

\[
SUM(T, DR(T)*XPO(T)*(AXPO** - (1/ED)))*((XPO(T)**(1/ED)))
\]

(a)

\[
+ SUM(T, DR(T)*(PT - ATF)*QTF(T))
\]

(b)

\[
- SUM(T, DR(T)*(BTF*I(T) + 0.5*CTF*I(T)*I(T)/K(T)))
\]

(c)

\[
- SUM(T, DR(T)*POF*XOF(T)) - SUM(T, DR(T)*PPM*QPM(T))
\]

(d)

(e)

\[
- SUM(T,DR(T)*MCP*QPD(T)) - SUM(T,DR(T)*MCJ*G1*QTF(T))
\]

(f)

(g)
\[ - \text{SUM}(T, \text{LRPM}(T) \times \text{QPMBAR}(T)) - \text{SUM}(T, \text{LRJV}(T) \times \text{QJVBAR}(T)) \]

\[ - \text{SUM}(T, \text{LRPD}(T) \times \text{QPDBAR}(T)) - \text{SUM}(T, \text{LPK}(T)) \times \text{KB} \]

\[ + \text{SUM}(T, \text{LPK}(T) \times ((1 - \text{DEP}) \times \text{K}(T) + I(TL))/((1 + \text{DRATE}) = E = \text{OBJ}) \]

\((l)\)

\textbf{Note}

- Term (a) is the net present value sum of revenues from domestic uses of pilchards outside tuna farming. The demand curve in these other uses is assumed to be log-linear and is assumed here to change only with changes in the real price of pilchards.

- Term (b) is the net present value sum of revenues from tuna farming net of operating costs.

- Term (c) is the net present value sum of gross investment in tuna farm capacity inclusive of adjustment costs of capacity expansions.

- Term (d) is the net present value sum of tuna feed costs excluding pilchards.

- Terms (e) and (f) are the net present value sums of the marginal costs of supplying imported and domestic pilchards to tuna farmers and other domestic users.

- Term (g) is the net present value sum of the marginal cost of supplying juvenile tuna to tuna farmers.

- Terms (h), (i) and (j) are the net present value sums of quota rental payments on pilchard imports, the total allowable juvenile tuna catch for tuna farming, and the total allowable domestic pilchards catch.

- Terms (k) and (l) are the opening and closing asset values of the capacity in tuna farming in the first and one period post-terminal projection periods. It is assumed that the unit price of capital is constant by the terminal period such that tuna farming and associated activities could be maintained at then prevailing levels given replacement investment in tuna farm capacity.
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$E1 LRK(T)$, tuna farm capacity constraint:

$$QTF(T) = L = K(T)$$

$E2 LCFD(T)$, tuna farm feed requirements:

$$G2*QTF(T) = L = FDX1*(XPT(T) + XOF(T))$$

$E3 LPPD(T)$, supply demand balance for pilchards:

$$XPO(T) + XPT(T) = E = QPD(T) + QPM(T)$$

$E4 LRPM(T)$, quota on pilchard imports:

$$QPM(T) = L = QPMBAR(T)$$

$E5 LRPD(T)$, quota on total allowable domestic pilchard catch:

$$QPD(T) = L = QPDBAR(T)$$

$E6 LRJV(T)$, quota on total allowable domestic juvenile tuna: catch for tuna farming:

$$G1*QTF(T) = L = QJVBAR(T)$$

$E7 LPK(T)$, capacity accumulation in tuna farming:

$$K(T) = E = (1 - DEP)*K(T-1) + I(T-1) + KBSTF(T)$$

**Note**
The opening tuna farm capacity in the first period TF is the predetermined value KB that is inherited from past activities.

$E8 XPO(T)$, demand curve for pilchards in other uses than tuna farming:

$$DR(T)*((XPO(T)/AXPO)**(1/ED)) = E = LPPD(T)$$

$E9 XPT(T)$, price rule on use of pilchards in tuna farming:

$$LCFD(T) * FDX1 = L = LPPD(T)$$
**PILCHARD IMPORT BAN**

**E10XOF(T), price rule on use of other feed in tuna farming:**

\[ \text{LCFD(T)} \times \text{FDX1} = L = \text{DR(T)} \times \text{POF} \]

**Note**
Equations (9) and (10) state that the unit value of other (non-pilchard) feed to tuna farmers cannot exceed the price paid for the feed.

**E11QPM(T), price rule on importation of pilchards:**

\[ \text{LPPD(T)} = L = \text{DR(T)} \times \text{PPM} + \text{LRPM(T)} \]

**Note**
Equation (11) states that the domestic price paid for imported pilchards (the unit worth of domestic pilchards, the perfect substitute to imported pilchards) cannot exceed the unit cost of imported pilchards inclusive of any unit quota rent on imports.

**E12QTF(T), price rule on production of farmed tuna**

\[ \text{DR(T)} \times \text{PT} = L = \text{DR(T)} \times \text{ATF} + \text{LRK(T)} + G2 \times \text{LCFD(T)} + \]
\[ G1 \times (\text{DR(T)} \times \text{MCJ} + \text{LRJW(T)}) \]

**Note**
Equation (12) states that the price of farmed tuna cannot exceed unit operating costs, capital rentals and feed costs, and the unit cost of supplying juvenile tuna inclusive of any quota rent on the total allowable catch used by tuna farms.

**E13QPD(T), price rule on domestic pilchard harvest:**

\[ \text{LPPD(T)} = L = \text{DR(T)} \times \text{MCP} + \text{LRPD(T)} \]

**Note**
Equation (13) states that the price of domestic pilchards cannot exceed the unit cost of supply inclusive of any unit quota rent on the total allowable catch.
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\( E_{14} I(T) \), price rule on gross investment activity in tuna farm capacity:

\[
LPK(T+1) + (LPK(T)/(1 + DRATE))STL(T) = L
\]

\[
= DR(T) * (BTF + CTF * I(T)/K(T))
\]

**Note**
Equation (14) states that the unit worth of gross investment in tuna farm capacity cannot exceed the unit cost of supply inclusive of investment adjustment costs. The second term in the equation accounts for the one period post-terminal unit value of gross investment in capacity. The unit value of capital is assumed to be constant by the terminal period.

\( E_{15} K(T) \), rental price for tuna farm capacity:

\[
LRK(T) = E = LPK(T) - (1 - DEP) * LPK(T+1) -
\]

\[
((1 - DEP) * LPK(T)/(1 + DRATE))STL(T)
\]

\[
-DR(T) * 0.5 * CTF * I(T) * I(T)/K(T) * K(T)
\]

**Note**
Equation (15) states that the rental value of a unit of tuna farm capacity exactly covers real interest costs and depreciation less any capital gain less reduced investment adjustment costs.

4. Welfare measures

**Scalars**

- **CSPO** Present value of consumer surplus to pilchard users other than tuna farmers
- **PSPF** Present value of profit to pilchard fishers
- **PSTF** Present value of profit to tuna farmers
- **TS** Total economic welfare

\[
CSPO = \text{SUM}(T, DR(T) * (AXPO**(-1/ED))*(ED/(ED+1))*(XPO(T)**(ED/(ED+1)))) - \text{SUM}(T, LPPD(T) * XPO(T))
\]
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\[ \text{PSPF} = \sum(T, QPD(T) \times (LPPD(T) - \text{DR}(T) \times \text{MCP})) \] or

\[ \text{PSPF} = \sum(T, LRPD(T) \times QPDBAR(T)) \]

\[ \text{PSTF} = \sum(T, \text{DR}(T) \times ((\text{PT} - \text{ATF}) \times \text{QTF}(T) - \text{BTF} \times I(T) -
0.5 \times \text{CTF} \times I(T) / \text{K}(T))) - \sum(T, \text{DR}(T) \times \text{MCJ} \times G1 \times \text{QTF}(T))
- \sum(T, \text{DR}(T) \times \text{POF} \times \text{XOF}(T)) - \sum(T, \text{LPPD}(T) \times \text{XPT}(T)) \]

or

\[ \text{PSTF} = \sum(T, LRV(T) \times QJVBAR(T)) + \sum(TF, \text{LPK}(TF)) \times \text{KB} - \sum(TL, \text{LPK}(TL) \times ((1 - \text{DEP}) \times \text{K}(TL) + I(TL)) / (1 + \text{DRATE}) \]

\[ TS = \text{CSPO} + \text{PSPF} + \text{PSTF} \]
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References


Campbell, D., Battaglene, T. and Brown 1996, Use of individual transferable quotas in Australian fisheries, ABARE paper presented to an International Workshop on Assessment and Distribution of Harvest Quotas in Fisheries, Aalesund, Norway, 8-11 July.


PILCHARD IMPORT BAN


National Task Force on Imported Fish and Fish Products 1996, Report of the National Task Force on Imported Fish and Fish Products: A Report into the Implications Arising from Aquatic Animal Products, Department of Primary Industries and Energy, AGPS, Canberra.


