SUBSIDIES AND DEEP-SEA FISHERIES MANAGEMENT: POLICY ISSUES AND CHALLENGES[1]

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ABSTRACT

Recent international developments have underscored the political importance attached to fisheries subsidies reform, particularly with respect to over-capacity and high seas fishing. The World Trade Organization undertook to clarify and improve WTO disciplines on fisheries subsidies, while the World Summit on Sustainable Development has issued a call to eliminate subsidies that contribute to illegal, unreported and unregulated fishing and to over-capacity. The bioeconomic and management characteristics of deep-sea fisheries make them particularly vulnerable to overexploitation and the provision of subsidies to the fishing sector is likely to exacerbate this vulnerability. The interactions between subsidies and deep sea fisheries exploitation are addressed in this paper. The impacts of subsidies on fishery resources will generally depend on the management regime in place. If the management regime effectively limits the catch or effort that can be applied to a fishery, then the provision of subsidies will generally not have a direct impact on fish stocks. However, this outcome depends critically on the effectiveness of the enforcement of regulations and the extent to which subsidised fishers operate outside national jurisdictions and outside international management arrangements. Such a situation is particularly relevant to deep sea fisheries, and subsidies clearly increase the pressure on national and international management arrangements for these fisheries.

1. INTRODUCTION

The issues of fisheries subsidies and the depletion of deep-sea fisheries have become increasingly prominent in international policy discussions in recent years. Deep-sea fisheries began to increase in importance in the 1970s, coinciding with declines in shallow-water fisheries and the extension of the Exclusive Economic Zone to 200 nautical miles under the UN Convention on the Law of the Sea. Improvements in technology in terms of larger vessels and more robust fishing gear helped expand the ability of fleets to exploit deep-sea resources. It is estimated that around 40 % of the world's trawling grounds are now in waters deeper than the continental shelves (Roberts 2002, p. 242). In its latest report on the state of world fisheries, the FAO reported that world catches of oceanic species had reached almost 8.5 million tonnes in 2000, just under 10% of the production from marine capture fisheries (FAO 2002, pp. 13-14).[2]

The phenomenon of sequential stock depletions, particularly with respect to orange roughy and more recently Patagonian toothfish, has focussed attention on the relative fragility of deep-sea fisheries and has

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1 The views expressed in this paper are those of the author and do not necessarily represent the views of the OECD Committee for Fisheries or the Member countries of the OECD.

2 This covers epipelagic and deep water species that occur principally on the high seas. The FAO notes that some of these species, particular the oceanic tunas, are also caught within EEZs and hence the figure for high seas fish catches may be overstated to some (unknown) extent.

lead to calls for improved management of these resources. In releasing its latest report on deep-sea fisheries, the International Council for the Exploration of the Sea (ICES) warned that "several deep-sea stocks are now heavily exploited and in some cases severely depleted" and "suggested that there should be an immediate reduction of fishing pressure on fully exploited or overexploited deep-sea stocks" (ICES 2003b). Non-governmental organisations, such as the World Wide Fund for Nature, have also highlighted the need to protect deep-sea stocks and there have been calls for the increased use of marine protected areas to protect deep-sea fish resources and the associated marine environment (WWF 2003).

Fisheries subsidies reform has also been at the forefront of recent international developments, particularly with respect to the links to over-capacity and high seas fishing. At its Fourth Ministerial Conference in Doha, Qatar, in November 2001, the World Trade Organization (WTO) undertook to "clarify and improve WTO disciplines on fisheries subsidies, taking into account the importance of this sector to developing countries" (WTO 2001b, para. 28). This was followed at the World Summit on Sustainable Development in Johannesburg by a call to "eliminate subsidies that contribute to illegal, unreported and unregulated fishing and to over-capacity, while completing the efforts undertaken at the WTO to clarify and improve its disciplines on fisheries subsidies …" (United Nations 2002, para. 30(f)). Discussions are continuing in the WTO Negotiating Group on Rules on how to proceed on addressing the mandate provided in the Doha Declaration.[3] Work on analysing the effects of fisheries subsidies is underway in other inter-governmental organisations, including the OECD, the FAO and UNEP. The need to take action on fisheries subsidies has also been strongly supported by environmental groups (see, for example, WWF 2002a, b).

The linkages between subsidies to the fisheries sector and deep sea fisheries exploitation are addressed in this paper. The main conclusion reached in the paper is that the bioeconomic and management characteristics of deep-sea fisheries make them particularly vulnerable to overexploitation, even in the absence of subsidies to the fisheries sector. The provision of subsidies will increase the expected net returns from fishing and lead to increased pressure on stocks. However, the impact of subsidies will depend very much on the management arrangements in place for the particular fisheries, particularly the type of management regime, whether management settings (such as total allowable catches or effort) are correct and the effectiveness of enforcement. In the absence of effective management, subsidy removal, which may be justified on economic grounds, will not necessarily result in reduced fishing pressure on deep-sea stocks.

In the next section, data on the types and amounts of subsidies in OECD countries for the period 1996-2000 are presented to provide some background on the size and composition of subsidies. The bioeconomic and management characteristics of deep-sea fisheries are then discussed. The economic and environmental effects of subsidies under various types of management arrangements are outlined and the implications for deep-sea fisheries discussed. Finally, some of the major challenges for subsidy reform and the improved management of deep sea fisheries are addressed.

2. SUBSIDIES TO THE FISHERIES SECTOR IN OECD COUNTRIES

The last few years has seen a great deal of effort being devoted to defining fisheries subsidies and developing frameworks for categorising and measuring subsidies. This has taken place in a range of forums and has resulted in a variety of definitions and classification frameworks. Porter (2002) provides a review of the various classification schemes that have been used by the OECD, APEC and the United States. The FAO has undertaken a number of expert consultations which addressed, amongst other things,

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[3] Schrank (2003, pp. 43-7) provides a brief review of the evolution of the discussions within the WTO on fisheries subsidies.

the issue of what constitutes a fishery subsidy (FAO 2000, 2003a). Long debate over subsidy definitions is common to many other sectors where subsidy discussions are underway (Steenblik 2003).

According to some experts, subsidies should be defined very broadly to could include all government actions — including the absence of correcting interventions — that potentially can affect (positively or negatively) the benefits of firms active in the fishery sector, either in the short or the long run (FAO 2001, pp. 4-5). However, this does not appear to be a very useful operational definition as it includes the full range of management actions that could possibly be applied to the fisheries sector and also requires some judgements to be made about the extent to which these actions deviate from what is perceived as "optimal".

It seems more tractable to employ a narrower definition of subsidy which covers the direct transfers made by governments to support the fishery sector (such as grants, direct payments, etc), as well as the government programs which are "off-budget" but which confer a direct monetary benefit (such as tax exemptions, loan guarantees, insurance underwriting, etc). This is the definition that was adopted by the OECD in its study, *Transition to Responsible Fisheries* (OECD 2000). Government financial transfers (GFTs) covers direct payments, cost-reducing transfers and payments for general services.[4] Direct payments are transfers that enhance the revenue of recipients and are paid from government budgets (that is, financed by taxpayers) directly to fishers. Examples include price support payments to fishers, grants for new vessels, grants for modernisation, vessel decommissioning payments, buyouts of licences and permits, buyouts of quota and catch history, income support and unemployment insurance (see OECD 2000, p. 130 for a more detailed listing of subsidies included in each category).

Cost-reducing transfers are payments from the government to fishers that reduce the costs of fixed capital and variable inputs. In this regard, they are a revenue-enhancing transfer that may affect the operating decisions of fishers with respect to output or the levels and types of inputs employed. Examples include fuel tax exemptions, subsidised loans for vessel construction and modernisation, provision of bait services, loan guarantees, underwriting of insurance costs, interest rebates, transport subsidies and government payment of access to other countries' waters.

General services is a catch-all category that covers transfers that are not received directly by fishers, but that reduce the costs faced by the sector as a whole. About half of this category includes expenditures on research, management and enforcement. General services also comprise expenditures by governments to support prices (for example, by withdrawing fish from markets) and expenditures on infrastructure that benefit the industry as a whole (in contrast with cost-reducing transfers that benefit individual fishers directly). Examples of the latter include stock enhancement schemes and investments in fishing ports.

GFTs in OECD countries have fluctuated over the period 1996 to 2000 (Figure 1). From a level of around USD 6.8 billion in 1996, GFTs declined to around USD 5.5 billion in 1998 before increasing to be close to USD 6 billion in 2000 (all in nominal terms).[5] It was noted in OECD (2000) that the estimated total is probably too low as it does not include significant support items for some countries such as tax

[4] A category of market price support was also included in the classification which covers gross transfers from consumers and taxpayers to fishers arising from policy measures (normally trade measures) creating a gap between domestic market prices and border prices of specific commodities. Market price support was not estimated for the *Transition to Responsible Fisheries* study due to technical and data difficulties. However, OECD (2003a, p. 18) provided an approximate value of market price support at USD 1 billion a year based on tariff revenue data for fish and fish products.

[5] Note that there are some data gaps for some countries over the period, particularly for 1998 and 1999. Inclusion of the data for the omitted countries could be expected to add around USD 120 million and USD 150 million to the totals in 1998 and 1999, respectively.

concessions, non-payment of fishing port berthing fees, support to builders of fishing vessels and regional and local government expenditures in many countries. The value of GFTs as a percentage of the gross value of production has remained relatively steady at around 18-19% over the period. Table 1 provides details of GFTs by country for each of the categories for 2000.

The main uses of transfers in OECD countries are for providing fisheries infrastructure, ensuring the sustainable use of fish stocks, dealing with fishery adjustment pressures, modernising fleets and acquiring access to fisheries in other countries' waters. The largest component of GFTs is general services, which accounted for 76% of total GFTs in 1996 and 71% of the total in 2000 (Figure 1). Research, management and enforcement expenditures account for around half of the expenditure on general services and for approximately 30% of the total GFTs in each year (Figure 2). The bulk of the rest of general services expenditure is devoted to the provision of fisheries infrastructure (including support for construction of port facilities for commercial fishers). Expenditures on direct payments and cost-reducing transfers account for between 4–6% of the gross value of fisheries production. These expenditures consist mostly of payments for vessel modernisation, vessel building, decommissioning of vessels, licence retirement, income support and unemployment insurance.

It is not possible, based on the data available at this stage, to identify or quantify the subsidy programs that are provided to operators in deep-sea fisheries or that will have a direct or indirect effect on deep-sea fisheries. However, it is clear that some types of subsidies are more likely to have an impact than others. For example, subsidies to vessel construction and modernisation have long been recognised as having contributed to the existing over-capacity in the world's fishing fleet. As fishing opportunities in national exclusive economic zones (EEZs) have declined as a result of overfishing and improved management

Figure 1: Government financial transfers in OECD countries, 1996-2000

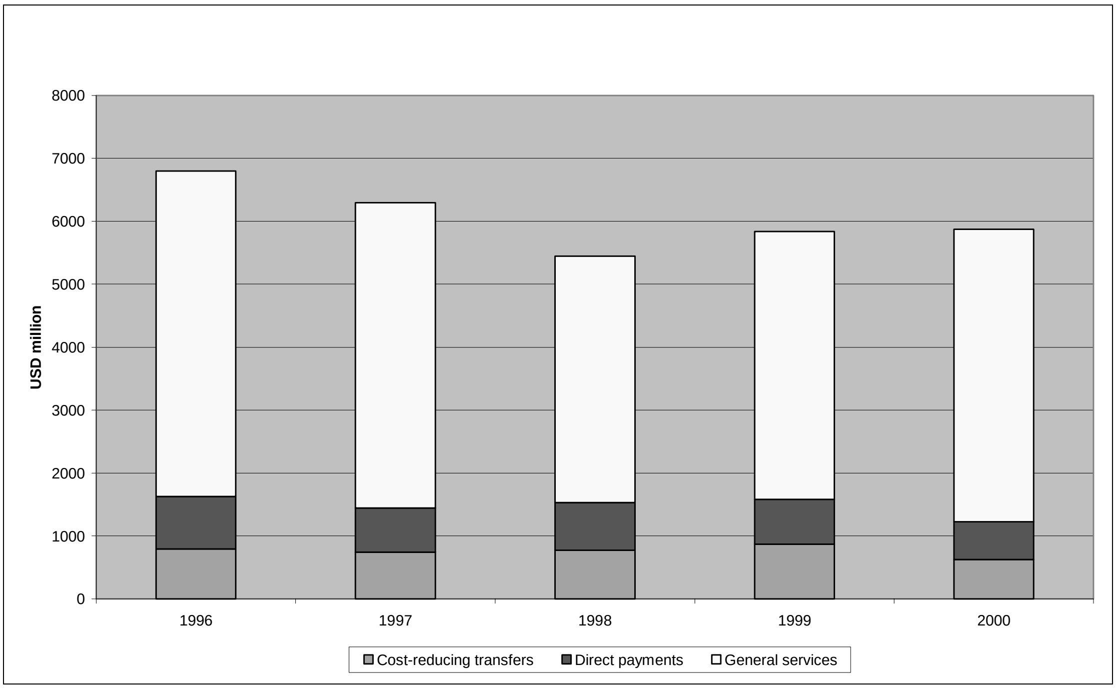


Figure 2: OECD GFTs by Programme Objective, 1997

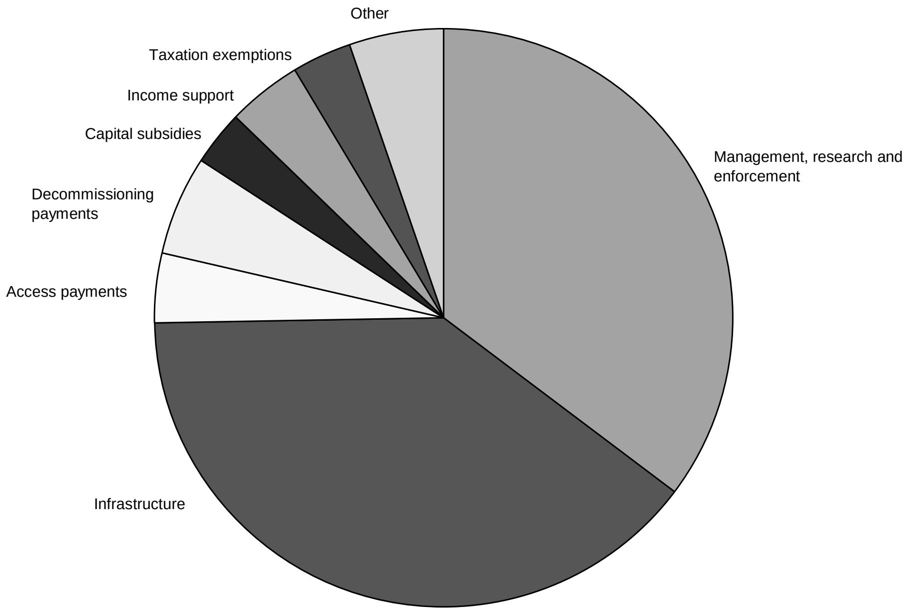


Table 1: Government Financial Transfers and Production, OECD Countries, 2000p

	Direct Payments (A)	Cost Reducing Transfers (B)	General Services (C)	Total Transfers (D)	Total Landed Value (TL)	GFTs as % of total landings
	USD million	USD million	USD million	USD million	USD million	%
Australia	..	56	26	82	1,011	8
Canada	209	69	230	476	1,418	34
European Union	295	322	278	895	6,255	14
Belgium	6	..	..	6	82	7
Denmark	6	..	2	8	404	2
Finland	0	4	7	11	21	53
France	60	9	98	167	952	18
Germany	1	8	..	9	150	6
Greece	18	15	30	62	233	27
Ireland	..	..	..	..	..	..
Italy	93	7	51	151	1,422	11
Netherlands[1]	0	..	..	0	446	0
Portugal	2	..	24	26	252	10
Spain	109	132	46	287	1,355	21
Sweden	1	2	18	21	106	20
United Kingdom	..	4	1	5	833	1
Iceland	..	16	26	31	735	4
Japan	19	37	2,807	2,864	12,021	24
Korea	34	68	214	316	3,667	9
Mexico	..	..	..	..	1,044	..
New Zealand[2]	..	..	27	15	..	..
Norway	2	18	85	105	1,112	9
Poland	..	..	..	..	91	..
Turkey	..	..	0	0	..	..
United States of America[3]	67	14	952	1,032	3,638	28
OECD Total	625	600	4,647	5,816	30,992	19

..: not available; 0 refers to data between 0 and 0.5; p: preliminary.

1. Turnover Dutch fisheries estimate.

2. Total transfers are net of the amount of cost recovery.

3. Includes an estimate of market price support (that is, transfers from consumers to producers).

Source: OECD (2003).

(reducing fishing capacity in the EEZs), the excess capacity shifted out to the high seas and other EEZs in search of new opportunities. This often meant a shift to deep-sea stocks. Indeed, in some cases, this shift was supported by governments in an effort to assist the transition of fishers out of overexploited fisheries (Haedrich, Merrett and O'Dea 2001). Similarly, subsidies supporting exploratory fishing in the deep-seas or research into the development of improved fishing gear and technology are likely to have an effect on deep-sea fish resources. However, further research is required at the level of national subsidy programs in order to identify those subsidies that may affect deep-sea resources either directly or indirectly.

3. BIOECONOMIC AND MANAGEMENT CHARACTERISTICS OF DEEP-SEA FISHERIES

Deep-sea fisheries are relatively loosely defined from a biological perspective. In general, deep sea fisheries are defined as fisheries carried out in waters deeper than around 400-500m (ICES 2003, Koslow et al 2000). Stock assessments for deep-sea stocks are mostly undertaken according to species in geographically defined areas. Prominent species often mentioned in relation to deep-sea fisheries include orange roughy, Greenland halibut, pelagic armourhead, Patagonian toothfish and blue grenadier. In brief, deep-sea species are generally characterised as having a very slow growth rate, being very long-lived and having low fecundity (Gordon 2001). They also tend to aggregate around ocean banks and seamounts. Orange roughy, for example, live up to 125 years, reaching maturity and a reproductive age at around 20-25 years (Koslow et al 2000, p. 550). Other species, such as sablefish, which populate the slopes and open seafloor tend to be not quite so long-lived (50-60 years), mature earlier at around 5-10 years but are also very slow-growing. The slow growth of deep-sea species is largely explained by the low levels of energy and nutrients in the ocean depths which they inhabit.

From an economic perspective, the characteristics of deep-sea fisheries (slow growth, low productivity, etc) mean that they are particularly vulnerable to overexploitation. This can be demonstrated using some basic results from fisheries economics, particularly that based on capital theory, and a simple model of a fishery is provided in the appendix to this paper to illustrate the key points. There are five aspects to the deep-sea fisheries problem that are particularly relevant to the economic dimension:

- the low natural growth rate combined with constant harvesting costs;
- a divergence between private and social rates of time preference;
- high initial catches in deep-sea fisheries;
- high capital costs and excess fishing capacity; and
- management arrangements for deep-sea fisheries.

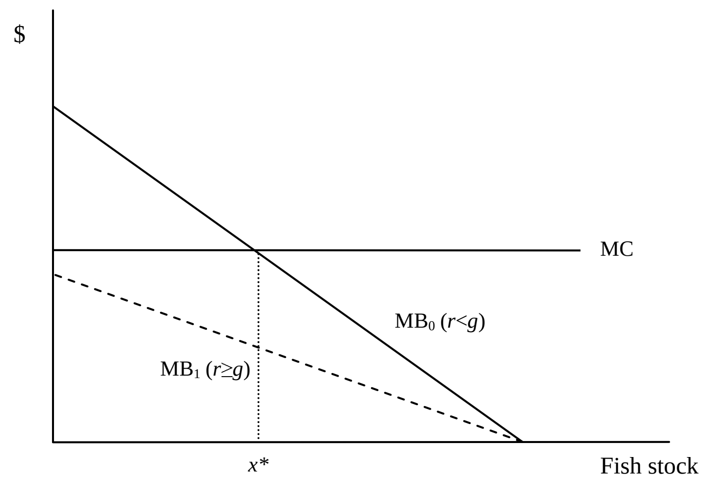
Low natural growth rates and constant harvesting costs

One of the basic results from the economics of renewable resources employing capital–theoretic models provides a key insight as to the vulnerability of deep-sea species (see Clark 1990, pp.59-62). Where the low natural growth rate of a fish stock is less than the discount rate and the costs of harvesting are constant, it is optimal for the single owner of the stock to extract the resource sooner rather than later and to invest the proceeds in other assets. By viewing the fish stock as an asset that can be drawn down (through fishing) or increased (by refraining from fishing), the owner has the option to invest in the fisheries asset or in some other asset depending on the rates of return available for the different forms of assets. As is demonstrated in the Appendix, the efficiency condition for allocating capital between alternative uses, such as between the fish stock and some other investment (for example, a bank), is that the rate of return on the two investments should be equal at the margin. The fish stock yields a rate of return determined by the biological production function, the alternative asset (money) yields the interest rate. If the rate of interest is greater than the intrinsic growth rate of the stock, then the optimal fish stock is zero — the stock should be fished out and the proceeds invested in the alternative asset which will provide a greater rate of return.

This is illustrated in Figure 3 which depicts the marginal benefits and costs of investing in a fishery. The horizontal axis represents the size of the fish stock while the vertical axis represents marginal benefits and costs in monetary terms. The marginal benefit of investing in the fish stock (MB_0) is downward sloping since the marginal benefit derived from holding an additional unit of stock will decline as the stock gets larger. If the interest rate (r) is lower than the intrinsic growth rate (g) and if there is a constant cost of harvest (MC), then the optimal stock size will be x^* where the marginal benefit and marginal cost of investing in the fishery are equated. If the interest rate is equal to or higher than the intrinsic growth rate, then the marginal benefit curve will rotate downwards to MB_1 and the optimum fish stock will be zero.

This result rests on two key assumptions. First, it assumes that there is a sole owner of the fish stock. This is equivalent to having the government manage the stock and providing fishers with perfectly enforceable property rights to exploit the stock. Second, the assumption of a constant harvest cost is consistent with fish stocks which exhibit schooling behaviour or have spawning aggregations, as is the case for many deep-sea species (Koslow et al. 2000, Gordon 2001). In these cases, the catch per unit of effort is largely independent of the level of the fish stock; the area occupied by the fish stock contracts to a smaller volume as the stock declines, with the result that the stock retains its density. This characteristic of deep-sea species is one of the reasons that serial depletion of stocks is observed and highlights the particular vulnerability of the stocks.[6]

Figure 3: Marginal benefits and costs of investing in a fish stock



6 The analysis does not change significantly when the assumption of constant harvesting costs is relaxed. If harvesting costs are stock dependent, the MC schedule will be upward sloping. It will, however, no longer be economically optimal to fish the stock out as the cost of extracting the last fish would be prohibitive. This may not be the case, though, where stocks exhibit critical depensation as it is possible that extinction may occur if the optimal stock level is sufficiently small.

It is worth noting that the same result can occur when there are very high prices for the target species in the marketplace. This is currently the case for Patagonian toothfish, for example. A high price will increase the marginal cost of investing in the fish stock and could increase the pressure on the stock. However, the story is more complex than may first appear; many deep-sea species do not have ready-made markets (as they are often relatively unknown to retailers and consumers) and so some effort has to be put into developing new markets for particular species. This can be a risky undertaking, and fishers' expectations about the success of future marketing ventures need to be taken into account when analysing the effects of price expectations on their decisions to exploit new fish stocks.

Divergence between social and private rates of time preference

While there are circumstances where it may be economically optimal to fish down a stock to extinction, it is not necessarily optimal to do so from society's perspective. Indeed, the effort being put into addressing the world's fishery problems by governments suggests that they do not seem to embrace the concept of optimal extinction. In Figure 3 above, it was assumed that the interest rate reflected the social rate of time preference and there was no divergence between the way that individual fishers or companies and society as a whole viewed the future. However, there are a range of reasons why the social rate of time preference may be lower than the private rate of time preference.

First, private agents tend to be myopic in the face of uncertainty and so will greatly discount benefits that might accrue in the future. We can see this in the case of those high seas fisheries where there are no entry restrictions or property rights in place which would reduce the incentives to "race to fish". There is no incentive for fishers to invest in conserving the stock as they are unlikely to reap the benefits. Second, the attitude of private fishers to risk is likely to differ from that of society as society is better able to pool and spread risk. Third, there is more than just the fish stock at stake. Deep-sea fisheries occur in areas of high biodiversity which are also relatively fragile (Roberts 2002, p. 243; Koslow et al. 2000, pp. 553-6). Fishing imposes external costs in the form of impacts on other species and on the ecosystem that are not taken into account by fishers. It is natural to assume that society would take a longer term view on these external costs, on the existence values attached to species and ecosystems and on the needs of future generations and, accordingly, have a lower rate of time preference than private agents.

As a result of these factors, it is likely to be the case that the private discount rate will be higher than the social discount rate. This can be reflected in Figure 3 by interpreting MB_0 as the marginal benefit schedule corresponding to the social discount rate and MB_1 as that reflecting the discount rate of private fishers. So what is optimal from a social perspective (x^*) may not necessarily be optimal from a private perspective. This divergence between private and social discount rates is a common justification for government intervention to ensure that the intertemporal allocation of goods and services reflects social as well as private preferences (Weimer and Vining 1992). Admittedly, this issue arises in a range of policy areas, not just in relation to deep-sea fisheries. However, the bioeconomic characteristics of deep-sea species (especially their low growth rate) means that they are likely to be particularly vulnerable to this problem.

High initial catches

A reasonably common feature of deep-sea fisheries is the high catches that are obtained in the initial phases of fishing activity. Preliminary surveys reveal large stocks and very high yields may be realised during the development and fish-down phases of the fishery, but then drop off quickly as the older, reproductive age classes are removed from the fishery (Roberts 2002, p. 242; Haedrich, Merrett and O'Dea 2001, p. 119). The slow growth and low natural mortality lead to an exceptionally low productivity for many deeps-sea species. For example, the sustainable yield for orange roughy has been estimated at only about 1-2% of the virgin biomass, yet the catches have been significantly higher than this level in almost all orange roughy fisheries to date, at least in the initial stages of the fisheries (Clark 2001).

In the absence of entry restrictions to a developing deep-sea fishery, the high initial catches and high expected profits will attract additional effort to the fishery. To the extent that fishing fleets are able to shift operations around the world at relatively short notice, the news of a potentially profitable developing fishery can set off a “race to fish”. The speed and degree of fishers’ responses will depend on how easily they can transfer gear (boats, nets, etc) from other fisheries to the developing fishery, the cost of such transfer and the rapidity with which new entrants can learn about the distribution of the fish stock and any new fishing techniques required. It will also depend on the restrictions that flag states impose on vessels flying their flag when undertaking fishing outside their EEZs.

High capital costs and excess fishing capacity

The speed and extent of new entrants to a developing deep-sea fishery will be influenced by the capital costs involved in developing capacity to increase effort and by the amount of idle capacity or latent effort that can be brought to bear on new fish stocks. Deep-sea fisheries tend to be more capital-intensive than fisheries in shallower waters on the continental shelves. Larger vessels tend to be the norm for these fisheries, and the fishing gear, winches, navigation and fish-finding equipment and on-board storage facilities are more expensive and specialised than for vessels engaged in other fisheries. As a result, there may be some delay in new capacity being constructed and brought into a fishery, other things being equal.

However, other things are not always equal and are unlikely to be so given the current state of world fisheries where there has long been a widely acknowledged situation of excess capacity (FAO 1991, 2003). This excess capacity has a very low, or zero, opportunity cost and so will only need to cover the variable costs of fishing operations in order to be encouraged to undertake fishing operations. It is also relatively mobile and may have the ability to quickly respond to new fishing opportunities. Combined with the characteristics listed above, particularly with respect to low or constant harvesting costs, the pool of excess capacity places deep-seas fish stocks at an even greater risk of overexploitation. The role that subsidies to vessel construction and modernisation in generating excess capacity is discussed later in the paper.

Management arrangements for deep-sea fisheries

There are four possible jurisdictional arrangements for deep-sea fisheries. First, they could occur entirely within national EEZs. In this case, they would fall under the fisheries management regimes in place for other fisheries within the EEZs. These regimes vary widely around the world, covering the spectrum from open access through to individual transferable quota (ITQ) schemes. OECD countries, for example, employ a range of management measures with an emphasis on catch and effort controls, and with some countries employing market-base management instruments such as ITQ schemes (OECD 1997, 2003a).

Second, deep-sea resources could occur as straddling stocks, either between adjoining EEZs or between EEZs and the high seas. They may or may not be subject to management in these cases. Third, deep-sea fisheries could occur entirely outside EEZs, but may be under the control of a regional fisheries management organisation (RFMO). The FAO provides an inventory of regional fisheries bodies, which includes management bodies, advisory bodies and scientific bodies (FAO 2003b) and a number of these are heavily involved in managing and assessing deep-sea resources (including, for example, the North-East Atlantic Fisheries Commission and the Commission for the Conservation of Antarctic Marine Living Resources) or in providing scientific advice (such as ICES). Finally, deep-sea fish stocks could occur on the high seas and not be under the control of any RFMO.

It is not possible to determine precisely how many of the current deep-sea fisheries lie outside national EEZs, and fall into one of the last three categories of jurisdictional arrangements. However, it is expected that a high proportion of deep-sea fisheries lie in this latter group, primarily because the depth of water they occupy would place many of them outside EEZs. The management instruments used in this group are primarily effort-based, with some RFMOs also employing catch quotas. As is discussed in the next section, these instruments will affect the incentives facing fishers in the presence of fisheries subsidies. There are, of course, no restrictions on catch or effort in the case of purely high seas fisheries.

These management characteristics make deep-sea fish stocks relatively more vulnerable to overexploitation for two key reasons. First, it has been observed by a number of commentators that management often comes too late to many deep-sea fisheries, partly as a result of the inadequate knowledge base used to make decisions about allowable catches and effort. For example, Haedrich, Merrett and O'Dea (2001, p. 119) remark that "assembling the data needed for conventional management will take a long time, in fact often far longer than a deep-water fishery may be expected to last." This is primarily a result of the relative slowness with which the effects of fishing pressure show up in catch data and the difficulty in developing adequate data to support models of population and growth dynamics. In addition, conducting sampling surveys in deep water is expensive and time-consuming. As a result, the science and underlying biology of many deep-sea species is not well understood, despite significant progress in recent years made through such groups as the ICES Working Group on Biology and Assessment of Deep-Sea Fisheries Resources (see, for example, ICES 2003a).

A second feature of the management arrangements is that enforcement of regulations is difficult and costly due to the isolated nature of many of the fishing grounds. This relates to both the prevention of illegal fishing and to the enforcement of effort controls, catch quotas and regulations relating to discards and incidental catch. Enforcement has been a particular concern in fisheries such as that for Patagonian toothfish in the Southern Ocean, where illegal, unregulated and unreported fishing has been a major problem in recent years (CCAMLR 2002, pp. 29-42). The expected net benefits from undertaking illegal fishing, taking into account the probability of detection and capture, are very high in many cases. In addition, illegal fishers have a very high discount rate and have no incentive to conserve stocks.

The result is that it is difficult to set appropriate, management measures based on solid biological information for many of the deep-sea fisheries and to enforce them once set. This increases the vulnerability of deep-sea fish stocks to fishing pressure, even in the absence of subsidies. Adding subsidies to the picture exacerbates the situation, as is discussed in the next section.

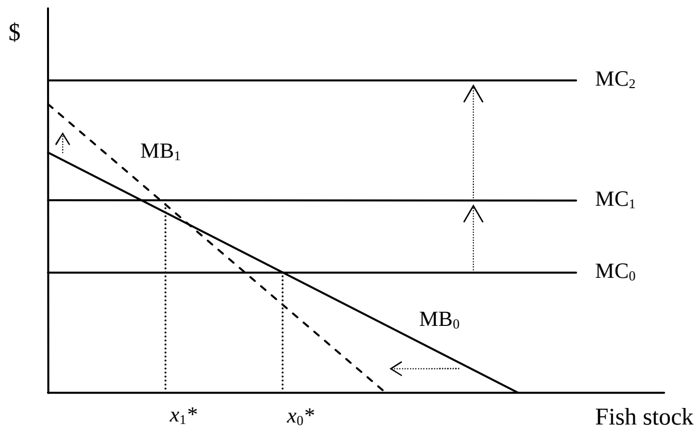
4. ECONOMIC AND ENVIRONMENTAL EFFECTS OF SUBSIDIES

The basic economic and environmental effects of subsidies are relatively straightforward and well-documented in the literature on fisheries, at least at the theoretical level (see, for example, Arnason 1998). Relatively little empirical work has been done on the impacts of subsidies on sustainability, trade and economic growth, particularly when compared to other sectors such as agriculture (FAO 2000, pp. 6-7). At least part of the reason lies in the complex dynamic bioeconomic interactions that need to be modelled in assessing the effects of subsidies on individual fisheries; this is not a trivial task and requires significant data. Nevertheless, it is still possible to gain significant insights from a qualitative analysis of the effects of subsidies, which will help inform policy discussions.

In the absence of management measures to constrain entry, effort or catch in a fishery, the provision of subsidies will serve to increase profits in the short term. Subsidies to variable costs will reduce the costs of operations, subsidies to capital costs will reduce the costs of buying and upgrading vessels and gear, and subsidies to incomes of fishers (including price support) will increase revenues. All these impacts, both singly or together, will initially increase profits and will attract increased effort to the fishery, either in the form of increased effort from existing fishers or from new entrants to the fishery. Over the longer term, these profits will be eroded as a result of a falling catch per unit of effort, reflecting an increase in effort and a depletion of fish stocks. Hence the long-term economic effect of a subsidy on aggregate profits in the industry will be small, or non-existent if all the fishing operations were identical. Intra-marginal operators may experience increased profits if, for some reason, they enjoy a cost advantage over the marginal operator.

Building on Figure 3 above, the effects of subsidies on the stock investment problem can be easily illustrated. If the government provides a subsidy to costs, this will raise the marginal cost of investing in the stock from MC_0 to MC_1 (Figure 4). The difference between the price received by the fishers from an additional unit of fish and the cost of extracting that fish now rather than later is increased such that it reduces the incentive to constrain catch as the opportunity cost of the fish conserved today increases as a result of the subsidy. Because the marginal benefits from investing in the stock also depend on the costs of harvesting, the provision of a subsidy will rotate the marginal benefit schedule (from MB_0 to MB_1 for example), although the equilibrium stock level will not be affected as the subsidy affects costs and benefits equally. Equating marginal benefits and marginal costs will then reduce the optimal stock size from x_0* to x_1*, with the magnitude of the final effect on stock depending on the slope of the marginal benefit schedule. If the subsidy is sufficiently large, the marginal cost of investing in the stock may increase to, say, MC_2 at which point it would be economically rational to fish the stock out. So it is readily apparent that, in the absence of management, the provision of subsidies will have an adverse impact on those fish stocks with the characteristics of deep-sea species — subsidies are likely to exacerbate their inherent vulnerability.

Figure 4: Marginal benefits and costs of investing in a fish stock, with subsidies to costs



Interaction with fisheries management

Fisheries management will influence the effects of subsidies on key variables, including fish stocks. The extent to which this occurs will depend on both the type of management regime in place and the effectiveness with which it is enforced. It is important to emphasise that any management regime is only as effective as its enforcement, so the theoretical advantages of one regime over another may not necessarily be realised if enforcement is lacking. Building on the framework developed in Hannesson (2001) and OECD (2003), management regimes can be classified according to three key aspects:

- extent of catch controls;
- extent of effort controls; and
- existence of rights-based structures.

In fisheries managed by catch control, subsidies will not have an effect on fish stocks or catches of fish (by definition), provided that the catch is set at a sustainable (equilibrium) level and effectively enforced. If there is no control on fishing effort (through restrictions on the number of boats or how they are used), the higher profits initially caused by subsidies will lead to increased fishing effort in much the same way and for the same reasons as when there is open access. The erosion of profits in the longer term will be caused by increased competition for a given catch and less efficient use of capital. As a result, the marginal resource rents are still competed away.[7]

Effort controls primarily take the form of restrictions on the number of vessels that are allowed to operate in a fishery, the amount of time they are allowed to fish, restrictions on the fishing gear and techniques that may be used, or some combination of these factors. The provision of subsidies under effort controls will increase profits in the short term, as in the case of catch controls. Unlike catch controls which have one dimension (amount of fish caught), there are many dimensions to fishing effort and it may be difficult for fisheries managers to identify and control all the variables that determine the effective effort that fishers can bring to bear on fish stocks.[8] For example, effort regulations in a particular fishery may specify restrictions on boat size, engine power and days at sea, which still leaves scope for fishers to expand fishing effort by increasing the use or effectiveness of other inputs such as labour and the amount or type of fishing gear.[9] Vessel owners are likely to respond to the increased profits by expanding effort along uncontrolled dimensions, for example through investment in new and more efficient boats, through upgrading of existing boats, and by adding new gear or equipment to existing boats or using them more intensively. Over the longer-term, increased effort will erode resource rents and will reduce target fish stocks.

The addition of structures based on property rights to the use of catch and effort controls adds a further dimension to the available menu of management regimes. Property rights can be used in conjunction with either catch controls or effort controls, with the most common form of property right being individual

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7 As noted in Hannesson (2001), the effect of subsidies on the actions of the fishers, and hence on the fish stocks, will also depend on whether the fish stock is initially under-exploited or over-exploited (that is, whether fish stocks are above or below the level providing maximum sustainable yield). This distinction is particularly significant when considering the short term and long term effects of particular types of subsidies under different management regimes. However, for most subsidies under consideration, there is no difference in the long-term effects on fish stocks whether the stocks are initially under-fished or over-fished.

8 This does not mean to say, of course, that catch controls are without problems. Issues of discarding, by-catch and catch monitoring can be significant in catch-controlled fisheries. The key point is the number of factors the fisheries manager has to assess and regulate in determining what is an appropriate level of fishing effort is made harder by the multi-dimensional nature of fishing effort.

9 The problems of input stuffing associated with effort regulations are highlighted in a number of studies, including Beddington and Rettig (1984) and OECD (1997, pp. 112-7).

quota rights (which may or may not be tradable). Rights-based regimes significantly alter the incentive structure facing fishers. They no longer have the incentive to race for fish as they can concentrate their efforts on catching their allowable catch in order to maximise profits. Nor do they have an incentive to increase the capacity and fishing power of their vessels beyond that which is needed to catch their allocation at minimum cost. With individual quotas the total catch will therefore be taken at a lower cost than with a race for the fish. Subsidies will raise the profits in the industry, which will raise the market value of the individual quotas if these are transferable. The quotas themselves would act as barriers to entry to the industry, as fishing would be impossible unless by having access to an individual quota, either by holding it directly, or by leasing it from somebody else (if such arrangements are permitted; in some countries the leasing of quotas is not permitted).

Individual rights can also be defined for fishing effort, although this is less common in practice. It is also problematic in terms of effective enforcement as the incentive to increase effort along uncontrolled dimensions remains; effort rights can generally only be defined along limited key dimensions (such as boat length, gross tonnage, days at sea, power, etc). The effects of subsidies in rights-based regimes will therefore be restricted to a transfer from taxpayers to the holders of the rights, with the value of the rights increasing as a result.

The long-term effects of subsidies under the different combinations of management parameters are summarised in Table 2. At this stage, it is important to note that the stylised analysis rests on a number of strong assumptions concerning the appropriateness of management settings and the effectiveness of monitoring and enforcement. First, it is assumed that allowable catch and effort levels are set optimally with respect to the long term equilibrium of the fishery. Second, it is assumed that the management regimes are perfectly and effectively monitored and enforced. While these assumptions have facilitated the analysis undertaken to date, relaxation of some or all of these assumptions will increase the complexity of

Table 2 Summary of long-term effects of subsidies under alternative management parameters

Management regime				
Rights based		**Not rights based**		
Catch controls	**Effort controls**	**Catch controls**	**Effort controls**	**No catch or effort controls**
No effect on catch or stocks, if catch limits effectively enforced No effect on effort Higher value of fish quotas	No effect on stocks, if effort effectively controlled Higher value of effort quotas If effective effort increases, reduced stocks and reduced resource rent	No effect on catches or stocks, if catch limits effectively enforced Greater effort and more vessels Same or lower revenue Higher costs and lower industry profits Negative resource rent	No effect on effort or stocks, if effort effectively controlled Higher revenues Higher profits Incentive to expand effort along uncontrolled dimensions If effective effort expands, reduced stocks and reduced	Greater effort and more vessels Reduced stocks Negative resource rent Lower catch, lower revenue and higher costs if initially overfished Higher catch, higher revenue and higher costs if initially

			resource rent	underfished

the analysis and may alter some of the conclusions. Relaxation may also assist in better explaining real world behaviour. For example, weak enforcement of catch limits in a fishery with or without property rights could mean that the effects of a subsidy on the environment are closer to those associated with open access.

As with most of the other literature on fisheries subsidies, the analysis in this paper necessarily abstracts from key political economy aspects of the real world of subsidies and may mean that that the effects of subsidies are likely to be less clear cut than the stylised analysis suggests. These aspects relate, among other things, to the power of interest groups to influence the outcomes of policy decisions and can be potentially significant for determining the outcomes of subsidy provision, both on the environment and in terms of economic and social outcomes. For example, under a catch control regime, the provision of transfers is likely to encourage lobbying for larger TACs, which are often decided in political fora in some cases (Hannesson 2001, p. 28). They may also make monitoring and compliance more difficult, partly because industry has less of a stake in the health of the fish stocks and partly because the increasing participation in the industry will make it more difficult to monitor the total catch and ensure compliance of individual vessels. While this may also happen under systems with property rights, it is less likely to occur as the market value of quotas or fishing licenses depends on the long-term health of the stocks. In another example, the continued provision of subsidies for income support in a particular fishery may occur for largely political reasons even though the management of the fishery is not sufficiently well-designed or enforced to ensure the sustainability of the fish stocks. In such a case, political priorities, together with ineffective management, may represent one of the key obstacles to the reform of subsidies.

Classifying fisheries

So how do the stylised regimes depicted in Table 2 reflect fisheries in the real world, particularly deep-sea fisheries? As noted earlier, most OECD countries manage their fisheries with catch controls, effort controls and a combination of the two, with some countries employing rights-based regimes in some of their fisheries (mostly ITQs but with some examples of effort-based rights regimes). OECD (2003b) classified OECD countries into three broad groups according to whether the countries' management was based on predominantly output controls, predominantly input controls or a mixture of input and output controls. The study found that most of the OECD countries fell into the mixed input and output controls, with relatively few in the category of predominantly output controls. So it is difficult to make broad generalisations about the effects of subsidies in the various countries.

Turning to the case of deep-sea fisheries, it has already been observed that most of these fisheries will be subject either to no control or to control through an RFMO. For those fisheries which are not subject to control (that is, open access), the impact of subsidies will obviously be significant, particularly given their bioeconomic characteristics as discussed above. For those fisheries subject to management through regional organisations, it appears that some are managed through effort control and some through catch control. For example, most deep-water species in the Regulatory Area of the North-East Atlantic Fisheries Commission are managed on the basis on effort restrictions (aggregate power, aggregate tonnage, fishing days at sea or number of vessels), while redfish are managed according to limits on national catches (NEAFC 2002a,b). Stocks of Patagonian toothfish are managed by the Commission for the Conservation of Antarctic Marine Living Resources on the basis of catch limits for countries who are party to the Convention. How the national allocations are then managed (for example through transferable quotas, etc) is decided upon by the individual countries.

In the case of those deep-sea fisheries which fall under national jurisdiction, it seems that the predominant management measure is through effort control. For example, the effort restrictions applied from 1996 by the European Union in member states for some ICES areas were based upon thousands of kilowatts of engine power multiplied by the number of days at sea, differentiated by gear type (trawl or fixed) (Gordon 2001, p. 998). Some countries use catch controls, such as Australia in the case of Patagonian toothfish.

Implications for deep-sea fisheries

Subsidies are highly likely to have an adverse effect on deep-sea fish stocks. By their very nature and location, these fisheries are mostly open access or are regulated under schemes which, in practice, tend not to reduce the incentives to increase effort when subsidies are provided to the industry (depending on the effectiveness of enforcement). The high initial catches associated with deep-sea fisheries mean that the effect of subsidies will be to further increase profits in the short term and may accelerate the process of new entry to the fishery. There are usually difficulties in imposing rights-based management regimes which may reduce (but not eliminate) the underlying incentives to expand effort that exist in pure catch and effort control fisheries. Moreover, there are concerns over the effectiveness of enforcing regulations; lack of enforcement will exacerbate the effects of subsidies as fisheries are then closer to the open access end of the management spectrum and subsidies will have a greater impact on catches and stocks. In addition, IUU fishing in deep-sea fisheries will reduce the benefit to legitimate operators of “investing” in the stock through restraining effort.

Given the capital-intensive nature of most deep-sea fisheries, the relative mobility of fishing fleets and the low opportunity cost of vessels, subsidies which encourage the expansion of capacity, either within the particular fishery or more generally, are likely to be particularly significant for deep-sea fisheries. Three categories of subsidies are relevant in this context and worthy of closer examination: subsidies to vessel construction and modernisation; decommissioning payments; and subsidies to particular types of research.

Subsidies to vessel construction and modernisation

This category of subsidies has long been regarded as one of the contributors to the current situation of excess capacity in world fisheries. As discussed above, the increased profits from any subsidy can encourage additional effort into a fishery, even with catch and effort controls. The use of vessel construction subsidies is likely to exacerbate this effect by altering the relative prices of capital and other inputs (such as labour, fuel, etc) and, in the absence of subsidies to these other inputs, will encourage a greater use of capital than would otherwise have been the case. Moreover, new vessels are generally able to bring more effective effort to bear on a fishery as they include improvements in technology and power. The case of subsidies to vessel modernisation is slightly different as the expansion of effort takes place through the upgrading of existing capital to improve capacity and effort, rather than through the creation of additional boats. However, while the number of vessels may not increase as a result of the subsidy, the effective effort that can be applied can increase within certain technical parameters.

In the medium to longer term, the excessive capitalisation in the sector that may result can place pressure on management authorities to relax catch limits (or not to tighten them if the fishery is overfished) to enable the individual boats to earn at least some revenue. In addition, there is also likely to be pressure to shift the excess capacity to other fishing grounds or to develop new fishing grounds, sometimes with the aid of government assistance. For example, a number of countries and country groupings assist their fleets by providing payments for access to other countries’ waters or to undertake joint ventures. As these payments are not generally recouped from the fishers, they may be considered to comprise a subsidy. There are also cases where subsidies are provided to undertake exploratory fishing in order to develop new fishing grounds with at least partly the aim of soaking up excess capital.

Subsidies for vessel decommissioning

Subsidies for vessel decommissioning are often viewed as one mechanism for overcoming the excess capacity problem. In general, these subsidies are payments for permanent vessel withdrawal through buy-back programs, permanent licence withdrawal and transfer of vessels to other fisheries (either domestically or internationally). It is one of the largest items of government financial transfers in OECD countries after expenditure on management, research, enforcement and infrastructure (Figure 2). The design and implementation of decommissioning and licence schemes varies significantly both between and within countries. For example, some countries require that decommissioning payments be tied to the physical scrapping of vessels while others allow vessels to be shifted to another fishery (in which case the payment is for the removal of capacity from a particular fishery rather than reducing the overall capacity in the country or globally). Other schemes are intended to remove latent capacity instead of capacity that is currently engaged in fishing.

There has been significant debate about the efficacy of many of these schemes in achieving their objectives both from an environmental and economic perspective (Arnason 1999; Holland, Gudmundsson and Gates 1999; Munro and Sumaila 1999). If there are no controls in place in a fishery, then such subsidies will have no effect on fish stocks as new vessels will enter the fishery to replace the scrapped vessels.[10] If there are catch controls, the effect on fish stocks will be zero as, in the absence of barriers to entry, the vessels being decommissioned would be replaced by new vessels. If the fishery is initially over-fished, then the subsidies will have no effect on stocks unless the allowable catch is also reduced. Such a combination of policy changes would have the effect of reducing capacity, reducing catches and increasing stocks. In the case of rights-based regimes, the effects of vessel decommissioning schemes on fish stocks would be negligible. The owners of the quota or effort rights would primarily benefit from capacity leaving the fishery.

The provision of decommissioning subsidies also has an impact on the risk faced by fishers in their investment and production decisions. The existence of vessel and licence buy-back programs can create expectations in the industry that the government will cover losses that may arise from excess investment in vessels, thereby reducing the risk-adjusted discount rate used in making investment decisions. Munro and Sumaila (2001, p. 25) conclude that subsidies used in vessel buyback schemes, if they come to be widely anticipated by industry, “can, and will, have a decidedly negative impact” on resource management and sustainability.

Subsidies to research

Successful fisheries management plans must be based on knowledge about the fish stocks involved and the ecosystem in which they are embedded. The better the research the greater is the potential success of the fisheries management plan, although there are likely to be diminishing marginal returns to research at some point. In most countries, the government meets the costs of research while some countries, such as Australia and New Zealand, are recovering some of the costs of research from industry (OECD 2003b).

The government provision of research reduces the costs of the industry as they would otherwise have to bear the costs themselves. A usual justification for the public provision of research is that it is a public good and that the benefits from the research flow beyond the fishing sector to the broader community. While this is true for many kinds of research (such as general research into ecosystem functioning, etc), it is not necessarily universally the case. Some forms of research may have a significant impact on the input costs of fishing operators. For example, research into improved gear technology, gear selectivity and so on is primarily directed at improving the productivity of fishing operations. Much of this research benefits the industry directly and it is not clear that the public good arguments usually associated with publicly funded

10 An exception to this may arise if the capacity of the fleet and the level of effort have expanded beyond the long term equilibrium level, but vessels are remaining in the fishery as revenues may still be sufficient to still cover their variable costs. In this case, decommissioning subsidies may assist in the adjustment to the long term equilibrium.

research necessarily apply (Arnason and Sutinen 2003; Cox 2003). The extent to which research can be classed as a public good is therefore something of a grey area.[11]

In the case of deep-sea fisheries, there is a strong justification for undertaking publicly-funded research into the basic biology and dynamics of the target fish stocks and supporting ecosystem. In the absence of government intervention, there is unlikely to be sufficient investment in research into these areas by the private sector. However, there appears to be less rationale for government support for research aimed at improving the productivity of fleets targeting deep-sea species, such as research into improved fish-finding technology, the refinement of gear for deep-water fishing and the exploration of new fishing grounds.

5. ISSUES FOR SUBSIDY REFORM AND THE MANAGEMENT OF DEEP-SEA FISHERIES

The interaction between fisheries subsidies and deep-sea fisheries is complex and much remains to be done to further explore the linkages empirically. However, the theoretical insights presented in this paper, coupled with the real-world experience from deep-sea fisheries, highlights a number of issues in relation to subsidies and deep-sea fisheries management that need to be addressed. These relate to the need for:

- improved transparency on subsidy provision;
- further empirical evaluation of the effects of subsidies;
- identification of subsidies particularly harmful to deep-seas fisheries;
- improved management of deep-sea resources; and
- effective enforcement of management measures.

The amount of information currently available on fisheries subsidies does not provide sufficient detailed information to allow the effects of subsidies to be readily identified and assessed and there is considerable scope for improving the transparency on subsidy programs. Some subsidy programs are notified to the WTO, but these only relate to those programs that come under the WTO definition of subsidies. It is also not clear the extent to which countries comply with the requirement to lodge subsidy notifications. For the period 1995 to April 2001, 14 countries and the European Union had notified a total of 191 subsidies to the WTO (Table 3). Whether this comprises the full set of notifiable fisheries subsidies remains uncertain as there is no independent verification of the notifications and, to date, there has not been a dispute involving fisheries subsidies which may help assess the data in the notifications. Ongoing work by the OECD to measure and assess GFTs will assist in improving transparency of fisheries subsidies. The OECD definition of GFT is more inclusive than the WTO definition, covering a greater number of subsidies, but coverage is restricted to OECD countries.

There is also a need for further empirical evaluation of effect of subsidies on deep-sea fisheries, and on fisheries in general. Much of the work to date, and that presented in this paper, has been largely theoretical. While these studies provide a solid basis on which to proceed, they fall short of the depth of analysis that is required at the level of individual subsidy programs. Importantly, such in-depth analysis will necessarily need to address the effectiveness and strength of management (including management settings, monitoring and enforcement) and the governance/institutional settings within which management takes place.

11 . Research aimed at improving stock assessments is such a grey area. It benefits the industry by improving the knowledge base on which management settings are based. It also benefits the broader community in terms of an improved understanding of the marine resources of the community. Moreover, it is hard to exclude anyone from the benefits of such research and, once undertaken, it is generally available to whoever can make use of it.

Table 3: Notifications to the WTO on Fisheries Subsidies, Jan 1995 to Apr 2001

	Sector				
	Harvesting	**Shipbuilding**	**Processing**	**Other**	**Total**
Canada	4				4
Japan	6			1	7
Korea	6	2	2	1	11
Norway	16	1	1	4	22
Philippines	1				1
Poland	3				3
Senegal	1				1
Slovakia	1				1
United States	5				5
EEC	75	9	9	34	127
Iceland	1		1	3	5
Tunisia				1	1
Singapore	1				1
Turkey	1				1
Thailand				1	1
TOTAL notifications	121	12	13	45	191

Source: WTO (1998, 1999, 2001a).

Identifying those categories of subsidies that are particularly harmful to deep-seas fish resources is an important aspect of the empirical task given the urgency associated with the conservation of these stocks. Traditional analytical frameworks, such as benefit-cost analysis, may be too data-intensive and time-consuming to provide policy makers with timely advice on policy alternatives. Alternative policy tools, such as the checklist developed by the OECD as part of its work on environmentally harmful subsidies, may augment the analyst's tool kit in providing advice on subsidy reform and the expected effects on deep-seas stocks (see OECD 2003c).

The introduction of management measures may offset some of the effects of subsides. However, the extent to which this occurs will depend on the type of management measures employed and the effectiveness with which they are enforced. The use of innovative management measures may assist in this regard. For example, the use of marine reserves to protect key stocks and ecosystems is being explored in many areas, although its use a fisheries management tool remains controversial. Haedrich, Merrett and O'Dea (2001, p. 120) propose moving towards management based on deep-sea ecosystems rather than focussing solely on individual species management (see also Hilborn and Walters 1992). The use of rights-based regimes could also be further explored, particularly within national jurisdictions and within RFMOs. A particular problem for deep-sea fisheries is the speed needed to respond to developments in terms of introducing management measures, usually on the basis of limited information. Flexibility and speed in terms of management response and enforcement is desirable but hard to implement, particularly in international fisheries and on the high seas. Greater cooperation between stakeholders and managers may help in this area. A recent example of this is the Coalition of Legal Toothfish Operators in the CCAMLR region.

Improving management regimes for deep-sea stocks will not be sufficient without ensuring effective enforcement of regulations. As has been discussed in this paper, the theoretical advantages of the various combinations of management parameters will be reduced, perhaps substantially, if the management measures are not effectively enforced. This is a particular problem for deep-sea fisheries, at least partly due to IUU fishing. The role played by national governments in managing their fleets outside their national

EEZs will be particularly important. The UN Convention on the Law of the Sea and other international instruments place specific responsibilities on flag states in managing vessels flying their flags when undertaking activities on the high seas and in RFMO areas. Many countries place restrictions on their vessels operating in these areas, but there is scope for improvements in both the coverage of vessels and the enforcement of existing regulations. Port states also have responsibilities specified in international law regarding the monitoring of fish catches. Programs such as catch documentation schemes play a role in improving transparency, monitoring and enforcement. The extent to which subsidies hinder the implementation and effectiveness of current and future regulations for addressing deep-sea fishery problems needs to be further explored.

6. CONCLUSION

This paper has addressed the twin issues of fisheries subsidies and deep-sea fisheries, two high-profile issues that are currently prominent in the international policy agenda. It is clear that deep-sea fish stocks have bioeconomic characteristics that make them particularly vulnerable to over-exploitation. These species are long-lived, slow growing and with low productivity. These conditions and the consequent vulnerability of the stocks exist irrespective of whether subsidies are provided. The provision of subsidies to fishing operators will reduce their costs and increase their revenues and is likely to place increased pressure on stocks and will exacerbate the vulnerability of deep-sea fish stocks in particular. The extent to which this occurs will depend on the type of management system in place and, importantly, the effectiveness with which management regulations are enforced. However, the bioeconomic characteristics and location of deep-sea fisheries present significant enforcement challenges. Removing or reducing subsidies will relieve pressure on stocks to some extent. However, it will not remove it entirely; the underlying vulnerability of deep-sea stocks will remain. As a result, it is important to pursue subsidy reform and improved management and enforcement of deep-sea fisheries simultaneously.

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APPENDIX: MODEL OF INVESTMENT IN FISH STOCK

Using a simple model of investment in the fishery (drawing upon Clark 1990), the key insights into the relationship between the rate of interest (discount rate) and the growth rate of the fish stock can be illustrated. The economic production function can be written as

$$H = AE^{\alpha} x^{\beta}$$

where, H is the harvest, E is effort, x is the stock (biomass) and A is the catchability coefficient and α and β are parameters such that $\alpha + \beta = 1$ (as in the Cobb-Douglas production function).

If the catch per unit of effort is independent of the level of the stock size, then $\beta = 0$ and H = AE. The unit cost of harvest is given by cE/H = c/A, where c is the cost of a unit of effort.

For illustrative purposes, a simple biological production function such as the logistic growth model can be used to illustrate the stock dynamics. In this function, K is the virgin biomass (in the absence of fishing), b is a constant of integration and g is the intrinsic growth rate of the stock.

$$x(t) = K/(1 - be^{gt}).$$

For biomass levels below K, the fish stock is growing at

$$\dot{x} = gx(1 - x/K).$$

Now introducing harvesting at a constant rate of H so that

$$\dot{x} = gx(1 - x/K) - H.$$

Sustainability requires that $\dot{x} = 0$ so the annual harvest should be set equal the growth rate of the stock. The benefit of investment in the fish stock is the value of the increase in the sustainable harvest resulting from the increase in fish stock. The increase in sustainable harvest is given by the derivative of H with respect to x

$$dH/dx = g(1 - 2x/K)$$

The net value of the benefit to increasing the stock by one unit is given as

(1) $$MB(x) = [(p - c/A)g(1 - 2x/K)]/r.$$

where MB(x) is the marginal benefit from investing in the fish stock and r is the interest rate. The efficiency condition for allocating capital between alternative uses is that the rate of return on the two investments should be equated at the margin. In terms of Figure 3 in the main body of the text, the marginal benefit schedule is downward sloping in terms of the size of the fish stock so as the size of the fish stock increases, the additional benefit from reducing the harvest declines.

The marginal cost of investing in the fish stock is the opportunity cost of not catching an additional unit of fish and allowing it to escape to increase the stock in the future. This is equal to price less the unit catching cost of the additional number of fish which are not harvested. Under a constant cost scenario, the marginal cost of investing in the stock is then

(2) $$MC = p - c/A.$$

Setting equation (1) equal to equation (2), the rule for determining the optimal fish stock is obtained as

$$r(x) = g(1-2x/K) = r.$$

And solving for x in terms of r and g

(3) $$x^* = (K/2)(1 - r/g)$$

For alternative values of r and g, it is possible to determine the optimal fish stock from equation (3):

$$r = 0 \Rightarrow x^* = K/2 > 0,$$

$$r \geq g \Rightarrow x^* \leq 0,$$

$$0 < r < g \Rightarrow x^* > 0.$$

That is, at a zero discount rate and for values of interest rate between zero and the intrinsic growth rate, the optimal fish stock will be greater than zero. For values of the interest rate greater than the intrinsic growth rate, the optimal stock will be zero.

Now assuming the government provides a subsidy (s) to the costs of operation. The marginal cost of investing in the stock will increase from

$$MC_0 = p - c/A \qquad \text{to} \qquad MC_1 = p - (c - s)/A$$

and $MC_0 < MC_1$ for all values of x. At the same time, the marginal benefits schedule also depends on c, and so the provision of a subsidy to costs will rotate the marginal benefit schedule with the intercept on the vertical axis in Figure 4 being higher than that without the subsidy and the intercept on the horizontal axis being closer to the origin. The equilibrium stock level will, however, be determined as in equation (4), which is independent of c and s, so that the effects of subsidies on the marginal benefits and costs are cancelled out.