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TRADE AND AGRICULTURE DIRECTORATE
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DRAFT CHAPTER 15: FISHERIES AND AQUACULTURE - OECD ENVIRONMENTAL OUTLOOK

18-20 April 2007

This Document is to be submitted for DISCUSSION at the 99th Session of the Committee for Fisheries, under item 11 i).

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NOTE FROM THE SECRETARIAT

Attached is a draft of the Fisheries and Aquaculture Chapter for the OECD Environmental Outlook. This draft for COFI is different from the document that was submitted to the Environment Policy Committee (EPOC, document ENV/EPOC/RD(2007)6) in that it includes an Annex that briefly describes the Envlinkages model.

The Outlook is being developed by EPOC for release in early 2008. While EPOC is responsible overall for the Outlook report, they have asked various other Committees and Groups -- including COFI -- to provide comments on draft Chapters of relevance to their areas of expertise. The Fisheries Secretariat has had the opportunity to comment on several earlier internal drafts of this document. At the 99th Session of COFI staff members from the Environment Directorate will present the chapter and inform the COFI of the EPOC's discussions (which takes place on 28-29 March 2007) on the document.

This document is distributed for information and comments.

KEY MESSAGES

- Global production from capture fisheries and aquaculture grew by 2.7% per year throughout the 1990s, and topped 132 million tonnes in 2003. The rapid expansion of aquaculture is expected to continue to 2030, compensating for declining or stagnant wild fish harvests.
- Over-fishing in capture fisheries remains a major challenge. An estimated 16% of world fish stocks are over-exploited, 7% depleted, and 1% recovering; 52% of stocks are producing catches near maximum sustainable limits.
- Marine and freshwater ecosystems experience a range of pressures from capture fishing, including stock depletion, destruction of habitats, and incidental kill of non-target species. Aquaculture increases pressure on species used for fish meal and contributes to habitat destruction and pollution.
- Pollution can decrease the value of fish products and can destabilise aquatic ecosystems that provide essential services for the fisheries sector. Consumers are increasingly concerned about the possible impacts on human health, for example from consumption of fish with high mercury levels.
- Climate change is projected to result in profound impacts on the number and distribution of fish stocks, the acidity of marine waters, and the resilience of aquatic ecosystems.
- The main policy options to reduce the environmental impacts of capture fishing include: limiting total catch levels, fishing seasons and zones; regulating fishing methods and gear use; eliminating subsidies for additional fishing capacity; improving the environmental performance of fishing vessels; and ensuring that consumer prices reflect environmental costs of production.
- The main policy options to reduce the environmental impacts of aquaculture include: regulating the location and operation of aquaculture farms to minimise negative environmental impacts (e.g. release of nutrients or antibiotics, escape of organisms, destruction of habitat, integrated coastal zone management, visual disturbance); developing alternative feeds that reduce the reliance on capture fisheries, and ensuring that consumer prices reflect environmental costs of production.
- Continued international co-operation will be necessary to strengthen management of straddling, highly migratory, and high seas stocks.

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1. Introduction

1. Almost one-quarter of the world's capture fisheries are now classified as over-exploited, depleted or recovering. In addition to over-fishing, fishing activities can also impact on ecosystems through incidental catch of non-target species (by-catch), over-fishing of young stocks, pollution, and habitat destruction (e.g. through bottom-trawling).

2. Ecosystem change or damage can, in turn, impact on the economic viability of fisheries. Some fisheries have faced economic collapse due to decimated fish stocks. Changes to marine ecosystems from climate change or pollution can upset ecosystems and lead to a decline or geographical shift in key fish stocks. The associated economic losses and disruption to fishing-based communities may be significant.

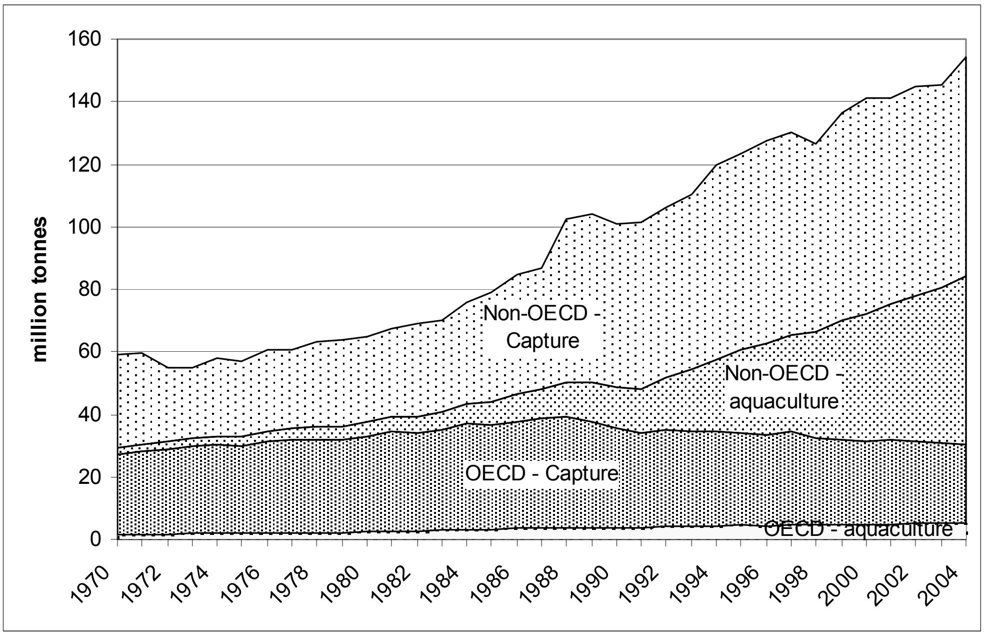
2. Projections for the fishery and aquaculture sectors

3. Average consumption of fish per person nearly doubled since 1960 worldwide, reaching 16.2 kg per year in 2002. Actual consumption varies widely among geographic regions, with per capita demand highest in OECD countries and in China, and lower in Africa and South America. It is projected that per capita demand for fish will continue to rise by a further 18% to 2015, driven by economic growth and increased awareness of the benefits of consumption of fish (FAO, 2004a). Improved access to international markets will further increase pressures on aquatic ecosystems, particularly in developing countries.

4. Global fisheries production, including from both capture fisheries and aquaculture, rose sharply during the past three decades, reaching 132.2 Mt in 2003 (Figure 1). Since 1988, total world fisheries production has grown by 2.6% annually.[1] Since then, most of the increase in fisheries has come from new aquaculture development, primarily in non-OECD regions. A very large share of this has come from China.

[1] The large increase in capture fish production seen in 1988 in Figure 1 represents the year when information became available on Russian and Eastern European catches.

Figure 1. World fisheries production, 1970-2004



Source: FAO, 2004a.

5. Global capture fisheries production have levelled off at between 90 and 95 Mt since the late 1990s, with marine capture fisheries contributing about 85 Mt, and inland freshwater fisheries the remainder. This levelling off reflects the fact that an estimated 52% of the world's fisheries are now fished at their maximum limit, and 24% are overfished, depleted, or recovering. OECD regions have been reducing their catches in recent years, by 40% between 1988 and 2004. Non-OECD regions increased their capture fisheries production by 35% over the same period.

6. The Food and Agriculture Organisation (FAO) projects that the global capture fisheries production is unlikely to increase much beyond present levels, an outlook that contrasts sharply with historical rapid growth (FAO, 2004b). Indeed, from 1950 to 1970, world capture fisheries production (marine and inland) tripled, growing at an average rate of 6% per year. During the 1970s and 1980s, the rate of growth of the total catch slowed to about 2% per year, before approaching zero in the 1990s, and declining slightly since 2002 (FAO, 2004a). OECD countries landed 27% of the world capture fisheries catch in 2002, with the United States (4.9 Mt), Japan (4.4 Mt) and Norway (2.7 Mt) among the world's top ten producing countries. China (16.6 Mt) and Peru (8.8 Mt) led the list, together landing 27% of world catch (Box 1).

7. Looking to 2030, OECD countries' collective share in global marine capture fisheries production can be expected to decline even further. Since 2000, catches have decreased or stagnated in marine areas adjacent to most OECD countries, as the majority of fish stocks in their EEZs are already being exploited fully or beyond maximum sustainable levels. Catches have only been increasing in the tropical Pacific and Indian Oceans, and in high seas areas.

[Red Light]

Over-fishing is likely to lead to economic collapse of some fisheries and disruption of marine ecosystems.

8. Global landings from inland capture fishing have reportedly been stable at about 8.6 Mt since 2000.[2] The bulk of this inland capture is landed in Asia (66% in 2002) and Africa (24%), with South America (4%), Europe (4%), North and Central America (2%) and Oceania (0.2%) having minor shares. China is the world's top producer, landing about 26% of global inland catch, while other developing countries together produce an additional 68%. In 2002, no OECD countries ranked among the top ten world producers of inland capture fisheries.

Box 1. China: the world's largest producer and consumer of fish products

China is the world's largest producer of fish, and its per capita fish consumption (27.7 kg per annum) is about twice the world average. Its reported total fisheries production was 44.3 Mt in 2002, roughly one-third of global production.[3] Two-thirds of the output comes from aquaculture, a sector which is rapidly expanding. From 1970 to 2000, China's inland aquaculture production increased at an average annual rate of 11%, compared with 7% for the rest of the world. Similarly, the country's aquaculture production in marine areas increased at an average annual rate of 11%, compared with 6% for the rest of the world (FAO, 2004a).

China is home to about one-third of the world's fishers and aquaculture workers. In 2002, 8.4 million Chinese worked in capture fisheries, and 3.9 million in aquaculture. But looking to 2030, China's employment in the fisheries primary production sector is expected to decline, as fleet-size reduction programmes are implemented in response to over-fishing. Indeed, such programmes implemented from 2000 to 2006 are projected to already shift 4% of Chinese capture fishers to other jobs by 2007 (FAO, 2004a). Policy tools used to accomplish these shifts included scrapping some fishing vessels and training redundant fishers in aquaculture.

9. Global production from aquaculture totalled 59 Mt of fish, crustacean, and mollusc products, aquatic plant products in 2004[4], constituting 38% of global fisheries production by weight. According to FAO simulations, aquaculture will contribute about 43% of global fish production by 2020 (FAO, 2004b). Worldwide, aquaculture has grown at 8.9% per annum since 1970 (compared with 1.2% for capture fisheries and 2.8% for terrestrial farmed meat-production systems during the same period). Freshwater aquaculture systems are the main contributors to overall aquaculture output (58% by weight), followed by marine (36%) and brackish aquaculture systems (6%). Since 1990, the growth has been even faster. To a large extent, the rapid increases in aquaculture have been a response to the increasing demand for fish products faced with the physical limits reached in capture fisheries.

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2 The FAO warns that global inland catch data should be considered indicative rather than reliable, due to gaps in reporting on catch quantities and species composition.

3 The FAO has issued caveats about the accuracy of statistics on China's capture fisheries and aquaculture production, suggesting that they are likely too high. Thus, these figures should be seen as indicative rather than authoritative.

4 This figure includes aquatic plant production of roughly 13 Mt. Unless otherwise noted, most figures below do not include aquatic plants..

10. Developing countries produce about 90% of aquaculture food fish output, cultivating mainly freshwater species that are herbivorous, omnivorous, or filter feeding. China and India are the world's top two producers of aquaculture, with annual output of 27.8 Mt, and 2.2 Mt, respectively.[5] Three OECD countries (Japan, Norway, United States) rank among the world's top ten aquaculture producers,[6] but OECD countries altogether account for less than 10% of world aquaculture production by weight (20% by value) (OECD, 2004b). However, OECD countries may be heavy investors in aquaculture development in developing countries.

11. In OECD countries, capture-based aquaculture (CBA) has expanded considerably, particularly for high value fish such as bluefin tuna. CBA involves capturing young organisms, or "seed", from the wild and raising them in captivity to marketable size. Increasingly, high-value species such as bluefin tuna or cod are being caught as juveniles and then raised in offshore "sea pens." CBA already makes up 20% of food fish production from aquaculture, by weight (FAO, 2004a). Controversially, while "seed" is counted against the total allowable catch for a species, the amount is only as "young" (hence smaller) and not having reached reproductive age; this should change the management approach to the stocks of fish where the juveniles are taken.

12. The baseline developed for this Outlook largely suggests that, in the absence of new policies, growth will continue in the fisheries sector for the next 25 years. The baseline determines growth in the demand for fisheries products through increases in population and economic productivity. Limitations in the supply of fisheries lead to a combination of aquaculture output increases and price increases – the price increases implicitly help overcome barriers to continued expansion of aquaculture. Global fisheries production increased by 2.6% annually between 1988 and 2004, but limitations in supply will cause this to slow to an average of 2.1% annually between 2005 and 2030 – a combination of higher growth in the initial years, followed by lower growth in the later years.

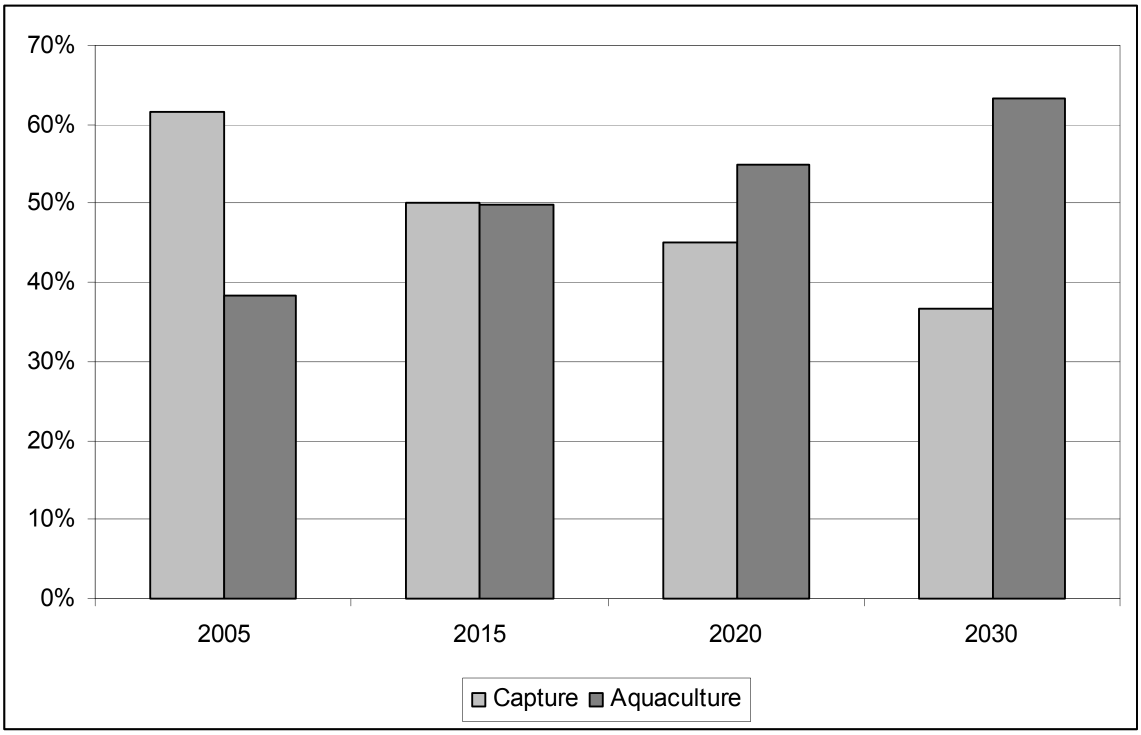
13. Future growth is assumed to come from aquaculture since capture fisheries are already showing signs of stress. The 2.1% total fisheries growth rate is therefore composed of robust growth in aquaculture, but no growth in capture fisheries. This implies an average growth rate in aquaculture of 3.9% annually to 2030 (compared to 8.1% annual growth between 1992 and 2005). This is induced endogenously in the baseline by a roughly 67% increase in the real price of fish by 2030 (relative to 2001). To understand how strongly this motivates aquaculture development, it is worth pointing out that the real price of almost all fish consumed fell sharply between 1970 and 2000 (Sumaila *et al.*, 2005). Figure 2 illustrates the projected evolution of relative shares of capture fisheries and aquaculture production to 2030. Capture fisheries is roughly constant in landed quantity, but declines as a share of total fisheries production.

14. Of course, aquaculture is in part dependent on capture fisheries for fish meal feed. Recent expansion of aquaculture has augmented demand for fishmeal, with 2 to 12 kg of fishmeal feed required to produce one kg of farmed fish or prawns, depending on the species. However, as the price of fish products increases, it is projected that substitutes for fish feed for aquaculture will become more economically viable, such as soya-based feed. Thus, FAO projects that the portion of fisheries output used to make fish meal and oil will decline from 35 million tonnes in 2000 to about 26 million tonnes in 2030 (FAO, 2004a). Other factors influencing demand for fishmeal and oil include trends in the broiler chicken and pork industries, and changes in the price ratio between fishmeal and its close substitutes.

5 Other developing countries among the world's top ten aquaculture producers in 2002 were Indonesia (third, 914 000 tonnes), Bangladesh (786 600 tonnes), Thailand (644 900), Chile (545 700 tonnes), and Vietnam (510 600 tonnes).

6 Global ranking and 2002 production as follows: Japan (fourth, with 828 400 tonnes), Norway (seventh, 553 900 tonnes), and the United States (tenth, 497 300 tonnes).

Figure 2. Projected composition of world fisheries to 2030: Capture and aquaculture



15. The FAO projects an increase in total fisheries production of 43 Mt from 2000 to 2015, the bulk (73%) of it coming from aquaculture. Even so, the FAO expects average annual growth in world fish production to trail off, going from the 2.7% seen in the 1990s to 2.1% per year from 2000 to 2010, before dipping to 1.6% per year from 2010 to 2015 (FAO, 2004b). The baseline for the OECD Environmental Outlook does not see such a strong falling off in production. It projects that the supply of fisheries products, particularly from aquaculture, increases as a result of price increases that provide strong incentives for the sector's expansion. The population and wealth increases to 2030 that underlie the baseline would require much stronger increases in prices to suppress demand sufficiently to lower fisheries growth to 1.6% (recall that global GDP growth in the baseline is over 2.5 % per year to 2030, and no new policies are assumed in the baseline that would affect fisheries demand).

Box 2. Fisheries in Envlinkages

The fisheries sector in the model (Envlinkages) used for the OECD Environmental Outlook is defined very broadly. It includes activities such as: fishing for all forms of aquatic species on the high seas, coastal zones and inland waters; the collection of pearls (natural and cultivated), corals, sponges, and algae; treatment of fish, molluscs, and crustaceans, on board ships; installation and operation of fish farms, algae farms, and all edible submerged aquatic plants; oyster farms for pearl cultivation and food; activities that service ocean and freshwater fisheries, aquaculture (e.g. owner-implemented repair and maintenance).

3. Environmental pressures from fisheries and aquaculture operations

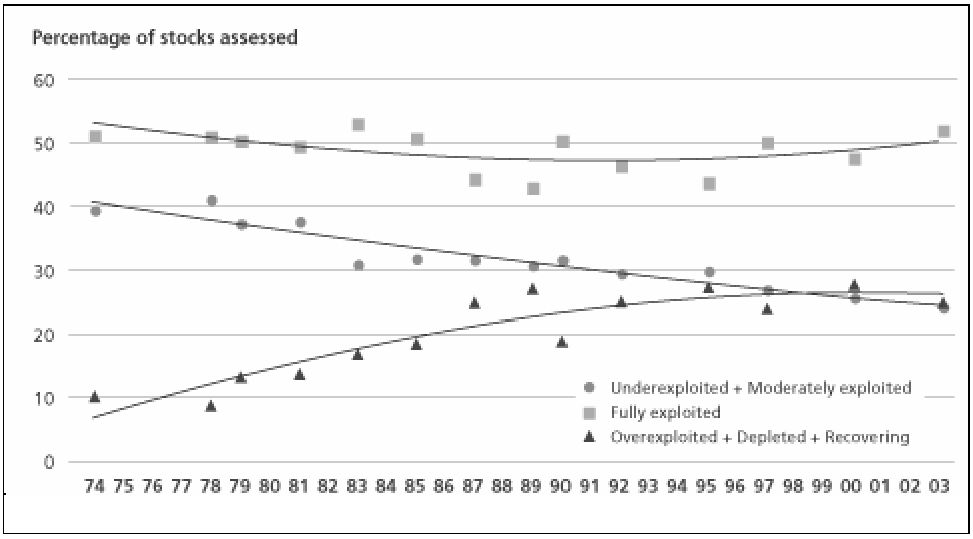
16. Overfishing – defined as the taking of more individuals than the remaining population can replace – has traditionally been seen as the major environmental pressure from fisheries activities. But the incidental catch of non-target species and physical damage to habitats caused by destructive fishing

techniques and construction of aquaculture installations also have significant impacts on aquatic stocks and ecosystems. In short, how fishing is carried out is as important as how many fish are taken.

3.1 Overfishing and by-catch

17. The overall status of marine fish stocks exploited by commercial capture fisheries is poor. About 16% are classified as over-exploited, 7% as depleted and 1% as recovering from depletion (FAO, 2004a). With a further 52% classified as fully exploited, only about one-quarter of commercially exploited marine stocks are considered to have some potential for further development,[7] a share which has decreased steadily since the 1970s (Figure 3). Similar global data are not available concerning the status of inland fish stocks, but regional data suggest that the majority are heavily over fished.

Figure 3. Global trends in the state of world marine stocks, 1974 – 2003



Source: FAO 2004a.

18. Depletion of fish stocks can disrupt ecosystems by distorting food webs and population dynamics. In over-fished regions, as stocks with high commercial value become depleted, fishing effort typically shifts to species that are lower in the food web. While in some cases heavily depleted stocks can recover if fishing pressure is removed, in others important fish stocks have failed to rebound even years after their fishing was banned. When a species is functionally absent[8] from an ecosystem for an extended time, shifts in predator-prey interactions and in food web structures can lead to alternative, stable states that effectively eliminate the niche of the depleted species, reducing the likelihood of re-establishment.

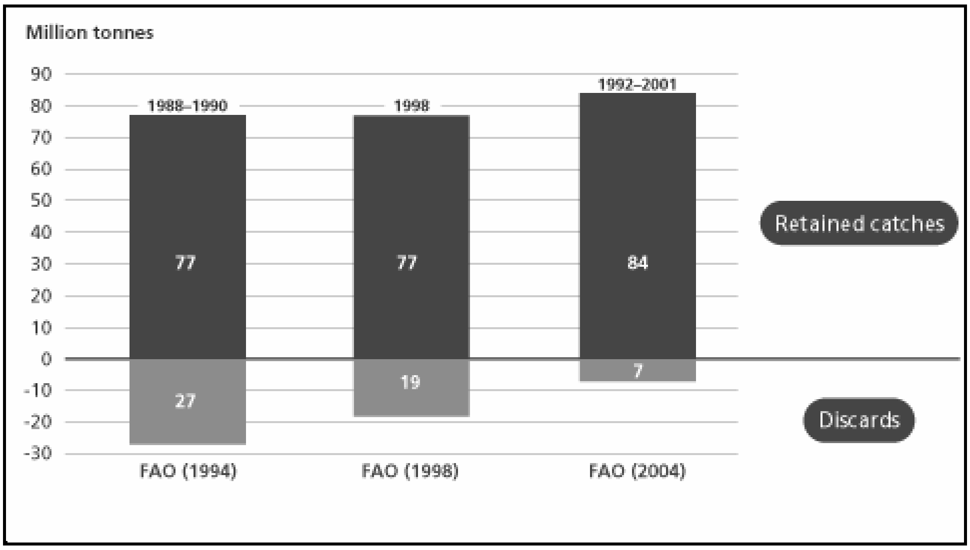
19. Capture fishing also contributes to the depletion of non-target organisms, including birds, sea mammals, crustaceans, and finfish, as they are inadvertently killed by fishing nets or lines. Such "bycatch" is typically discarded overboard if the organisms have low commercial value, are below minimum size, or do not fit one of the boat's quotas. FAO estimates of global discards have declined from 27 Mt in 1994, to 20 Mt in 1998, and to 7.3 Mt in 2004 (Figure 4). Although the downward trend in global discards is in part explained by changes in estimation methods, the bycatch intensity of certain fisheries is believed to have

7 This includes 3% classified as under exploited and 21% classified as moderately exploited.

8 A species can be considered to be functionally absent from an ecosystem if the number of individuals is so low that it cannot fill its usual niche in the ecosystem.

diminished in recent years due to the wider use of selective fishing gear and "best practice" fishing techniques. Certain fishing gears (e.g. bottom trawling) are now recognised as so bycatch-intensive and damaging to sea beds that some countries have banned their use. Trawlers targeting shrimp and flatfish are estimated to discard up to 50% of their catches (FAO, 2004b).

Figure 4. Comparison of discard estimates and retained catches, 1988 – 2001

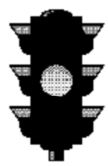


Source: FAO 2004a.

3.2 Habitat destruction

20. Fishing and aquaculture can also contribute to the physical degradation of aquatic habitats. Damages can be so extensive that the resource base supporting fisheries activities is threatened. For instance, 83% of Baltic Sea biotopes are listed as endangered (68%) or heavily endangered (15%) on the HELCOM Red List. Certain fishing gear and methods are highly destructive to habitats. Gear that is scraped along the bottom to catch organisms is the most damaging (e.g. bottom trawls, dredges). Some trawls leave furrows 20 to 30 cm deep, and frequent trawling of an area is correlated with loss of biodiversity.

21. Construction of aquaculture farms contribute to destruction of habitats in coastal and inland areas. In a number of marine areas, littoral or estuarine waters that are most commonly developed for aquaculture are also of high ecological importance, having a key role in development and/or recruitment of young organisms.



[Yellow Light]

Aquaculture can help to alleviate pressures for fish production from capture fisheries, but their environmental impacts need to be addressed.

3.3 Other pressures

22. The spread of invasive species and pathogens can be facilitated by fisheries and aquaculture. Fish meal and seed stock used in aquaculture farms are traded internationally, and can spread pathogens and parasites from one marine region to another. Intensive aquaculture can lead to the transfer of disease from organisms raised in sea pens to adjacent wild populations. Organisms that escape from aquaculture farms often survive in the wild where they compete with native species for habitat and food, and may spread diseases and parasites (e.g. sea lice

spread by escaped sea trout). In some cases, they can also interbreed with native species, leading to "genetic pollution".

23. Discharges from fishing vessels and aquaculture units can contribute to pollution of marine and inland waters. Fishing vessels generate air and water pollution and waste products, and older fishing vessels generally lack modern pollution control equipment. Water pollution from aquaculture farms comes from uneaten food fish, excreta, chemicals and antibiotics used to control diseases.

4. Environmental pressures that affect fisheries and aquaculture

24. The economic viability of the fisheries and aquaculture sectors depends on functioning aquatic ecosystems which deliver essential ecosystem services. Long term climate change, El Nino events, and other environmental changes threaten the sustainability of fisheries and aquaculture activities. In addition, pollution can degrade the health of aquatic ecosystems, and thus destabilise the resource base supporting fisheries. Contamination of fisheries products by pollutants can lower their economic value.

4.1 Environmental perturbations

25. As the result of anthropogenic climate change, the mean temperature of sea surface waters is expected to increase and mean sea level is expected to rise by 2100 (IPCC, 2007). Based on current model simulations, it is very likely that there will be a slow down of the oceans' thermo-haline circulation by 2100 and some predict its shutdown by 2200, with severe consequences for fisheries and aquatic ecosystems. As ocean circulation drives larval transport, recruitment patterns and population dynamics of marine organisms will be altered worldwide.

26. The pH of ocean surface waters is projected to fall by 0.14 to 0.35 pH units by 2100, due to the uptake of rising levels of atmospheric CO_2 (IPCC, 2007). The consequent acidification of surface waters will change the saturation horizons of aragonite, calcite, and other minerals which are essential to calcifying organisms (Feely et al., 2004). While many aquatic organisms are adapted to thermal fluctuations, the expected changes in pH are higher than any pH changes inferred from the fossil record over the past 200 to 300 million years (Caldeira and Wickett, 2005).

27. The frequency and severity of extreme weather events such as cyclones, floods, typhoons, and tidal waves, are expected to increase as a result of global warming in the 21st century. The consequent damage to equipment and infrastructure will compromise the productivity of fishing and aquaculture activities, as did the 2005 tsunami in the Indian Ocean which destroyed fishing boats, aquaculture pens and equipment. Developing countries suffer disproportionately from extreme weather events, as they often have weak response capacities.

28. The term "El Niño" refers to periods of strong and prolonged warm weather in the Eastern Pacific, accompanied by surface waters that are 0.5 to 3°C warmer than usual. Because changes in air pressure, called "the Southern Oscillation", typically accompany these periods, the whole phenomenon is referred to as the "El Niño Southern Oscillation" (ENSO). During an ENSO event, the upwelling of cold, nutrient-rich waters virtually stops, and primary productivity plunges in the eastern Pacific, resulting in a decrease in fish production. At the same time, the phenomenon disrupts weather patterns worldwide, leading to unusually high precipitation near the equator. ENSOs usually occur about every four to five years, and last 12 to 18 months, but their frequency is projected to increase with global warming.

4.2 Environmental pollution

29. Elevated levels of nutrients contribute to algal blooms which cause hypoxic zones (often referred to as "dead zones") in marine coastal areas and inland water bodies. The number and extent of such zones

have increased since the 1970s. In 2006, UNEP identified some 200 persistent 'dead zones' in the world's marine areas (UNEP, 2006).[9] Although estuaries and bays are most affected, eutrophication is also apparent over large areas of semi-enclosed seas. For example, eutrophication affects almost all areas of the Baltic Sea, with the frequency and the spatial extent of toxic blooms both increasing since the mid-1990s. Cyano-bacterial blooms that have regularly occurred since 2000 reduce the reproductive success of cod and other fish species, with eggs dying in anoxic waters caused by the decay of algae (EEA, 2002).

30. Exposure to organic pollutants can compromise the breeding success, immunity, and health of aquatic organisms. As they have the tendency to bioaccumulate in the body fat of fish, they can also pose health risks to humans who eat contaminated fish. After a 2004 study found that dioxin concentrations were higher in farmed salmon than in wild salmon, consumer concern led to a drop in retail orders of 25% (FAO, 2004a). Since the late 1990s, Baltic Sea countries have faced restricted market access for herring, due to dioxin contamination. Inorganic pollutants are often found in fish products from near-shore areas, estuaries and rivers, as well as from regional seas that have relatively little exchange with the open ocean (e.g. Baltic, Mediterranean). Such contamination of fish products can lower their market value or block market access altogether (e.g. arsenic contaminated mussels, mercury contaminated fish).

31. About 80% of all marine pollution comes from land based sources (UNEP, 2006). In most OECD countries, considerable progress has been made in reducing land-based discharges to the sea, particularly from municipal wastewater outfalls and industrial effluents. Diffuse pollution from agriculture and urban areas remains a rather big challenge, however. Coastal development, aggregate extraction and dredging also contribute to the destruction or deterioration of key near-shore habitats for juvenile marine organisms.

32. The global shipping fleet[10] generates air and water pollution, including considerable operational and accidental discharges of oil. For example, European ships emitted an estimated 2.6 Mt of SO_2 and 3.6 Mt of NO_x to the air in 2000 (Richartz and Corcoran, 2004). Ships are also major sources of solid waste. An estimated 70 000 m^3 of litter enter the North Sea per year, 95% of it non-biodegradable plastics (Richartz and Corcoran, 2004). Exposure to tributyltin (TBT), an anti-fouling compound used worldwide on ship hulls, has been linked to reproductive anomalies in molluscs and other marine life. Invasive species spread worldwide by "hitch-hiking" in ship ballast waters or on hulls, have in some cases accelerated the collapse of fish stocks (e.g. the comb jellyfish and the collapse of Black Sea anchovy fishery).

33. Oil and gas production platforms, present on most continental shelves, contribute to marine pollution levels through operational and accidental discharges of oil and chemicals. In the North Sea, operational discharges from the 475 offshore installations amount to 16 000 to 17 000 tonnes of oil per year (EEA, 2002). Elevated levels of hydrocarbons can be found in the sediment up to 8 km from offshore platforms, and levels of cadmium, mercury, and copper are also high in some locations (Richartz and Corcoran, 2004). A number of the chemicals discharged in the "produced water" from platforms have been implicated as endocrine disruptors which reduce the breeding success of certain fish stocks.

5. Policy approaches to managing the environmental impacts of fisheries and aquaculture

34. Looking to 2030, it will be important for governments to address gaps in the institutional and legislative framework for managing the environmental impacts of fisheries and aquaculture activities, at both the international and the national level. For example, strengthened legislation is needed to control the introduction of invasive aquatic species via ballast water and hull fouling (see also Chapter 7 on Biodiversity), and to address the environmental impacts of aquaculture.

[9] Some of the earliest recorded dead zones were in the Chesapeake Bay, the Gulf of Mexico, the Baltic Sea, the Kattegat, the Black Sea and the Adriatic Sea. Others have been reported off China, Japan, Australia and New Zealand.

[10] The global shipping fleet includes some 60 000 vessels with tonnage over 250 gross registered tonnes.

35. Illegal, unregulated, and unreported (IUU) fishing contributes to overfishing, by making it more difficult to ensure that limits on fishing are respected. IUU fishing is difficult to control due to the open access nature of most fish stocks, and due to the expense and technical challenge of monitoring vast marine zones. But the recent introduction of trade and catch certification schemes, coupled with rapidly evolving information technologies, is helping in a number of regions (Table F.4).

36. As fishing and aquaculture technologies evolve, it will be necessary to routinely update the institutional framework, to ensure that resultant environmental pressures do not become unsustainable. Enhancing surveillance and enforcement activities will also be essential to address implementation gaps and to facilitate recovery of over-exploited stocks, particularly on the high seas. The assumption that 'economic extinction' will necessarily precede 'biological extinction' of an over-exploited species has proven unfounded for particularly high value species. In some cases, prices have risen so high as the species becomes rare (e.g. up to USD 170 000 for a single bluefin tuna) that it has been economically viable to use aircraft to direct boats to single individuals (RCEP, 2004).

[Green Light]

Wider use of remote sensing and GPS technologies can help surveillance and monitoring of illegal fishing activities.

International governance

37. Global governance of fisheries is managed through recommendations by international bodies — such as the UN, the FAO's Committee on Fisheries, and regional fishery management organisations — through which countries agree instruments and frameworks for managing common fish stocks. According the UN Convention on the law of the Sea (1982), codified the practice of state jurisdiction over marine fisheries resources within 200 nautical miles of their coastlines, referred to as Exclusive Economic Zones (EEZs). It is estimated that EEZs cover about 90% of the world's marine capture fisheries. The creation of EEZs aimed to assign national ownership and management responsibility for fisheries management within these zones, thus shifting the fisheries management problem to individual countries. International governance remains important for setting the right international legal frameworks for fisheries manageement, and not least for addressing the management of high seas fisheries (outside the EEZs) and straddling fisheries.

38. At the 2002 World Summit on Sustainable Development in Johannesburg, governments jointly declared the objectives of restoring global fish stocks to sustainable levels by 2015; and of significantly reducing the rate of biodiversity loss by 2010. A number of international fisheries arrangements adopted since the 1992 Earth Summit have helped to strengthen international approaches to fisheries management, such as the 1995 UN Fish Stocks Agreement, the 1993 FAO Compliance Agreement, and the 1995 FAO Code of Conduct for Responsible Fisheries.

39. The role of regional fishery management organisations (RFMOs) in management of wild stocks of marine fish has augmented considerably in recent years. Whereas in the 1980s, the mandates of many RFMOs limited their role to research and advisory functions, amendment of these mandates since the Earth Summit has in many cases expanded their mandates to include conservation and management of stocks. However, RFMOs are constrained by the reluctance of member states to delegate sufficient decision-making power and responsibilities to them, as well as hesitation to implement the decisions of the RFMOs.

40. Greater understanding is also needed of the potential impacts of climate change and other weather phenomena (e.g. El Nino) on fisheries and aquaculture activities. In developing countries,

assistance may be needed in developing appropriate measures to adapt to climate change, and more broadly to support sustainable fisheries management.

Economic instruments

41. Economic or market–like instruments are increasingly used in fisheries management to internalise the environmental pressures associated with fishing and aquaculture by limiting fishing pressure (e.g. tradable permits, access charges), influencing fishers' incentives to overcapitalise in fishing effort (e.g. through vessel buyback schemes), or encouraging compliance with regulations (e.g. fees and fines). Limiting access to wild stocks through the allocation of catch permits is a widely used approach to limiting fishing pressure. There is an increasing recognition that market-based instruments can improve the efficiency of fisheries resource allocation and use, and help to align the economic incentives of fishers' with societal objectives (OECD, 2006a).

42. Historically, subsidies for shipbuilding and fleet enhancement have contributed to the creation of excess fishing capacity. Government financial transfers in OECD countries amounted to EUR 6.4 billion in 2003, or about 21% of landed value of the catch (OECD, 2006b). Increasingly, government support to fisheries is targeting more sustainable fisheries management, rather than increasing fisheries production. Thus, 38% of subsidy expenditures now supports research, management and enforcement; 33% goes to infrastructure; with the remainder to cost-reducing or income-enhancing measures.

43. A policy simulation was undertaken in the ENV-Linkages modelling framework to examine a potential — if idealised — means of achieving sustainability through the use of tradable quotas. This analysis is illustrative of an optimal fisheries management instrument while making a number of simplifying assumptions concerning fish ecology.

44. The simulation examines the economic impacts of applying an internationally tradable quota scheme that would reduce total allowable catch in capture fisheries by about 25% worldwide.[11] Trades in quota between countries result in international payments between those countries. Table 4 reports the expected economic impact of the simulation on fisheries production for each country. The results reported are percentage changes from a baseline.

45. Since the capture fisheries represent some 62% of total fisheries in the baseline in 2005, a 25% reduction in capture fisheries results in a decline of 16% in total (capture and aquaculture) fisheries. As shown in Table 2 earlier, capture fisheries are a declining share of total fisheries in the baseline. This 25% reduction then represents a 14% reduction of global fisheries production in 2010, and a 9% reduction in 2030, both below the baseline. The message here is that, since capture fisheries are becoming a smaller share of total fisheries, making capture fisheries sustainable causes a smaller relative disruption, over time, to total fisheries. Moreover, the reduction in total fisheries would be even smaller if there was a strong response in aquaculture to the price incentive induced by the imposed reductions in capture fisheries – something the model was exogenously constrained from doing. It was assumed that the growth in aquaculture already present in the baseline – an average of 3.9% per annum to 2030 – was likely to be the maximum feasible rate of expansion over that period.

[11] Some estimates suggest that current catches may be roughly 25% more than a "sustainable" fisheries could permit (Worm, et al, 2006). Given 2004 catch levels, and assuming that the fisheries which are overexploited are equally distributed between OECD and non-OECD catches, the simulation allocated 25% of the reduction to OECD, and 75% to non-OECD. The quota was allocated in proportion to the 2001 capture fisheries production.

Table 1. Reductions below baseline in total fisheries

(real output, in constant 2001 USD)

Regions	2010	2015	2020	2030
OECD	**-15%**	**-15%**	**-15%**	**-14%**
North America	-10%	-10%	-10%	-9%
US & Canada	*-12%*	*-12%*	*-11%*	*-10%*
Mexico	*-8%*	*-8%*	*-8%*	*-8%*
Europe	-18%	-17%	-16%	-14%
Pacific	-12%	-14%	-15%	-16%
Asia	*-13%*	*-15%*	*-16%*	*-17%*
Oceania	*-9%*	*-9%*	*-9%*	*-8%*
Transition Economies	**-16%**	**-11%**	**-9%**	**-6%**
Russia	-16%	-12%	-9%	-6%
Other EECCA	-18%	-12%	-9%	-6%
Other Transition economies	-9%	-8%	-8%	-6%
Developing countries	**-14%**	**-12%**	**-10%**	**-7%**
East & SE Asia, Oceania	-13%	-11%	-10%	-7%
China	*-14%*	*-11%*	*-10%*	*-7%*
Indonesia	*-12%*	*-10%*	*-9%*	*-6%*
Other East Asia	*-13%*	*-12%*	*-10%*	*-8%*
South Asia	-13%	-11%	-10%	-8%
India	*-15%*	*-13%*	*-11%*	*-9%*
Other South Asia	*-10%*	*-9%*	*-8%*	*-6%*
Middle East	-17%	-15%	-14%	-11%
Africa	-14%	-10%	-7%	-4%
Northern Africa	*-21%*	*-14%*	*-11%*	*-6%*
Republic of South Africa	*-15%*	*-11%*	*-8%*	*-4%*
Other sub-Saharan Africa	*-11%*	*-8%*	*-6%*	*-3%*
Latin America	-20%	-15%	-12%	-9%
Brazil	*-23%*	*-18%*	*-15%*	*-11%*
Other Latin America	*-20%*	*-15%*	*-12%*	*-9%*
Central & Caribbean	*-19%*	*-15%*	*-12%*	*-9%*
World	-14%	-13%	-12%	-9%

46. The most interesting aspect of Table 4 is the heterogeneity across countries. Each country was given a similar percentage reduction in the fish that can be caught, so the uneven reductions shown in the Table highlight differences in response to the policy – some countries are buying permits while others are selling. Estimates used in the model of consumer demand responsiveness, substitution between fisheries inputs such as capital, labour, and energy, and international trade responses all combine to give the results shown in the Table. At a practical level, on the supply side some countries will be better able to adapt to a higher cost of capture fishing (that includes the cost of acquiring permits) and will be net buyers of permits. On the down-side, this may translate into impacts on specific fisheries – the economics of some fisheries may not be well aligned with the ecology of those fisheries. These impacts will not be desirable, so a specific spatial distribution of reductions may be warranted; that is, the quota may have to specify a region where they can be used. On the demand side, since the policy will cause global increases in the price of fish products, which are traded internationally in significant quantities, the changes outlined in Table 4 are not necessarily reflective of changes in consumption in those countries.

47. The results indicate that the policy might initially have a more significant impact on poorer nations, such as Northern Africa and Brazil, but that over time the impact on them decreases. Furthermore, the impacts of this initial reduction in fisheries production might be even stronger in developing countries than the Table suggests – fish represents a more important part of people's diets in those countries than it does in developed economies.

Regulatory approaches

48. Regulatory approaches are being used, for example, to limit fishing effort and gear types, and to optimise the location and operation of aquaculture farms (e.g. total catch limits, spatial planning and zoning, effluent discharge permits). Sensitive habitats or important breeding or feeding grounds of at risk species can be set aside as conservation areas. Marine Protected Areas declared for fisheries purposes (such as areas closed to specific gear types, or set up to protect key habitats) can also support biodiversity conservation goals, but they can also have a role in improving the productivity of capture fisheries (Ward and Hegerl, 2003).

49. Regulatory standards for fishing gear can also be effective means of reducing impacts on habitats and non-target species (e.g. turtle excluder devices, seabird scaring streamers). But propagation of these "gear fixes" through the global fisheries has been slow, and where regulations for their use do exist, monitoring and enforcement may be poor. Measures to reduce by-catch of seabirds include setting the line at night, use of streamer bird scaring lines and optimal weighting of line to ensure it sinks quickly. Many of these measures are required in southern ocean fisheries, but are not yet mandatory in northern hemisphere fisheries that also have a high bird by-catch intensity (e.g. off the coast of Scotland). Acoustic deterrent devices for sea mammals and bird scaring devices for seabirds are also available.

50. Measures for stock rebuilding include reducing mortality through reduction of effort, including moratoria as needed, and by-catch reduction; reducing or eliminating environmental degradation; and enhancing factors of growth, for example through stock enhancement and habitat rehabilitation. Species that are particularly vulnerable to fishing pressure, such as those that are long-lived and only start breeding after a relatively long period of immaturity[12] may in particular require long-term management recovery plans. Since the late 1990s, there has been an increase in the percentage of stocks recovering, although it is not known to what extent this is attributable to improved management or climatic conditions.

51. Regulation of aquaculture has progressed considerably since the 1990s, with most OECD countries now requiring operators to acquire permits or licenses to establish a farm. Environmental impact assessments are generally required for new facilities, and licenses typically specify some operating conditions designed to limit environmental impacts. In addition, technical advances have helped to reduce the intensity of environmental pressures from aquaculture production. For example, improved management practices have limited the spread of pathogens from cultured to wild stocks even while reducing the intensity of use of veterinary drugs to raise the stock. There have also been advances in improving feeding efficiency, and thus reducing the nutrient output of farms. Research and development of new aquaculture technologies will be important to help reduce fishmeal and fish oil requirements, as well as to further reduce and mitigate the environmental impacts of intensive aquaculture.

Information-based approaches

52. Voluntary and trade-related approaches are used to encourage the spread of best practices among fishers and fish farmers (e.g. codes of practice, ecolabels, and catch certificates). As major consumers and importers of fish products, OECD countries have an interest to promote measures that will ensure the

[12] Sharks, rays and skates, and many species of fish in deep water fall into this category.

long-term sustainability of capture fisheries in developing countries. The link between pollution and food safety in fish production, including pollution sources from outside the sector, will receive more attention worldwide in the future. Trade related measures ca be used to raise the accountability of producer countries (e.g. catch certificates, trade certificates).

53. Eco-labelling of fisheries products is still in its infancy. In 1997, the Marine Stewardship Council (MSC) began as a joint initiative between the World Wildlife Fund and Unilever, a multinational company and one of the world's largest buyers of fish (supplying about 25% of the frozen fish in Europe and the United States). In 1999, MSC became an independently run non-profit organization, administering an eco-labelling programme that aims to promote sustainable marine fisheries. Sustainable fisheries are defined as those that "ensure that the catch of marine resources are at levels compatible with long-term sustainable yield, while maintaining the marine environment's bio-diversity, productivity and ecological processes." MSC certification takes into account compliance with relevant laws, measures of ecological sustainability of the fish stock and integrity of the ecosystem, quality of management systems, and some social considerations.

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ANNEX: ENVLINKAGES MODEL

54. The Envlinkages model continues an OECD tradition of quantitative simulation analysis that dates back to early versions of the INTERLINK model[13]. For environmental policy[14] the work with the GREEN model established a line of analyses that has continued to the present. GREEN was originally used for studying climate change policy, and culminated in Burniaux (2000).[15] It was developed into the Linkages model, and subsequently became the JOBS/Polestar modelling platform that was used to help underpin the OECD Environmental Outlook to 2020. A version of that model is also currently in use at the World Bank for research in global economic development issues. Further developments have been incorporated, and it is now the Envlinkages model in use in the Environment Directorate. Recent work using the model include development of a baseline to 2030 (ENV/EPOC/GSP(2006)5) and a study of the consequence of structural change (including some environmental implications) associated with economic growth (ENV/EPOC/GSP(2006)7).

55. The Envlinkages model is a global economic model built primarily on a database of national economies. The model represents the world economy in 34 countries/regions, each with 26 economic sectors – of which fisheries is one. Each of the 34 regions is underpinned by an economic input-output table (usually published by a national statistical agency). Those tables identify all the inputs that go into the fisheries industry, and identify all the industries that buy fish (e.g. fish processors, agriculture, etc). Industries such as fisheries and forestry are also identified to have a "natural resource" input – i.e. fish and trees.

56. Since it is an economic model, it does not represent individual fish species or oceans. Inputs and output are measured in the constant currency of a base year – inflation is thus removed from the value of output. Moreover, output can be calculated in either the real price of a given year, or the initial price of the base year. Calculating output in the base-year price gives a "volume" measure that would closely parallel the tonnage landed in that year.

57. In the model, the technological representation of production is accomplished using a nested sequence of constant elasticity of substitution (CES) functions. Four factors are specified: land, labour, capital, and a sector-specific natural resource. Energy is an input that is combined with capital. There is a parameterisation of the substitutability between inputs, so the intensity of using capital, energy and labour changes when their relative price changes – as labour becomes more expensive, less of it is used relative to capital and energy. The fisheries sector thus combines a natural resource (i.e. the fish) with other inputs to produce the output of the fisheries sector – landed fish.

58. Trade is modelled using nested Armington and production transformation structures. Two vintages of capital, and a full range of market policy instruments (tax rates) are also specified.

13 . Helliwell, J.F., P. Sturm, P. Jarrett and G. Salou (1985), "Aggregate Supply in INTERLINK: Model Specification and Empirical Results", OECD Economics Department Working Paper, No. 26, Paris.

14 . Burniaux, J-M, G. Nicoletti and J. Oliveira Martins (1992), "GREEN: A Global Model for Quantifying the Costs of Policies to Curb CO2 Emissions", *OECD Economic Studies*, 19(Winter).

15 Burniaux, J-M, (2002), A Multi-Gas Assessment Of The Kyoto Protocol, OECD Economics Department Working Papers No. 270.

59. All production is assumed to operate under cost minimization with an assumption of perfect markets and constant return to scale technology. The production technology is specified as nested CES production functions in a branching hierarchy. The top node thus represents an output – using intermediate goods combined with value-added. This structure is replicated for each output, where the parameterisation of the CES functions may differ across sectors.

60. Total output for a sector is actually the sum of two different production streams: resulting from the distinction between production with an "old" capital vintage, and production with a "new" capital vintage. The substitution possibilities among factors are assumed to be higher with new capital than with old capital. In other words, technologies have putty/semi-putty specifications. This will imply longer adjustment of quantities to prices changes. Capital accumulation is modelled as in traditional Solow/Swan growth model.

61. The valued-added bundle is specified as a CES combination of labour and a broad concept of capital. In the "crop" production sector, this broad capital is itself a CES combination of fertilizer and another bundle of capital-land-energy. The intention of this specification is to reflect the possibility of substitution between extensive and intensive agriculture. In the "livestock" sectors, substitution possibilities are between bundles of land and feed on the one hand, and of capital-energy-labour bundle on the other hand. This reflects a similar choice between intensive and extensive livestock production. Production in other sectors is characterised by substitution between labour and a bundle of capital-energy (and possibly a sector-specific factor for primary resources).

62. Household consumption demand is the result of static maximization behaviour which is formally implemented as an "Extended Linear Expenditure System". A representative consumer in each region – who takes prices as given – optimally allocates disposal income among the full set of consumption commodities and savings. Saving is considered as a standard good and therefore does not rely on a forward-looking behaviour by the consumer.

63. The government in each region collects various kinds of taxes in order to finance a given sequence of government expenditures. For simplicity and without loss of generality it is assumed in the baseline that these expenditures grow at the same rate as the real GDP of the previous period. The government budget is balanced through the adjustment of the income tax on consumer income.

64. International trade is based on a set of regional bilateral flows given in the GTAP database (Purdue University). The model adopts Armington assumptions that domestic and imported products are not perfectly substitutable. Moreover, total imports are also imperfectly substitutable between regions of origin. Bilateral exports are modelled in a parallel manner (except that CET functions and not CES are used for imports). Allocation of trade between partners then responds to relative prices at the equilibrium.

65. This general overview of the model is intended to provide a flavour of what is driving the results. More detailed information on its structure will be available when time permits, but a technical description is available in van der Mensbrugghe (2004).[16]

[16] van der Mensbrugghe, D. (2003), "Linkage Technical Reference Document Version 5.4", Development Prospects Group, World Bank, Washington.