AN ECONOMIC AND INSTITUTIONAL ANALYSIS OF NUTRIENT ENRICHMENT IN THE DANUBE-BLACK SEA SYSTEM

by

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An Economic and Institutional Analysis of Nutrient Enrichment in the Danube-Black Sea System

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Abstract

The nutrient pollution in the Danube-Black Sea System is an international environmental problem worthy of analysis because of the number and diversity of the countries involved as well as the severity and the scope of the pollution in the region. This issue is characterized by the downstream flow of nutrient pollution in the Danube River Basin to the Black Sea where coastal countries also emit nutrients, and where significant environmental degradation has occurred. Theoretical analyses suggest that downstream countries must use payments to convince upstream countries to abate because these countries would not have any incentive to reduce pollution in the absence of these payments. This paper offers an economic formalization of the Danube-Black Sea pollution problem and analyzes the effects that these incentives have on the role of payments from downstream to upstream countries, and the prospects for international environmental cooperation in the region.

This paper offers several important conclusions. First, payments from downstream to upstream countries will be unlikely because of European Union enlargement and water policy, institutional linkages and interdependence among the countries of the region, and wealth constraints in downstream countries. Second, upstream abatement in the Danube that is aimed at improving water quality in the Black Sea will likely have a negative impact on the incentives for cooperation among the Black Sea riparian states. Third, cooperation among the Black Sea riparian states will be a critical part of addressing the Danube-Black Sea pollution problem.

Dedication

To the approximately two million Black Sea fishers and their dependants who suffered greatly when the Black Sea fishery collapsed.

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Abbreviations and Acronyms

BSEP	Black Sea Environmental Program
c	Full-cooperative Outcome
CEE	Central and Eastern Europe
CPR	Common-pool resources
DSAP	Strategic Action Plan for the Danube River Basin
DRPC	Danube River Protection Convention
EPDRB	Environmental Program for the Danube River Basin
EU	European Union
FYR	Former Yugoslav Republics
GDP	Gross Domestic Product
GEF	Global Environment Facility
HDI	Human Development Index
ICPBS	International Commission for the Protection of the Black Sea
ICPDR	International Commission for the Protection of the Danube River
kt	Kilo-tonne
MC	Marginal Costs
MB	Marginal Benefits
N	Nitrogen
n/a	Not Applicable
n.d.	No Date
OECD	Organization for Economic Cooperation and Development
P	Phosphorus

Plc	Public Limited Company
PPP	Purchasing Power Parity
Q	Quantity
R	River
SAP-BS	Strategic Action Plan for the Rehabilitation and Protection of the Black Sea
UK	United Kingdom
UNDP	United Nations Development Programme
USD	United States Dollars
WTP	Willingness to Pay
y	Year

Chapter One: Introduction

The proliferation of international environmental problems has resulted in increasing interest in international environmental cooperation, and the factors that affect this cooperation. The nutrient pollution problem in the Danube-Black Sea System is an interesting example of a complex international environmental problem. The Danube River Basin is the most international river basin in the world in terms of the number of countries (CEC, 2001), the Black Sea is the most polluted inland sea in the world (Duda and LaRoche, 1997), and the Danube is the most important source of pollution in the Black Sea (SAP-BS, 1996). These factors, along with the unique political circumstances that have resulted from the European Union (EU) enlargement and the recent fall of communism in the region, make environmental cooperation in the Danube-Black Sea System worthy of study.

The Danube-Black Sea pollution problem is characterized by the relationship between upstream countries that pollute and downstream countries that are victims of this pollution. As the Danube flows downstream through Central and Eastern Europe to its mouth in the Black Sea, several countries pollute it with large amounts of nutrients, notably phosphorous and nitrogen. While these pollutants have an ecological impact on Danube countries, their effects are particularly pronounced in the Black Sea where they accumulate. Theoretical analyses suggest that downstream countries must use payments or other similar mechanisms to convince upstream countries to abate because these countries would not have an incentive to reduce pollution in the absence of these payments (Maler, 1992, Bennet et al., 1997 in Frisvold and Caswell, 2000). This paper will offer an economic formalization of the Danube-Black Sea pollution problem by modelling the incentives to pollute and abate that countries face. It will then analyze the effects that these incentives have on the role that payments from downstream to upstream countries can play in addressing this problem, and the prospects for international environmental cooperation.

Purpose of the Research

General Objective: To identify and analyze the incentives to abate nutrient pollution facing the countries of the Danube-Black Sea System.

Specific Objective: To determine how these incentives affect the prospects for cooperation in the region and the role of payments from downstream countries to upstream countries to increase upstream abatement.

Report Organization

Chapter Two provides a literature review, addressing key concepts associated with international environmental cooperation, environmental economics in an international context, and environmental applications of game theory. Chapter Three offers background information on the Danube-Black Sea pollution problem, discussing the environmental effects of pollution, the political economy of the region, and the role of the EU. Chapter Four provides a formal analysis of incentives to abate facing the countries in the Danube and in the Black Sea, considering the two systems separately. Chapter Five considers the two systems together and uses the results to develop potential outcomes for the Danube-Black Sea system as a whole. These outcomes form the basis for a discussion of the effects of side payments on the prospects for cooperation in the Black Sea. Chapter Six discusses some key institutional considerations, elaborating on the effects of the EU and providing some institutional context for the formal analyses in the previous two chapters. Chapter Seven offers some conclusions and suggestions for further research.

Chapter Two: Literature Review

This chapter will discuss some of the theoretical aspects of international environmental problems and cooperation relevant to the Danube-Black Sea pollution problem. Environmental externalities will be addressed, focussing on transboundary and international resources. Common pool resources and the collective action problem will then be discussed in conjunction with the institutions and regimes that are often prescribed to address them. Subsequently, the theoretical aspects of international environmental problems and cooperation will be addressed from a game theoretic perspective focussing on cooperative and non-cooperative outcomes, the Nash equilibrium, and the ways that the number of countries involved in environmental problems affects outcomes. Issue linkage, side payments and other methods of changing the nature of environmental problems to achieve cooperation will be addressed, followed by a brief discussion of some of the impediments to international environmental cooperation.

Externalities

Environmental problems are often conceptualized as environmental externalities, and the need for public intervention in private markets is often justified because of the existence of these externalities (van Kooten, 1993). Externalities exist, "when the utility of an economic agent is affected by the actions of another," and the effect is external to the causing agent (Asafu-Adjaye 2000: 73). Maler (1992) divides international environmental externalities into three broad categories: global environmental problems, unidirectional externalities and regional reciprocal externalities. The latter two will be discussed because of their relevance to the Danube-Black Sea pollution problem.

According to Maler (1992), unidirectional externalities are typified by upstream polluters polluting those downstream. He considers three cases. In the first case, there is one upstream and one downstream country, which results in bargaining between the two parties. The second case exists when there are several downstream countries that have an incentive to free ride on upstream abatement and wait for other downstream countries to address the pollution problem. In the third case, there are numerous countries emitting pollution and the challenge is to find a cost efficient way of allocating abatement measures among emissions sources. (Maler, 1992)

The distribution of property rights among upstream and downstream countries plays a key role in the case of a unidirectional externality. When addressing the allocation of property rights to achieve optimal outcomes, Coase (1960) argued that it does not matter who receives the property rights as long as they are allocated[1]. An agreement among upstream and downstream parties will be reached, and the allocation of property rights will determine whether the upstream or downstream party pays the abatement costs (polluter pays versus victim pays) (Maler, 1992). While economic efficiency can be satisfied regardless of who pays, victim pays outcomes may not be acceptable because they run counter to the polluter pays principle (and the conceptions of fairness embodied in it) that was adopted by OECD countries in 1972 (Maler, 1992). Bennet et al. (1997 in Frisvold and Caswell, 2000) state that unidirectional externalities tend to result in victim pays outcomes in game theoretic solutions, and Frisvold and Caswell (2000) add that downstream countries that are substantially poorer than their upstream counterparts may be unable to offer side payments for upstream countries to abate pollution.

Maler's second group of externalities, regional reciprocal externalities, exist when "a group of countries is both the source and victim of an environmental problem" (1992:

[1] Coase (1960) argues that, in the absence of transactions costs and subject to a series of other assumptions, the initial distribution of property rights does not matter because bargaining will result in socially optimal outcomes.

473). These externalities are characterized by the incentive for countries to free ride, "hoping that the other countries will undertake abatement measures" (Maler 2002: 481). An international lake or sea that is polluted by many countries is a good example of a regional reciprocal externality. In this case, several countries emit pollution into this lake or sea, but these same countries also suffer from the collective pollution of the water body.[2]

Pearson (2000) also classifies international environmental externalities, dividing them along three separate dimensions. The first distinguishes between reciprocal and unidirectional externalities, using the terms in the same sense as Maler (1992). Pearson (2000) uses a transboundary international river as an example of a unidirectional externality and a regional sea with two or more countries as an example of a reciprocal externality. He also indicates that in the case of a unidirectional externality, and in the absence of "strong international law, compensation, or coercion," the source country will not abate pollution unless significant costs accrue to it (Pearson 2000: 344). However, a country sharing a resource that is affected by a reciprocal externality "may find it in its self-interest to moderate pollution" (Pearson 2000: 344).

Pearson's (2000) second dimension is the number of countries involved, and his third the ease with which damages are objectively measurable. Cases that involve a large number of countries are more prone to the free-rider problem; however, where the interests among countries are very unequal, "the number of countries may be less important than the behaviour of the few countries for whom the outcomes are important" (Pearson 2000: 344). When addressing the third dimension, Pearson (2000) states that international agreements should be easier to negotiate when the externality and the damage are easy to quantify.

[2]Maler (1992) uses the North Sea fishery and atmospheric pollution resulting in Acid Rain in Europe as examples of regional reciprocal externalities.

Global Common Pool Resources and Collective Action Problems

An extensive literature has developed on Common Pool Resources (CPRs – also know as common property resources) at local, regional and international levels (e.g. Ostrom, 1990; Ostrom et. al 1994; Singleton, 1998; and Harrison and Matson, 2001). There are two important features of CPRs that affect the way they can be managed. The first is excludability, or access. CPRs are subject to open access, meaning that it is very difficult and costly, or impossible, to exclude potential users (Feeny et al., 1998). The second is subtractability. The subtractability problem means that each user using the resource can subtract from the welfare of other users (Feeny et al., 1998); and hence a resource is depletable.

Rational self-interested actors have no incentive to conserve common pool resources acting alone, meaning that resources such as oceans, air quality, rivers and many others will be significantly degraded (Feeny et al., 1998). Hardin's (1968) example of herdsmen using common pastureland to feed animals has become conventional wisdom, and has been an influential starting point for many supporting and dissenting arguments. The essence of the example is that an individual herdsman will always have the incentive to add one more animal to the communal pasture because the benefits accrue to him alone, while the costs are born by the community that uses the pasture. The cumulative impact of all herdsmen maximizing their personal well-being will result in overgrazing and degradation of the pasture.

Hardin's (1968) example can easily be applied to global resources that are held in common. A country that emits greenhouse gases reaps all of the benefits of doing so while the costs of climate change are spread among all countries. Harrison and Matson (2001: 221) state that, "like the degradation of Hardin's pasture, the degradation of the atmosphere also results from an incompatibility between individual motives and the greater good." The difference between individually rational and collectively rational outcomes that exists for CPRs is the essence of the collective action problem. Collective action problems exist in situations where individually rational actions result in collectively sub-optimal or irrational outcomes (Taylor, 1987 and Singleton, 1998). In an international context, the actions of nation states acting rationally and in their own self-interest result in outcomes that are collectively sub-optimal or irrational.

Changes in institutions are often prescribed as solutions to collective action problems. Young (1992: 8) states that, "the key to solving these collective-action problems, most observers now believe, lies in the creation of international regimes or, more broadly, international institutions."[3] Young and Levy (1999: 23) point out that regimes can enhance international environmental cooperation by "mitigating the collective action problems that stand as barriers to the realization of joint gains." More specifically, they "alter the costs and benefits individual actors attach to well-defined options" (Young and Levy 1999: 22), and establish norms that are internalized by states (Oye, 1986). Norms that are internalized by states serve to define roles for international actors, and socialize these actors to behave in a certain way (Young and Levy, 1999). The overall effect is that regimes and institutions create conditions to facilitate cooperation that would not have occurred in their absence.

Game Theory and International Environmental Cooperation

An extensive body of literature has developed addressing the theoretical aspects of international environmental cooperation, much of which is built on game theoretic approaches. Broadly defined, game theory "analyzes the interaction between agents and formulates hypotheses about their behaviour and the final outcome in games" (Finus, 2001: 1). It is well suited to the analysis of international problems and international cooperation because it considers the strategic behaviour of self-interested actors on an anarchic international stage. It has been used to analyze the strategic aspects of international relations (e.g. Oye, 1986), and pure collective action and cooperation problems (e.g. Axlerod, 1984 and Snydal, 1985). Game theory has also been applied extensively to environmental problems, particularly on the international stage (e.g. Finus, 2001; Helm, 2000; Folmer et al., 1998; and Sandler, 1997). Folmer et al. (1998:2) state

[3] Meyer and Frank (1997: 623) define the world environmental regime as, "a partially integrated collection of world-level organizations, understandings, and assumptions that specify the relationship of human society to nature." International environmental regimes exist at regional levels as well. Regimes are also a type of institution.

that: "The typical features of many environmental problems can be most adequately handled by means of game theoretic notions and models ... these provide a comprehensive framework for the analysis of the fundamental cause of environmental problems: multi-actor decision making in situations characterized by the lack of property rights and the existence of externalities."

An important focus of the literature on international environmental cooperation is the difference between cooperative and non-cooperative outcomes. Barrett (1993: 5) describes the full-cooperative outcome as "the outcome that maximizes collective net benefits." Folmer et al. (1998: 4) describe it as the solution "which would result if a central planner was to optimize the welfare of all countries with respect to the control of transboundary pollution." The full-cooperative outcome can be thought of as that which would occur were all externalities internalized,[4] and pollution were abated to the point where the marginal benefits of abating pollution are equal to the marginal costs of pollution for all countries involved in the environmental problem. It is not an equilibrium because not every country will necessarily be better off under the full-cooperative outcome, and there is an incentive for all countries to free ride (Folmer et al., 1998). It is often the case with international environmental problems that the full-cooperative solution requires more abatement than non-cooperation, but will also deliver more collective benefits (e.g. Barrett, 1990). Folmer et al. (1998: 12) state that the main conclusion of the literature on static game theory is that "full-cooperation outperforms non-cooperation and leads to lower levels of pollution."

The Nash equilibrium is among the most important concepts in game theory and is particularly useful when comparing cooperative and non-cooperative outcomes. In an environmental pollution context, the Nash equilibrium "results when countries choose their (optimal) abatement strategies in reaction to the choice of abatement strategies of all other countries" (Folmer et al., 1998: 6). If cooperation does not materialize, the Nash equilibrium will occur (Folmer et al., 1998). In the absence of cooperation, it is the best state a country can achieve maximizing its own welfare (Folmer et al., 1998). The Nash equilibrium is important to international environmental problems because it is the non-cooperative outcome, where nations degrade (or conversely conserve) to the point where it is individually rational for them to do so. The problem of international environmental cooperation can be conceptualized as the effort to increase pollution abatement and move away from the Nash equilibrium (or to a point where pollution abatement is higher than the Nash equilibrium), which is collectively sub-optimal because externalities are not internalized. The Nash equilibrium can also be conceptualized as the "threat" point: the Nash outcome will occur if an agreement cannot be established (Folmer et al., 1998).

One particularly significant contribution of the game theoretic literature on international environmental cooperation is the relationship it outlines between the number of countries involved in an international environmental problem, and the type of cooperation that can be achieved. Barrett (1990) asserts that international environmental agreements can accomplish little when the number of countries involved in an international environmental problem is high, no matter how many of these countries sign onto the agreement. He states that this is because "the defection or accession by any country has only a negligible effect on the abatement of the other co-operators (Barrett 1990: 75). Young (1992:10) states that, "the number of participants is important because the transaction costs of reaching an agreement rise as the size of the group increases."

Other research on international environmental problems and international cooperation confirms this relationship. Using game theory to analyze fishing on the high seas, Hannesson (1995) concludes that cooperative solutions are much more likely to emerge when few countries manage a coastal resource than for international waters where the potential number of participants is very large. Conybeare (1986) illustrates that the difficulties of cooperation increase when there are a large number of players in the game.

Side Payments, Issue Linkage and Changing the Playing Space

The distribution of payoffs, or environmental benefits and costs, will have a significant impact on the prospects for international environmental cooperation. Young (1992:10) states that:

[4] Barrett (1993) refers to the internalization of externalities in this context.

> While virtually all cases of interactive decision making involve a mix of incentives to compete and cooperate, the nature of this mix in specific situations is an important determinant of success or failure in efforts to form international regimes.

This mix of payoffs will vary according to specific situations and circumstances and will determine the nature of the game that is played. Oye (1986) points out that the payoff structure determines if mutual benefits can be realized, and if coordination is necessary to achieve cooperation and the realization of these mutual benefits. He outlines how the payoff structure will determine if nations are playing chicken, prisoners' dilemma, stag hunt or other games. The distribution of payoffs essentially determines the structure of games, affecting equilibriums and the possibility of cooperation. Some games will have a single equilibrium, some will have many and others will have none. Some will sustain cooperation, and others will not. It is even possible that it will not be entirely clear what payoff structure actors face and what games are being played. When discussing the Franco-Italian tariff war of 1887-1898, Conybeare (1986) illustrates that, among other things, it is not always clear what is motivating nations.

As is mentioned above, it is possible that the payoff structure will, in some situations, not sustain cooperation if the issue in question is considered in isolation. An example of such a situation would be a unidirectional externality, where polluting countries have no incentive to abate their emissions (Barrett, 1997). The payoff structure in this situation is such that the polluter has no incentive to cooperate because it has nothing to gain from cooperation.[5] This situation will not yield a cooperative outcome if the environmental issue in question is considered in a vacuum.

In reality, environmental problems are usually not addressed in a vacuum but in connection with other policy fields (Finus, 2001), where negotiation issues are linked (Frisvold and Caswell, 2000). Issue linkage essentially expands the playing space to permit solutions that would otherwise be impossible. It allows for the development of package deals that "avoid possible asymmetric distributions of the gains from

[5] When discussing trade wars, Conybeare (1986) provides examples where countries prefer non-cooperation to cooperation.

cooperation" (Finus 2001: 2). Returning to the example of the unidirectional externality, the victim of the pollution can choose to link the environmental issue with another issue area in order to provide the country causing the environmental damage with an incentive to abate pollution. Hirsch (1998: 118) observes that, "legal mechanisms, such as retaliatory rules and linkage arrangements are valuable tools in encouraging international environmental cooperation." Frisvold and Caswell (2000) show how issue linkage can balance out asymmetries between Mexico and the USA regarding the management of transboundary water resources. Additionally, it is often the case in international politics that issues are inextricably linked regardless of specific efforts to make those linkages. For example, when addressing international cooperation as it applies to the global greenhouse problem, Andresen and Wettestad (1992: 291) state that, "due to strong functional linkages between the different issues areas, institutional separation has proved very difficult."

There are other ways aside from issue linkage that asymmetries among actors can be addressed. Frisvold and Caswell (2000:108) note that, "third parties can balance asymmetries in bargaining power by ensuring that access to information and technical expertise is not monopolized." An example of this would be international institutions such as the United Nations Environment Programme or the Global Environment Facility providing equal access to information and technology used to assess and address international environmental problems. Young (1992) also highlights the importance of acknowledging the bargaining power of apparently weak players that can issue credible threats to increase pollution unless other players make it worthwhile for them not to do so. Threats from weaker players would be effective with reciprocal externalities, but would obviously not work with unidirectional externalities where the threat comes from a victim.

Side payments or transfers can also be used to change the nature of the playing space. For example, the downstream victim of a unidirectional externality may pay the upstream polluter to abate because the upstream polluter would have no incentive to do so without being paid. While this solution runs contrary to the polluter pays principle, side payments can be used to expand the playing space to achieve international environmental cooperation. Barrett (1997: 78) states that signatories to an environmental agreement can "make side payments to a subset of non-cooperators to encourage them to sign the agreement" and that "an international environmental agreement that specifies abatement levels *and* side payments can manage the global common property resource better than one that prohibits side payments" (italics in original). Where benefits and costs are asymmetrically distributed, side payments may in fact be a prerequisite for cooperation. When discussing the acid rain problem in Europe, Maler (1989) concludes that side payments are necessary to get all countries to participate in pollution abatement.

Finally, side payments or transfers can play an important role in making international environmental agreements more economically efficient, while satisfying equity considerations and maintaining incentives for countries to cooperate. In order to maximize the net benefits accruing to a group of signatories to an international environmental agreement, "the marginal abatement costs of every signatory must be equal; the abatement undertaken by the group must be achieved at minimum total cost" (Barrett, 1997). It is clear, however, that equalizing marginal abatement costs among countries will probably require different levels of total abatement for these countries, and instances where some are required to abate much more than others. Essentially, cost efficient solutions will result in different burdens being imposed on signatories (Folmer et al., 1998). These may not be perceived as equitable solutions. Side payments and mechanisms that allow income to be transferred among countries can solve this problem by allowing countries to share the burden of abatement. Tradable discharge permits and schemes where signatories with high abatement costs can pay for abatement in signatories with lower costs are an example of such mechanisms (Folmer et al., 1998). Simple side payments from one country to another serve the same purpose.

Chapter Three: Political, Economic and Environmental Aspects of the Danube-Black Sea Pollution Problem

This section will address the political, economic and environmental factors that affect the Danube-Black Sea pollution problem. Initially, the physical features of the Danube River Basin and the Black Sea will be discussed along with the environmental impacts of nutrient enrichment. General economic and political features of the Danube-Black Sea countries will then be addressed. Subsequently, notable impacts of EU enlargement in the region will be discussed, followed by the effects of EU water policy in the region.

Nutrient Pollution and the Environment

The River Danube flows 2,850 kilometres from its source in Germany to the western end of the Black Sea (ICPDR, 1999). It drains approximately 817 000 square kilometres from 18 countries in Central and Eastern Europe and is the largest watercourse in a basin that contains approximately 300 tributaries, 30 of which are navigable (ICPDR, 1999). The countries included in the Danube River Basin are: Albania, Austria, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, the Federal Republic of Germany, Hungary, Italy, Macedonia, Moldova, Poland, Romania, the Slovak Republic, Slovenia, Switzerland, Ukraine and the Federal Republic of Yugoslavia (ICPDR, 2001). Although the Black Sea is the final destination of the streams that drain almost a third of the European land area, the Danube is "by far the single most important contributor to the nutrient pollution of the Black Sea" (CEC 2001: 7). Of the 171 million people living in the Black Sea catchment area, 81 million live in the Danube River Basin (Stanners and Bourdeau, 1995). According to BSEP (1997), the Danube contributes 79 percent of all nutrients that enter the Sea, including 80 percent of its nitrogen inputs, and 69 percent of its phosphorous inputs. (Table 3.1 documents the sources of nutrient pollution that enter the Black Sea.) While nutrient pollution will be the focus of this paper, numerous other pollutants such as heavy metals and hazardous organic substances are dumped into the Danube and its tributaries to make the journey downstream towards the Black Sea (Rodda, 1994).

Table 3.1. Sources for Nitrogen and Phosphorous Emission that Enter the Black Sea

Sources	Nitrogen		Phosphorus		Nutrients	
	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total
Danube R	345.66	80.29%	25.44	68.99%	371.1	79.39%
Dnieper R	11.18	2.60%	3.97	10.77%	15.15	3.24%
Dniester R	22.75	5.28%	0.98	2.66%	23.73	5.08%
Don R	7.048	1.64%	3.386	9.18%	10.434	2.23%
Sea of Azov	43.9	10.20%	3.1	8.41%	47	10.06%
Total	430.538	100.00%	36.876	100.00%	467.414	100.00%

Source: Adapted from BSEP, 1997

The nutrient pollution emissions of individual Danube and Black Sea countries are also highly asymmetric. Table 3.2 outlines the nutrient pollution contributions to the Danube system of all countries that have more than 2000 square kilometres of Danube Basin territory[6], and Table 3.3 lists the nutrient pollution contributions to the Black Sea of all countries that have a coastline on that body of water (these countries are Russia, Turkey, Romania, Bulgaria, Ukraine and Georgia). Total nutrient pollution inputs (N+P) to the Danube system range from 1.5 percent of the total for Moldova to 25.7 percent for Romania. Other important polluters include Yugoslavia (12.3 percent), Germany (12.6 percent), Austria (10.2 percent) and Hungary (9.5 percent). The values for countries with

[6] The 2000 square kilometre figure was chosen because only those countries that have Danube Basin territories greater than 2000 square kilometres plus the European Community have access as contracting parties to the Danube River Protection Convention (DRPC), an important international convention in the region (ICPDR, 2001).

Black Sea coastlines range from 0.88 percent of the total for Georgia to 33.3 percent of for Bulgaria, with Ukraine (20.6), Romania (19.9 percent) and Turkey (19 percent) all contributing significant amounts of nutrients to the Black Sea.

The extensive pollution loads from the Danube, along with pollution from Black Sea states, over-fishing, the dumping of toxic wastes, intense shipping, mineral exploitation, the introduction of non-native species and the damming of inflowing rivers, has resulted in severe environmental degradation in the Black Sea (Mee, 1992), such that it has become the most polluted inland sea in the world (Duda and LaRoche, 1997). Nutrient pollution is the focus of this paper because it is among the most important environmental problems affecting the Black Sea. As a result of 30 years of heavy nutrient pollution, the Black Sea (which was once oligotrophic) is now critically eutrophic (Mee, 1992 and ICPDR, 1999). The northwestern portion has been transformed from a diverse ecosystem to a eutrophic plankton culture (Mee, 1992 and Middleton, 1999). This has had a major impact on biodiversity and human use of the Black Sea (CEC, 2001). Other important contaminants in the Black Sea include oil, synthetic organic compounds and radionuclides deposited by the Chernobyl accident (Stanners and Bourdeau, 1995).

Environmental degradation in the Black Sea Region has had economic costs in a number of sectors. One of the hardest hit is the fisheries sector, where catches of the most lucrative fish fell dramatically in the 1980s and 1990s (World Bank, 2000). Only five of the 26 commercial fish species once abundant in the Black Sea in 1970 remain commercially viable today (Stanners and Bourdeau, 1995), a result of pollution and the introduction of non-native species, most notably the comb jelly *Mnemiopsis leidyi* (Mee, 1992 and Travis, 1993). The Black Sea's fishery, which supported approximately 2 million fishers and dependents, suffered almost total collapse (Mee, 1992 and Travis, 1993).[7] Also, Suarez de Vivero and Rodriguez Mateos (2002: 396) state that: "the Black Sea has seen the collapse of some of its stocks (anchovy, sprat) on account of the sharp decline of its estuarine environments."

[7] BSEP (1997) confirms the collapse of fish stocks.

Table 3.2. Nitrogen and Phosphorous Emissions into the Danube River Basin[8]

Country	Nitrogen				Phosphorus				Nutrients	
	Point Source (kt/y)	Diffuse Source (kt/y)	Total (kt/y)	Percent of Total	Point Source (kt/y)	Diffuse Source (kt/y)	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total
Germany	20	100	120	13.4%	1.2	5.8	7	6.5%	127	12.6%
Austria	24	72	96	10.7%	2.2	4.6	6.8	6.3%	102.8	10.2%
Czech Republic	13	19	32	3.6%	2.6	0.8	3.4	3.2%	35.4	3.5%
Slovakia	14	40	54	6.0%	3	2.6	5.6	5.2%	59.6	5.9%
Hungary	19	63	82	9.1%	5.4	7.8	13.2	12.3%	95.2	9.5%
Slovenia	12	12	24	2.7%	1.5	1.3	2.8	2.6%	26.8	2.7%
Croatia	8	27	35	3.9%	1.4	2.7	4.1	3.8%	39.1	3.9%
Bosnia-Herzegovina	8	29	37	4.1%	3.2	1.9	5.1	4.8%	42.1	4.2%
Yugoslavia	32	74	106	11.8%	9.8	7.9	17.7	16.5%	123.7	12.3%
Romania	74	157	231	25.7%	12	15.6	27.6	25.7%	258.6	25.7%
Bulgaria	18	16	34	3.8%	3.6	2.5	6.1	5.7%	40.1	4.0%
Moldova	1	12	13	1.4%	0.2	2	2.2	2.1%	15.2	1.5%
Ukraine	3	31	34	3.8%	1.1	4.6	5.7	5.3%	39.7	3.9%
Total	246	652	898	100.0%	47.2	60.1	107.3	100.0%	1005.3	100.0%

Source: Adapted from ICPDR, 1999

Table 3.3. Nitrogen and Phosphorous Emission into the Black Sea From Countries with Black Sea Coastlines

Country	Nitrogen		Phosphorus		Nutrients	
	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total
Bulgaria	75.467	34.8%	1.13	8.3%	76.592	33.25%
Georgia	1.585	0.7%	0.44	3.2%	2.02	0.88%
Romania	45.373	20.9%	0.53	3.9%	45.901	19.92%
Russia	13.491	6.2%	1.04	7.6%	14.528	6.31%
Turkey	38.008	17.5%	5.86	43.0%	43.865	19.04%
Ukraine	42.83	19.8%	4.64	34.1%	47.468	20.60%
Total	216.75	100.0%	13.6	100.0%	230.374	100.00%

Source: Adapted from BSEP, 1997

The costs of environmental degradation have manifested themselves in many other sectors as well. Along with fisheries costs, the World Bank (2000) documents extensive tourism, agricultural and health costs that result from pollution in the Black Sea. The World Bank finds that a full investment programme to reduce nutrient loads

[8] Diffuse source is also known as non-point source.

entering the Black Sea would have at least a 1.23 ratio of benefits to costs, highlighting the net economic gain that can be achieved with pollution abatement in the Danube-Black Sea Region. This benefit-cost ratio is a conservative estimate and does not include benefits that are more difficult to quantify, such as those that accrue from wetlands restoration, reduced groundwater contamination and biodiversity conservation.

Central and Eastern European Political Economy and the Environment

In order to understand the reasons that the Danube and the Black Sea have become so polluted and to evaluate potential solutions, it is important to consider the political and economic circumstances in the countries of the region. These countries are very diverse, with important divisions between Western and post-communist countries playing a dominant role. Upstream in the Danube basin are Germany and Austria, Western European countries with democratic and market traditions, and high levels of economic development and prosperity. They are members of the EU and, with the exception of the former German Democratic Republic, they do not have communist and central planning legacies, as do most of the other countries of the region. While these countries can afford higher levels of environmental quality, they are also the most geographically removed from the downstream consequences of pollution in the Black Sea.

Communism and the Soviet system had varying degrees of influence on different countries in the Danube-Black Sea Region, but after the system's total collapse in 1989, virtually all countries in the region experienced shrinking economies and economic decline. Bulgaria exemplifies the hardship that was widespread in the region: its GDP shrank by 22.6 percent between 1990 and 1996 (Karadjova et al. 1999). Poland and Hungary saw their GDPs shrink by 18 percent between 1989 and 1994 (Bluffstone and Larson, 1997). While growth has returned to the region and most of the countries are on the road to economic recovery, the Central and Eastern European countries that form the majority of the Danube-Black Sea Region still lag far behind their Western counterparts in economic terms, and are working to develop democratic and market characteristics that have long been present in Western Europe.

There are also important differences among the Central and Eastern European countries that are part of the Danube-Black Sea Region. Many of those that are further upstream, such as Hungary, the Czech Republic and Slovenia, are faring relatively well in economic terms and are close to EU accession (Economist, 2001). Countries like Bosnia and Herzegovina, and the Former Yugoslav Republics (FYR) are experiencing significant economic and political difficulties resulting from war and political instability, and are not on the current EU enlargement agenda (although the possibility of eventual membership is a factor in these countries [Economist, 2001]). Finally, the downstream countries that are on the Black Sea are a long way from EU accession (Bulgaria, Romania and Turkey are at the end of the accession line) or are not on the enlargement agenda at all. Yet these countries are the most affected by Black Sea pollution, and have comparatively low levels of human and economic development.[9]

European Union Enlargement and the Danube-Black Sea Region

Of particular importance to the Danube-Black Sea pollution problem is the enlargement of the EU to include many countries of Central and Eastern Europe. While environmental issues were of great interest to the public (but not necessarily the governments) in these countries before the fall of communism (Klarer and Francis, 1997), these issues slipped down, and almost off, the political agenda as the difficulties of the economic transition were felt in the region (Waller, 1998). However, once communism fell, most of the governments of the region decided to take whatever steps were necessary to join the EU (Waller, 1998). This desire remains as one of the most (if not the most) significant drivers behind improving environmental policy in the region. As such, it will be a very important incentive affecting the environmental policy and nutrient polluting behaviour of many of the countries in the Danube-Black Sea Region.

There are currently thirteen countries that have asked to join the EU, many of which are from the Danube and Black Sea Region and have been interested in joining since communism collapsed in 1989. Ten countries, Cyprus, the Czech Republic, Estonia,

[9] For more information in human and economic development in the Danube-Black Sea countries, see Table 4.1 in Chapter Four.

Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia, are scheduled to join in the spring of 2004 (EU, 2003), adding 75 million people to the EU's 375 million (Economist 2001a). Three other countries, Turkey, Bulgaria and Romania have also applied for membership; however, they will not be admitted with the ten other countries because they lag behind in compliance with EU requirements in numerous areas. The EU is planning for Romania and Bulgaria to join in 2007, although no dates have been set for Turkey's accession (EU, 2003).

Environmental compliance will be a significant challenge for the applicant countries as they endeavour to join the EU. Of particular importance is the requirement that applicant countries adopt the *acquis communautaire* (all EU policy and legislation) (Klarer and Francis, 1997). This means that, in order to become a full member of the EU, applicant countries will have to comply with all EU law, including environmental legislation.[10] Environmental improvements are not one of the main motivations for the applicant countries to join the EU (Klarer and Francis, 1997); however, because they must adopt the entire *acquis*, these countries will have to improve their environmental policy if they want to become full EU members and enjoy all of the benefits associated with membership. While the EU and other international institutions provide financial assistance for environmental improvements, the governments and people of the applicant countries themselves will have to pay for most of the cleanup (Waller, 1998). The ten countries scheduled to join in 2004 have completed all negotiations with the EU related to the adoption of the *acquis*, and are in the process of implementing the EU's environmental (and other) policies (EU, n.d.).

European Union Water Policy

As part of adopting the *acquis,* applicant countries will also have to comply with EU water policy along with current members. Considering that 17 percent of the Danube Basin lies within the territory of current EU members, 57 percent within the candidate countries and 25 percent within non-applicant countries (CEC, 2001), EU water policy

[10] Kroiss (1999: 187) states that, "it is quite clear that an extension of the EU to the CEE countries will force them to accept EU legislation and its implementation by the national governments."

will have a significant impact on future efforts to abate pollution in the Danube-Black Sea System.

The Water Framework Directive (WFD) is the key document that outlines the EU approach to river basin and water resources management (see EU, 2000). Before the recent implementation of the new WFD in 2000, EU water policies were quite specific to issue areas (ECOTEC, 2001). The WFD takes an ecosystem approach, and defines the approach the EU is taking to managing the water resources of the Danube-Black Sea Basin.[11] The EU has stated that it will, "assist in the implementation of the guiding principles of the EC Water Framework Directive in the entire Danube Basin and the Black Sea coastal states, starting with the Candidate Countries" (CEC 2001:22).

According to a 2001 communication from the European Commission, the requirements of the EU WFD that apply to the Danube-Black Sea System include "water management based on river basins"[12] and "achieving good status for all waters by a certain deadline" (CEC 2001:19). These requirements will have important implications for the countries involved in the Danube-Black Sea pollution problem. A river basin approach to management highlights the importance of cooperation among the many countries of the Danube-Black Sea System, and provides for an integrated approach. In the case of river basins that extend beyond the EU, the WFD requires that member countries ensure compliance with WFD requirements within their territories, but it also requires that members work with non-members to achieve the WFD objectives throughout the entire basin (EU, 2000). River basin management plans will be the main tool used to implement the WFD (Grant et al., 2000). Taking a river basin approach will make it more difficult for those in the upstream area of the basin to ignore the downstream impacts of their polluting behaviour.

Achieving good status for all waters is another key requirement of the WFD that will have an important impact on members and candidates alike. The WFD states that countries will have 15 years from the entry into force of the directive to achieve good status (EU, 2000). The concept of defining good status has been be left to a scientific committee that will determine what "good" means considering chemical and ecological status (Grant et al., 2000). The overall condition of surface and groundwater will also be considered (Grant et al., 2000). The requirement of good status will drive upstream countries that are members or anticipate to accede in 2004 to abate pollution to achieve good water quality. This will, in turn, minimize the pollution that is flushed downstream.

Overall, the EU WFD takes an integrated approach to water policy (combining surface water, groundwater, estuaries and coastal areas together), and shifts away from the prescriptive, standard-setting legislation that it replaced (Grant et al., 2000). This shift acknowledges that previous water policy was burdensome, difficult to apply, and did not achieve its environmental objectives (Grant et al., 2000). This new approach should be more effective at addressing complex macro-scale aquatic pollution problems such as the Danube-Black Sea pollution problem. These issues are best resolved with an integrated strategy based on watersheds and ecosystems, instead of with prescriptive policy developed in a wide variety of sectors that results in a fragmented piecemeal approach. The WFD, with its river basin focus and requirements to cooperate with non-members, should also help foster international environmental cooperation in the basin and make it more difficult for upstream countries to disregard the downstream impacts of their pollution.

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[11] ICPDR (2001) states that the Water Framework Directive will harmonize water quality assessment on a European level.

[12] In their discussion of the Danube-Black Sea pollution problem, Somlyody et al. 1999: 15 point out that, "the development of a basin wide integrated strategy is of crucial importance."

Chapter Four: An Economic Formalization of the Unidirectional and Reciprocal Externalities

This chapter will provide a formal analysis of the Danube-Black Sea unidirectional and reciprocal externalities using a series of economic models. These models will identify the incentives that the countries face to pollute and abate by outlining the net benefit functions and equilibriums for the countries involved in each externality. The role that side payments from downstream to upstream countries can play will be the focus of this analysis. The unidirectional and reciprocal externalities will be considered separately in this chapter. This treatment then forms the foundation for the subsequent discussion in Chapter Five where the two externalities are considered together, and the results of the formal analysis are used to develop potential system wide outcomes.

The countries will first be divided into groups based on geography (in particular their position in the Danube-Black Sea Region), the countries' relationships with the EU, and their level of social and economic development. The first model will then be developed to analyze the unidirectional externality aspect of the Danube-Black Sea problem where cooperative and non-cooperative outcomes among groups are compared. Subsequently, the role of side payments will be analyzed formally in the context of the unidirectional externality. The Black Sea reciprocal externality will then be modeled, comparing once again the differences among cooperative and non-cooperative outcomes and briefly discussing the role of side payments among Black Sea countries.

Dasgupta (1982), Maler (1992) and Barrett (1990 and 1993) have modeled various aspects of international environmental problems, from both the unidirectional and reciprocal perspectives. These models focus on defining the economic nature of environmental problems that result from reciprocal and unidirectional externalities, using both theoretical problems and actual case studies, such as pollution in the Rhine River. These models also highlight the polluter-victim relationship that results from unidirectional externalities, and the collective action problem that characterizes reciprocal externalities, where all parties are affected by each other's behaviour. The models developed in this chapter build on the work of these authors.

Grouping the Countries of the Danube-Black Sea Pollution Problem

In order to analyze the interaction among the actors in the Danube-Black Sea pollution problem, all of the countries will be allocated to one of three distinct but interconnected groups:

Group 1 – The Upstream Danube Group

The key attribute of this group is its position at the upstream extremity of the Danube, where it discharges pollution that harms both other groups downstream, but where it is not victimized by any upstream pollution. It is composed of the wealthy EU member countries and middle-income EU accession candidates that have Danube Basin territories greater than 2000 square kilometres. The countries are Germany, Austria, Hungary, Slovenia, Slovakia and the Czech Republic. Excluding countries that have less than 2000 square kilometres of Danube Basin territory simplifies the analysis by eliminating those countries that play an insignificant role in the pollution problem.[13] As mentioned in Chapter Three, the 2000 square kilometre figure was chosen because only those countries that have Danube Basin territories greater than 2000 square kilometres plus the European Community have access as contracting parties to the Danube River

Protection Convention, (ICPDR, 2001), an important international convention in the region.

Austria and Germany are Western democracies that lie within the Danube Basin, but are far removed from the Black Sea and the consequences of pollution there. They are the wealthiest countries in the Danube-Black Sea Region, and have high levels of human development (see Table 4.1).[14] Hungary, Slovenia, Slovakia and the Czech Republic are middle-income countries with relatively high levels of human development. They have completed all requirements to join the EU, and will most likely become members in 2004. Considered in aggregate, the Group 1 countries have levels of human and economic development that are much higher than Groups 2 and 3. All countries in this group must comply with EU policy, including the Water Framework Directive (WFD) These countries have a combined population of 117.8 million, 36.7 million of whom live in the Danube River Basin (see Table 4.1). Thirty-nine percent of the land area of the Danube River Basin lies in these countries.

Group 2 – The Downstream Danube Group

While this group has no Black Sea coastline and is therefore not affected by pollution there, its midstream position on the Danube means that it is both a victim of pollution from Group 1 upstream as well as a polluter of the Black Sea downstream.[15] It is composed of Croatia, Moldova, the Former Yugoslav Republics (FYR), and Bosnia and Herzegovina, which are in a mid-stream position on the Danube. The members of this group are not currently on the agenda for EU enlargement and do not have to worry

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[13] Including countries with less than 2000 square kilometres of basin territory in the analysis would be problematic because there is less data available on the limited role that those countries play in the Danube-Black Sea pollution problem, and it would distort the characteristics of the groups to include countries that have no significant interest in the Danube pollution problem For example, including Italy in Group 1 would skew the HDI and GDP data for Group 1 significantly despite the fact that the Italy plays only a very minor role in the pollution problem.

[14] All human and economic development data in this section is from UNDP (2003).

[15] Note that because Moldova and Bosnia and Herzegovina are not actually on the Danube and are only in the Danube Basin, they will not be victims of pollution from Group 1 in the same way that the FYR and Croatia are. Because the analysis in this paper does not focus on the victim role for Group 2 countries, it is assumed for simplicity that all Group 2 countries face the same incentives and are victims of Group 1 pollution. Further research that focussed on polluter and victim roles of Group 2 countries in more detail should separate these two types of countries into distinct groups

Table 4.1. Economic, Human Development, Population and Geographic Data for Danube-Black Sea Countries and Groups

Country	GDP Per Capita (2000 USD PPP)[a]	HDI Ranking (2000)[a]	Total Population (Millions in 2000)[a]	Estimate of Population Living in Danube Basin (Millions in 1997)[b]	Percentage of Danube Basin in Country[c]
Group 1					
Austria	$26,765.00	15	8.1	7.7	10
Germany	$25,103.00	17	82.0	9.1	7
Czech Republic	$13,991.00	33	10.3	2.7	3
Hungary	$12,416.00	35	10.0	10.3	11
Slovak Republic	$11,243.00	36	5.4	5.2	6
Slovenia	$17,367.00	29	2.0	1.7	2
Average	$17,814.17	27.5			
Total			117.8	36.7	39
Group 2					
Croatia	$8,091.00	48	4.7	3.2	4
Bosnia-Herzegovina	n/a	n/a	3.2[b]	2.5	7
FYR	n/a	n/a	10.4[b]	9.1	9
Moldova	$2,109.00	105	4.3	1.1	1
Average	$5,100.00	76.5			
Total			22.6	15.9	21
Group 3					
Bulgaria	$5,710.00	62	7.9	4.4	6
Georgia	$2,664.00	81	5.3	n/a	n/a
Romania	$6,423.00	63	22.4	21.8	29
Russia	$8,377.00	60	145.5	n/a	n/a
Turkey	$6,974.00	85	66.7	n/a	n/a
Ukraine	$3,816.00	80	49.6	3.1	4
Average	$5,660.67	71.8			
Total			297.4	29.3	39

Source: a: UNDP (2003) b: ICPDR, 2001 c: CEC, 2001

about compliance with EU standards for the foreseeable future.[16] This group has substantially lower levels of economic and human development than Group 1, but is similar (although slightly lower) to Group 3 in this respect (see Table 4.1). Group 2 has a total population of 22.6 million people, 15.9 million of whom live in the Danube River

[16] There is, however, an interest among these countries to eventually join, and the EU is "encouraging them to think about membership" (Economist 2001: 14).

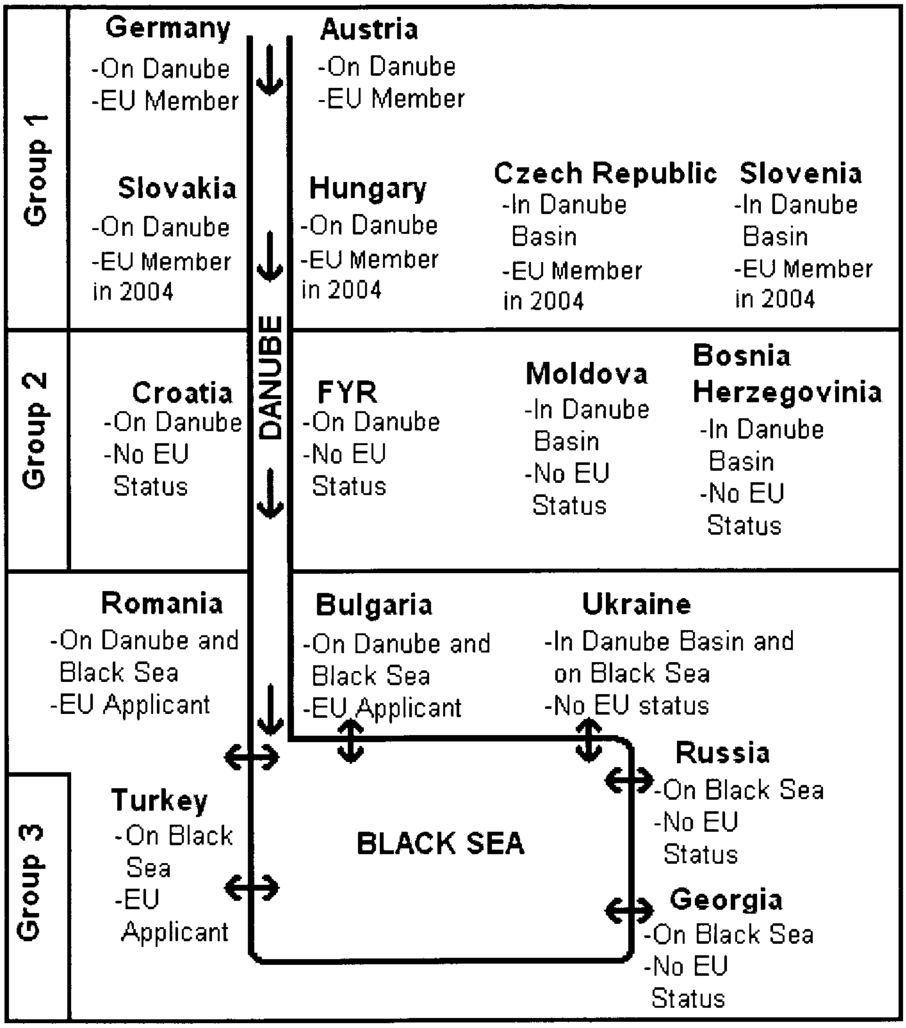
Basin. Twenty-one percent of the land area of the Danube River Basin lies in these countries.

Group 3 – The Black Sea Group

The members of this group, composed of Bulgaria, Romania, Turkey, Ukraine, Georgia and Russia, all share one very important attribute: they have Black Sea coastlines. They are downstream recipients of the nutrient pollution externality and, additionally, are affected by the environmental problems of the Black Sea. They are either last in line for EU accession, as is the case for Bulgaria, Romania and Turkey (Economist, 2001), or not part of the enlargement agenda at this time (as is the case with the other members of this group). Taken as a group, these countries have a lower level of economic and human development than the countries of Group 1, and similar (although slightly higher) human and economic development to Group 2 (see Table 4.1). This group has an aggregate population of 297.4 million people, 29.3 million of whom live in the Danube River Basin. Thirty-nine percent of the land area of the Danube River Basin lies within the Group 3 countries.

Figure 4.1 provides an illustration of the relationship among Danube-Black Sea countries and groups, outlining each country's EU status, group membership, and approximate geographic position, including whether or not that country is on the Danube or on tributaries. Note that the geographic positions are approximate, used to illustrate upstream-downstream relationships and to demonstrate which countries are directly on the Danube and which are not.

Figure 4.1. Danube-Black Sea Flow Chart



The Danube-Black Sea Unidirectional Externality

This first model analyzes the unidirectional externality aspect of the Danube-Black Sea pollution problem. In this section, the incentives facing the three groups are modeled in isolation, ignoring the effects of the EU, the Black Sea reciprocal externality and other factors that are addressed in subsequent sections. Discussion of the non-cooperative situation, which is the equilibrium outcome for this unidirectional externality, is followed by consideration of the full-cooperative outcome, which is an unstable point of reference (not an equilibrium). It is, however, an important point of reference because it is the optimal outcome. The role that side payments can play to improve on the non-cooperative outcome by moving the situation towards the optimal full-cooperative outcome is modeled from the perspective of upstream and downstream countries.

A key assumption for this model, and all subsequent models that analyze the pollution problem at the group level, is that individual countries within each group act independently but consistently because they are assumed to share identical interests. Because of their geographic position, relationship with EU, and their level of social and economic development, it is assumed that the countries in each group act as a coalition that faces identical economic incentives as a result of the Danube-Black Sea pollution problem.[17] Countries may, in fact, be very different in terms of the amount of basin territory they have and the amount they pollute, and in a variety of other ways as well. These factors will affect the magnitude of the incentives countries face in terms of costs and benefits, but not the underlying nature of these incentives. Because of this assumption, the unidirectional externality model analyzes the problem at the group level only.

Along with the above stated assumption of groups that face identical incentives and act cohesively, it is also assumed that:

- There are zero transaction costs both within and among groups;
- The issue of nutrient pollution is considered in isolation;
- Groups have perfect information about other groups' abatement/polluting behaviour and the costs/benefits that result from this behaviour;
- All countries and groups face identical increasing marginal costs of abatement, while marginal benefits of abatement are decreasing with abatement;[18]
- Marginal benefits of abatement in downstream groups are a decreasing function of abatement in upstream groups;

[17] Pham Do and Folmer (2003) use coalitions in a similar manner to the way groups are used in this analysis. In their game theoretic analysis, coalitions maximize aggregate benefits and interact with other coalitions and with countries that are playing as singletons.
[18] While typical, this may not always be the case. Maler (1992) points out that if a water body (or other environment) is sufficiently polluted, marginal benefits may be zero at lower levels of abatement. The example he uses is of a river that is sufficiently polluted to be an open sewer. A minor improvement in water quality will not bring fish back to the stream, or result in any aesthetic improvement.

- Groups treat upstream pollution/abatement as exogenous.

This last assumption allows us to sidestep the question of each group's ability to abate upstream pollution without any cooperation or side-payments (i.e. by using wetlands or technology that removes nutrients as they enter a given group's territory).[19] These assumptions will apply to all models in this chapter, unless stated otherwise.

Before cooperative and non-cooperative outcomes are formalized, a net benefits functions must be outlined for the three groups.

Let,

a_i = The absolute level of abatement in group i, where i = 1, 2 or 3;

$B_i(a_i, a_j)$ = Benefits of abatement that accrue to group i as a function of a_i and a_j, where i, j = 1, 2 or 3, and i > j;

$C_i(a_i)$ = Costs of abatement that accrue to group i as a function of a_i;

In the case of the unidirectional externality, net benefits of abatement that accrue to group i (NB_i) can be formalized as:

$$NB_i = B_i(a_{i,}, a_{j,}) - C_i(a_i) \qquad (1)$$

This equation demonstrates that group i's net benefits are affected by abatement in group i as well as abatement in any upstream groups.[20] Note that if (1) were solved with nutrient load data from the Danube, transport coefficients would have to be incorporated into a_i and a_j to reflect the rate at which nutrients are captured or dissipate into the environment as they travel away from their source (this applies to all abatement variables in this analysis).

The Non-Cooperative Equilibrium

The non-cooperative equilibrium for the unidirectional externality in the Danube-Black Sea System will occur when each group maximizes its own well-being considering the behaviour of the other groups. In this case, each group sets private marginal benefits equal to its private marginal costs, considering the abatement of any upstream group(s) and ignoring the benefits of its own abatement for any downstream groups. Abatement by upstream groups in treated as exogenous (depicted throughout this paper by a bar over the variable in question). The non-cooperative outcome for that any of the three groups can be formalized as follows:

$$\frac{dC_i(a_i*)}{d(a_i*)} = \frac{\partial B_i(a_i*,\overline{a_j})}{\partial(a_i*)} \qquad (2)$$

Where * is used to delineate the non-cooperative equilibrium.

The derivative on the left-hand side of (2) represents marginal costs of abatement in group i, and the partial derivative on the right-hand side of (2) represents the marginal benefits of abatement in group i, which are affected by exogenous upstream abatement that is held constant ($\overline{a_j}$). This shows that group i's equilibrium will be affected by abatement decisions upstream.

[19] Relaxing the assumption would be interesting because it would allow downstream groups to essentially abate upstream pollution in the absence of any cooperation or side payments; however, this aspect is not one of the focuses of this analysis.
[20] Note that j = 0 for Group 1.

The Full-Cooperative Outcome

The model of the unidirectional externality discussed above assumes that each group is acting in narrow self-interest, considering only its private benefits and costs without cooperating with other groups. We now relax this assumption to see what will happen if all groups consider the costs and benefits of all other groups, and abate to a level that is optimal for the entire system; this is the full-cooperative outcome. Because there is no incentive for upstream countries to cooperate, and no collective action problem in the instance of a unidirectional externality considered in isolation (i.e. in the absence of side payments or issue linkage, international norms and rules, and reciprocity among countries in other issue areas), the full-cooperative outcome is just a point of reference.

The full-cooperative outcome will occur when each group abates to the point where its marginal abatement costs are equal to the marginal benefits that accrue in the entire system (all groups) as a result of its abatement. This outcome can be formalized for group i by introducing k, which represents any group that may lie downstream from i (i.e. $j < i < k$):

$$\frac{dC_i(a_i\wedge)}{d(a_i\wedge)} = \frac{\partial Bi(a_i\wedge, a_j\wedge)}{\partial(a_i\wedge)} + \sum_k \frac{\partial B_k(a_i\wedge, a_j\wedge, a_k\wedge)}{\partial(a_i\wedge)} \qquad (3)$$

Where ^ delineates the full-cooperative outcome.

In this case, group i is not only considering the benefits of its abatement that accrue to itself (as it did under non-cooperation), but it is also considering the benefits of its abatement that accrue downstream in group k, subject to how these benefits are affected by abatement in groups j and k. When there is more than one group downstream (as is the case for Group 1), group i will consider the benefits of abatement in all groups k (signified by the summation term in (3).[21]

Side Payments and the Unidirectional Externality

The full-cooperative outcome discussed above is a point of reference and not an attainable equilibrium given the actual decision problem facing each country. In the latter sense, we are assuming that each country in each group is acting in self-interest considering only its private benefits and costs. Under this scenario, unidirectional externalities are not conducive to cooperation if they are considered in isolation because polluters cannot be made better off by cooperating with victims. Side payments, issue linkage mechanisms and other tools that allow the incentives or payoffs facing the polluters to be altered can create an incentive to abate to some point beyond the non-cooperative outcome.

Because the pollution problem is still being considered in isolation, we are assuming that the victim pays principle applies. We therefore assume that the original property rights regime is clearly defined, and that this regime allows the polluter the right to pollute. Following Maler (1992) we also assume that changes in property rights will not affect the parties' marginal cost or marginal benefit function. Working within these assumptions, downstream groups will have to pay upstream groups in order to obtain any abatement from these groups, as upstream groups will have no incentive to abate on their own.

Maler (1992) provides a formalization of the bargaining process between upstream and downstream countries involved in a unidirectional externality and potential equilibriums that result from this process. In the case of the Danube and Black Sea, downstream countries will maximize the net benefits they receive from incremental upstream abatement, and upstream countries will maximize the net benefits they receive from pollution abatement and side payments from downstream countries. A set of solutions will exist where the net benefits for each party are greater than or equal to zero.

[21] Note that the third term in (3) will be zero for Group 3.

Side payments will be discussed in more detail in Chapter Five in the context of the full system, and will therefore not be discussed any further here.

The Black Sea Reciprocal Externality

Now that side payments have been discussed in the context of the unidirectional externality, the effects of the Black Sea reciprocal externality on side payments can be considered. The discussion of the Danube-Black Sea pollution problem as a unidirectional externality in the previous section assumes that the countries in Group 3, and in the other two groups, act in a consistent manner. There is an important distinction, however, between the two upstream groups and Group 3. While the countries in Groups 1 and 2 are involved in a unidirectional externality with each other and Group 3, the countries in Group 3 are recipients of a unidirectional externality from both other groups, and are involved in a reciprocal externality with other countries in their own group.

Aggregating the interests of upstream countries into the two groups simplifies this analysis (by allowing us to deal with two groups instead of ten countries), without losing much of the contextual richness. This is clearly not the case for Group 3 countries. The Black Sea reciprocal externality instead requires us to conduct an analysis at the country level.[22] The Black Sea reciprocal externality is modeled in isolation below, comparing cooperative and non-cooperative outcomes and ignoring the effects of the unidirectional externality, the EU and other factors that are discussed in subsequent sections.[23]

The Nash Equilibrium

The non-cooperative outcome for the reciprocal externality in the Black Sea will occur when each country maximizes its own well-being considering the behaviour of other groups. This is the Nash equilibrium in the Black Sea.

Let,

Let a_n = The level of abatement in country n, where n = Turkey, Romania, Bulgaria, Russia, Ukraine or Georgia;

$B_n(a_n)$ = Benefits of abatement that accrue to country n as a function of a_n;

$B_n(\sum_{n=1}^{m} a_n)$ = Benefits of abatement that accrue to country n as a function of abatement in all Group 3 countries, where there are m = 6 Group 3 countries;

$C_n(a_n)$ = Costs of abatement that accrue to country n as a function of a_n;

The net benefits that will accrue to Black Sea country n (NBn) will be the benefits from abatement by all Black Sea countries (including country n) that accrue to country n, minus the costs of abatement in country n. The abatement decision of country n will therefore be affected by the abatement decisions of all other Black Sea countries. Net benefits for country n can be formalized as:

$$NB_n = B_n(\sum_{n=1}^{m} a_n) - C_n(a_n) \qquad (4)$$

The non-cooperative equilibrium for country n occurs when it considers only the benefits of abatement that occur within its own borders. In this case, country n sets its own marginal costs of abatement equal to its own marginal benefits of abatement, after considering how these benefits will be affected by the abatement behaviour of all

[22] Because there is no change in relationship, the relationships among the countries in Groups 1 and 2 will not be analyzed below the group level.
[23] The modelling in this section builds on previous modelling of reciprocal externalities by Dasgupta (1982), Maler (1992), Barrett (1990 and 1993), and Hanley et al. (2001).

countries on the Black Sea.[24] Hence a_n* will depend on $\sum_{n=1}^{m} a_n$. When all countries act in their own self-interest and maximize their well-being subject to the behaviour of all other countries, the non-cooperative Nash equilibrium occurs in the Black Sea:

$$\frac{dC_n(a_n*)}{da_n*} = \frac{\partial B_n(\sum_{n=1}^{m} a_n*)}{\partial \sum_{n=1}^{m} a_n*} \times \frac{\partial \sum_{n=1}^{m} a_n*}{\partial a_n*} \quad (5)$$

The derivative on the left-hand side of (5) represents the marginal costs of abatement in country n. The first derivative on the right-hand side of (5) represents the change in benefits of abatement that accrue to country n from changing abatement in the entire Black Sea. The last derivative represents the change in the level of abatement in the entire Black Sea that results from changes in abatement in country n. By multiplying the two terms on the right-hand side together, we can determine the change in benefits that accrue to country n from a change in abatement in country n, considering the polluting behaviour of all other Black Sea countries.

The Full-Cooperative Outcome

Under full-cooperation, the Black Sea countries will maximize their collective well-being and set a level of pollution that is optimal for all Black Sea countries collectively. This will occur when country n abates to the point where its marginal abatement costs are equal to the marginal benefits that accrue in all Black Sea countries as a result of abatement in country n. When all countries behave in this manner, the full-cooperative outcome for the Black Sea occurs:

[24] When every other country is emitting its Nash equilibrium level of pollution, then it is optimal for the remaining country to emit to its own Nash equilibrium level as well (Maler, 1989).

$$\frac{dC_n(a_n\wedge)}{da_n\wedge} = \frac{\partial \sum_{n=1}^{m} B_n(\sum_{n=1}^{m} a_n\wedge)}{\partial \sum_{n=1}^{m} a_n\wedge} \times \frac{\partial(\sum_{n=1}^{m} a_n\wedge)}{\partial a_n\wedge} \qquad (6)$$

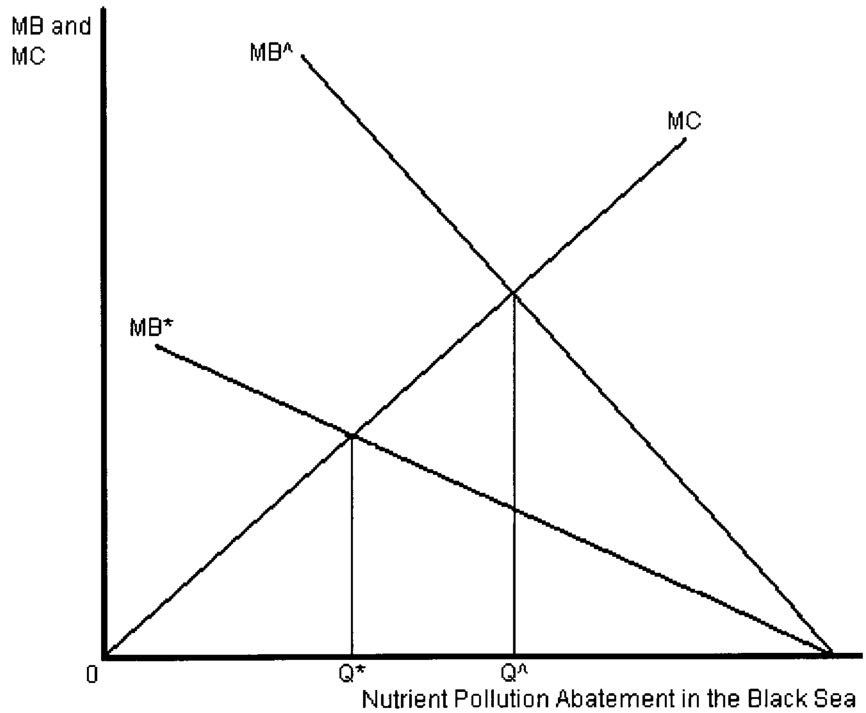
In this case, country n considers the damages from its emissions that occur within all Black Sea countries, not just within its own borders.[25] Because of the reciprocal nature of the problem, country n's abatement decision will again be affected by all other countries' abatement decisions; however, because this is a cooperative solution, all countries will negotiate with each other to determine the share of abatement to be assigned to each country in order to achieve a collectively optimal level of abatement for the Black Sea. The full-cooperative outcome implies that all Black Sea countries cooperate to set a collectively rational level of abatement; however, it does not mean that all countries will have the same level of abatement. Nor does it imply that all countries will receive net benefits greater than zero. For example, Black Sea countries may collectively choose to abate a greater amount of pollution in countries where abatement is cheap. Cooperative game theory and other similar tools could be used to analyze the negotiations among Black Sea countries to assign abatement responsibilities after these countries have agreed on a collectively optimal solution.

The relationship between the Nash equilibrium and the full-cooperative outcome can be illustrated graphically (Figure 4.2). MB* represents the marginal benefits available to any Group 3 country n, MB^ represents the marginal benefits of abatement aggregated over all Black Sea countries, and MC represents the marginal costs of pollution abatement in country n, assumed equal for all countries. If country n chooses non-cooperation, it will abate to the point where MB* meets MC, resulting in the Q* level of abatement. The country is simply setting its own marginal costs equal to its own marginal benefits of abatement. All Black Sea countries behaving in this way results in the Nash equilibrium. If country n chooses full-cooperation, it will abate to the point where MB* is equal to MC, resulting in the Q^ (higher) level of abatement. In this case,

[25] This is because the first term on the right-hand side of the (6) represents the change in benefits of abatement that accrue to all Group 3 countries (instead of just country n) from changing abatement in the entire Black Sea.

the country is setting its own marginal costs equal to the marginal benefits from its abatement in all Black Sea countries. All Black Sea countries behaving in this way results in the full-cooperative outcome, and higher net benefits of abatement.

Figure 4.2. The Nash Equilibrium and Full-Cooperation in the Black Sea



Source: Adapted from Barrett (1997), Folmer et al. (1998) and Hanley et al. (2001).

Side Payments and the Reciprocal Externality

In the discussion of the full-cooperative outcome in the Black Sea, it was stated that Group 3 countries would negotiate with each other to determine the share of abatement in each country. In this negotiation, side payments and other similar tools may be required to assure the cooperation of all Black Sea countries. This will not be necessary if solutions exist where all countries are better off under full-cooperation than they were under the Nash equilibrium and are hence 'winners' from cooperation. If there are losers from cooperation (i.e. countries that must incur negative net benefits as a result of cooperation), side payments from winners to losers will be required.

These side payments may be transfers of money where losers are bribed to cooperate or compensated for the losses they incur from cooperation. They can also take place in the form of arrangements where winners agree to pay for abatement by losers to achieve the full-cooperative outcome, and other similar schemes. In either case, the result is the same. Additionally, while this discussion uses the full-cooperative outcome as a point of reference and examines side payments in this context, side payments may also be required to reach agreements for collective abatement levels that lie between the Nash level and the full-cooperative level.[26] This paper focuses on the role of side payments within the full system that considers groupings of Black Sea countries and upstream countries on the Danube. As a result, side payments among Black Sea countries will not be discussed any further.

[26] Maler (1989) uses cooperative game theory to provide a formalization of a reciprocal externality, and finds that international transfers are required in all simulations to induce all countries to reduce emissions to the full-cooperative level.

Chapter Five: Interaction Between the Unidirectional and Reciprocal Externalities

Until now, the unidirectional externality in the Danube and the reciprocal externality in the Black Sea have been discussed separately, ignoring the linkages between the two and between the upstream countries in Groups 1 and 2 and the downstream countries in Group 3. This chapter will build on Chapter Four and consider the linkages between the two types of externalities, focussing on the role of side payments and the joint effects of the two types of externalities on the prospects for cooperation. This discussion will take place in the context of potential system-wide outcomes.

The first section will build on the modelling from Chapter Four and use the results to outline four potential system-wide outcomes that can occur when the unidirectional and reciprocal externalities are considered together. These will serve as points of reference against which cooperation in the system can be gauged, and they will provide the foundation for the second section, which will consider the role of side payments and the prospects for cooperation in the Black Sea. This discussion will focus on side payments; however, downstream countries could use issue linkage and other comparable mechanisms in a similar manner (see Chapter Three).

Potential System-Wide Outcomes

The results of the formal analysis in Chapter Four provide a series of potential system-wide outcomes that will be summarized here. There are an infinite number of possible levels of abatement;[27] however, these outcomes will serve as useful points of reference in future discussions of side payments and cooperation. These outcomes are:[28]

1. Full-cooperation among all three groups and full-cooperation among all Black Sea countries.
2. Full-cooperation among all three groups and non-cooperation (the Nash equilibrium) among the Black Sea countries.
3. Full-cooperation among Black Sea countries but non-cooperation at the group level.
4. Non-cooperation at the group level and non-cooperation (the Nash equilibrium) among all Black Sea countries.

The first possibility occurs when all three groups and all Black Sea countries abate to the full-cooperative level. Upstream groups will consider the impacts of their abatement downstream, and each Black Sea country will consider the effects of its abatement on all other Black Sea countries. This outcome is defined at the group level in terms of the Danube unidirectional externality by equation 3 and in the Black Sea by equation 6. Side payments from Black Sea to Danube states and from lower Danube to upper Danube states will be a prerequisite for this outcome.

The second possibility occurs when there is full-cooperation among the three groups, but no cooperation among the countries in the Black Sea. In this case, Black Sea countries can agree on the need to increase abatement levels in the two upstream groups, and cooperate to make side payments in order to achieve upstream abatement, but they

[27] Note that these outcomes are not necessarily equilibriums and many will not occur without side payments or other similar measures.
[28] The outcomes discussed do not focus on the dynamics of cooperation at the group level in terms of addressing the possibility that two groups may choose to cooperate while another chooses non-cooperation. Interesting discussions on this topic could certainly take place, but are not a focal point of this research.

cannot cooperate among themselves (resulting in the Nash equilibrium). This outcome is defined at the group level in terms of the Danube unidirectional externality by equation 3, and in the Black Sea by equation 5. As was the case with the first outcome, side payments from Black Sea to Danube will be a necessary prerequisite for this outcome.

The third possibility occurs where there is full-cooperation among the Black Sea countries but no cooperation among the groups. In this case, all the countries in each group maximize their own well-being, while the Black Sea countries maximize their collective well-being. This outcome is defined at the group level in terms of the Danube unidirectional externality by equation 2, and in the Black Sea by equation 6.

The final possibility occurs where there is no cooperation in the entire system. In this case, each of Groups 1, 2 and 3 and each individual country in the Black Sea will abate to the level where its own marginal costs of abatement are equal to its own marginal benefits of abatement. There is no cooperation among countries in Group 3, and no cooperation among groups. This outcome is defined at the group level in terms of the Danube unidirectional externality by equation 2, and in the Black Sea by equation 5.

Cooperation and Side Payments

When side payments were discussed in the context of the unidirectional externality in Chapter Four, it was concluded that Group 2 countries could use side payments to obtain abatement in Group 1, and that this upstream abatement would not occur in the absence of these side payments. Working within the same set of assumptions discussed in Chapter Four, the same conclusion applies to Group 3 countries. These countries can also make side payments to countries in the two upstream groups, and these payments will be a prerequisite to any abatement over and above the non-cooperative level in these two groups. There are, however, other factors that will affect side payments as well as the prospects for cooperation in the Black Sea. These factors result from the fact that Group 3 countries are involved in a reciprocal as well as a unidirectional externality. This section will discuss these factors in the context of the interaction between the unidirectional and reciprocal externalities, referring back to the system-wide outcomes described above and clarifying how these outcomes, and others that lie between these points of reference, might occur.

The Effect of Black Sea Cooperation on Side Payments

The level of cooperation in the Group 3 countries will have an important effect on the size of side payments that the Black Sea countries in Group 3 would be prepared to make to upstream countries, as well as the incentive they will face to make payments. It is well known that full-cooperation results in greater aggregate benefits than the Nash equilibrium,[29] a conclusion that applies equally to the Black Sea. When Black Sea countries cooperate to optimally manage the Black Sea environment, they receive greater net benefits. These greater net benefits provide these countries with more resources to make larger side payments.[30]

Another important factor that will affect side payments will be the level of cooperation among Black Sea countries in managing marine resources. The Black Sea fishery provides an ideal example. Failure to cooperatively manage the fishery could result in the dissipation of the fishery-related benefits of nutrient pollution reduction, whereby non-cooperation leads to over-fishing and stock depletion. Knowler (1999) compares the fishery-related benefits of nutrient pollution abatement under open access and optimal management regimes, and finds that optimal management affords significantly greater benefits to Black Sea countries. Optimal management increases the benefits that accrue to Black Sea countries per unit of upstream pollution abatement, benefits that would otherwise be dissipated under open access. This provides an incentive for Black Sea countries to increase side payments for upstream abatement.

The effects of Black Sea cooperation on side payments can be conceptualized in terms of the four potential outcomes discussed earlier in this chapter. The incentive for side payments is greater when Black Sea countries cooperate, therefore side payments are more likely to occur when Black Sea countries cooperate (the first outcome is more likely than the second). Additionally, the size of side payments when the first outcome occurs will likely be larger than side payments when the second outcome occurs. Although the outcomes initially outlined in the beginning of this chapter are four among an infinite number of possibilities, this effect remains the same for other possibilities. The incentive for Black Sea countries to make side payments to upstream groups increases as the situation moves from the Nash equilibrium in the Black Sea to the full-cooperative outcome.

The Effects of the Unidirectional Externality on Black Sea Cooperation

The unidirectional externality that results from the downstream flow of pollution in the Danube will have important effects on Group 3 countries. The level of side payments to upstream groups will affect the level of upstream abatement, which will in turn affect the level of pollution entering the Black Sea. There are, therefore, several possible levels of pollution that may enter the Black Sea from the Danube. These levels of pollution depend on the size of side payments, which may range from amounts that result in the non-cooperative level of abatement (no side payments) to amounts that result in the full-cooperative level. These different levels of side payments and upstream abatement will have important effects on the incentive that Black Sea countries face to cooperate among themselves.

The effect that greater side payments and upstream abatement have on the incentive for Black Sea countries to cooperate is demonstrated in Figure 5.1. Different levels of upstream abatement will result in different levels of downstream benefits in the Black Sea for both full-cooperation and the Nash equilibrium in the Black Sea. Figure 5.1 displays different levels of the MB* and MB^ curves that describe the different marginal benefits available for any Black Sea country (MB*) and all Black Sea countries aggregated (MB^) (see Figure 4.2). Like Figure 4.2, it is from the perspective of any given Black Sea country, and the MC curve represents the marginal costs of abatement for that country.

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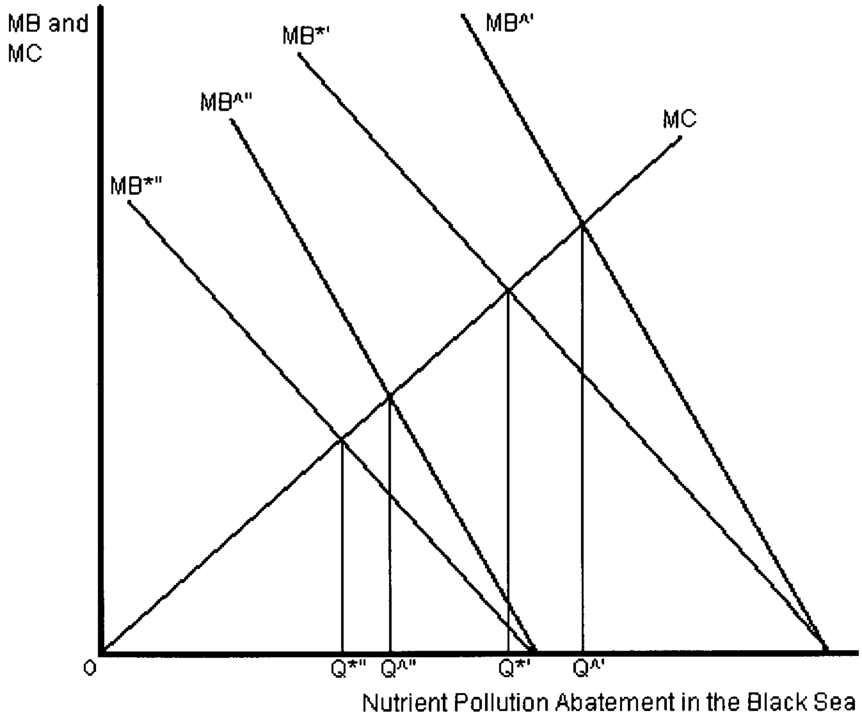
[29] See Barrett (1990), Folmer et al. (1998) and Hanley et al. (2001).
[30] The benefits of cooperation can also be conceptualized as relaxing the resource constraint on side payments that is discussed in the last section of this chapter.

Figure 5.1. Effect of Upstream Abatement on the Black Sea Countries



MB*' and MB^' describe the initial position of the two Black Sea marginal benefit curves (the Nash equilibrium and the full-cooperative outcome respectively) before side payments from Black Sea countries to Groups 1 and 2 are used to move the situation in the Danube-Black Sea System towards the full-cooperative outcome. The equilibrium where MB*' meets the MC curve resulting in the Q*' level of abatement is represented by the fourth potential outcome discussed above, and the equilibrium where the MB^' curve meets the MC curve resulting in the Q^' level of abatement is represented by the third potential outcome. As Black Sea countries make side payments to the two upstream groups, MB*' and MB^' shift down and to the left, resulting in MB*'' and MB^''. In terms of outcomes, this shift can be conceptualized as a move towards the second outcome for MB*'' and a move towards the first outcome for MB^'', both of which are characterized by the full-cooperative outcome at the group level. This shift will occur because upstream abatement is improving water quality in the Black Sea, which in turn is reducing the benefits for every unit of abatement undertaken in the Black Sea. As Black Sea countries make side payments to upstream groups, both the Nash and full-cooperative marginal benefit functions are being shifted down and to the left. This process will eventually result in an equilibrium level of side payments being attained, beyond which there will be no incentive for Black Sea countries to make further side payments. This equilibrium will occur where the marginal benefit of making side payments in terms of decreased pollution in upstream countries is equal to the marginal cost of making those side payments. Because this equilibrium is not a central part of this analysis, it is not discussed any further in this paper.

Increasing side payments from Black Sea countries to upstream groups will decrease the incentive for Black Sea countries to cooperate among themselves. Two effects that lower the incentive to cooperate are discussed in detail below. The first is that increasing side payments to upstream countries results in a lower incentive to cooperate because fewer marginal benefits are at stake. In this case, Black Sea countries are substituting upstream abatement for downstream cooperation. The second reason is that side payments will cause the MB^ curve to pivot closer to the MB* curve as these two curves shift down and to the left. Both these effects are the result of the shrinking distance between Q* and Q^, or the smaller benefits that are available when moving from the Nash equilibrium to full-cooperation. When there are fewer benefits available, there is less of an incentive for the Black Sea countries to cooperate.

As we have seen above, increasing side payments and the associated increasing upstream abatement will result in improving Black Sea water quality and decreasing marginal benefits from abatement by Black Sea countries in both the Nash and full-cooperative situations. As water quality improves in the Black Sea and the marginal benefits from their own abatement decrease, there are fewer marginal (and total) benefits associated with moving from the Nash equilibrium towards full cooperation (although the full-cooperative level will still yield higher benefits, as is demonstrated in Figure 5.1). This is the first way that side payment will decrease the incentive for Black Sea cooperation, and it results entirely from the downward movement of the MB* and MB^ curves in Figure 5.1. As these curves shift and marginal benefits decrease, Black Sea countries have less to gain from cooperation and will therefore be more interested in addressing other issues. Although there still will be difference between the Nash and full-cooperative outcomes, the nutrient pollution essentially is less of a priority and Black Sea countries can side step cooperation among themselves because there is less at stake. If marginal benefits of abatement are lowered enough, it is even possible that Black Sea countries will abate to a level below the Nash equilibrium. In this case these countries essentially ignore the nutrient pollution issue altogether in terms of the need for abatement in Black Sea countries (see Folmer et al. (1998) for a discussion of the possibility of abatement levels below the Nash equilibrium). It is important to add that this effect will be even more pronounced if transaction costs are considered. This is because countries will be less willing to incur these costs when they are rewarded with lower benefits of abatement.

Along with the first effect described above, there is a second way that upstream abatement may result in a lower incentive for Black Sea countries to cooperate among themselves. It is possible that the MB^ curve in Figures 4.2 and 5.1 will move closer to the MB* curve as the two curves shift downward and to the left. The first effect resulted entirely from the curves shifting down and to the left, and not from convergence. This second effect would result from the difference between the marginal benefits that are available at the Nash equilibrium and the full-cooperative outcome shrinking as upstream countries abate and water quality is improved. Taken to the extreme, this effect could result in no difference existing between the Nash equilibrium and full-cooperative outcome at high levels of side payments and upstream abatement (MB^ would merge into MB* as the two curves shifted down and to the left).

The extent to which the effect will actually occur will depend on the physical attributes of the nutrient pollution that enters the Black Sea and the ecological characteristics of the sea itself. While precise empirical determinations on this subject are beyond the scope of the paper, the two curves will at least converge to some extent. As water quality in the Black Sea improves, the behaviour of one country will have less of an impact on the other countries. This is because better water quality and lower nutrient loads mean that it is more likely that nutrients emitted from individual Black Sea countries will dissipate or be absorbed before they can cross international boundaries (see Turner at al. (1999) and Gren and Folmer (2001) for discussions of similar effects in the Baltic Sea). Essentially, improving water quality will mean that nutrient pollution in the

Black Sea will become more of a domestic and less of an international or system-wide problem. Hence the linkages between pollution in one country and marginal benefits in another become less strong and there is a lower incentive to cooperate as the difference between the Nash equilibrium and the full-cooperative outcome narrows. The overall effect of this process is to lessen the incentive for cooperation in the Black Sea.

Chapter Six: Institutional Considerations

In previous chapters, the Danube-Black Sea pollution problem was modeled in order to uncover the economic incentives to abate/pollute that countries face, and determine how these incentives affect the role for side payments and the prospects for cooperation. These models provided several useful insights. They showed that Black Sea countries could make side payments to their upstream counterparts to abate pollution and in order to move the level of upstream abatement from the non-cooperative to the full-cooperative level. They also showed that when Black Sea countries cooperate to address the reciprocal externality they face, they have a greater incentive to make side payments. However, the above models also demonstrated that upstream abatement, for which side payments are a prerequisite above the non-cooperative level, decreases the incentive for Black Sea countries to cooperate among themselves.

This chapter will expand on the previous chapter's economic model and broaden the scope of analysis in order to investigate the impacts of certain key institutional factors on the role of side payments and the prospects for cooperation. The first section will show that side payments from Black Sea to upstream countries are very unlikely, if not virtually impossible. This will be accomplished by examining important institutional factors and constraints on side payments. Although side payments are unlikely, analysing and modeling the Danube-Black Sea pollution problem focussing on the role of side payments still provides a useful framework from which to draw lessons for policy making in downstream and upstream countries. The second section will discuss some of these lessons.

Why Side Payments are Unlikely

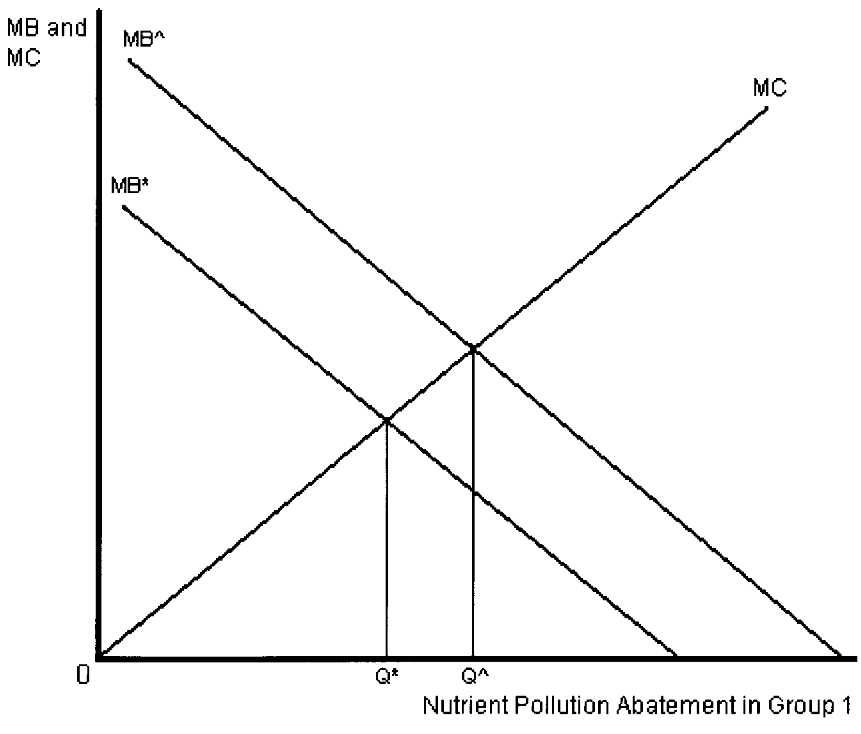
This section will address three important factors that will affect the role of side payments that have not been considered in the models above. These are the effect of the EU, institutional constraints on side payments that result from the interdependence of the countries in the Danube-Black Sea Region, and the role of wealth disparities among downstream and upstream countries.

The Effect of the European Union

EU water policy, which applies to members and soon-to-be members in Group 1, will constrain the polluting behaviour of many Danube countries by requiring them to work towards good water quality in the entire Danube-Black Sea System. These countries will have to implement the new EU Water Framework Directive (WFD), which essentially limits the amount of pollution these countries can emit into the Danube-Black Sea System (see Chapter Three). This constraint that the EU is placing on the polluting behaviour of Group 1 countries will affect the willingness of the downstream countries in Groups 2 and 3 to make side payments to Group 1 countries to increase abatement by Group 1. Downstream countries will only be willing to pay Group 1 countries for abatement that is over-and-above what is required by the EU, whereas the earlier model for side payments used the non-cooperative outcome as the reference point to measure this incentive. Depending on the magnitude of the EU constraint, it is also possible that they will not be willing to pay Group 1 countries to abate at all.

Figure 6.1 below displays possible effects of the EU constraint on pollution (or requirement for abatement), from the perspective of Group 1. The MC curve represents the marginal costs of abatement for Group 1, the MB* curve represents Group 1's marginal benefits of abatement, and the MB^ curve represents the marginal benefits of Group 1 abatement that accrue to all three groups. The point where the MC curve meets the MB* curve is the non-cooperative equilibrium for Group 1 (which results in the Q* level of abatement), and the point where the MC curve meets the MB^ curve is the full-cooperative outcome (which results in the Q^ level of abatement). Although there are an infinite number of possible levels of abatement that the EU could require in Group 1, all of these can be allocated to three different areas in Figure 6.1. In the first case, the EU requires an abatement level in Group 1 that falls between the origin and Q*. In this case, the EU requirement will have no effect on downstream countries as Group 1 countries will abate to the Q* level regardless of what the EU requires. In the second case, the requirement falls between Q* and Q^. In this case, downstream countries will only be willing to pay for abatement that is over and above what is required by the EU, up to a maximum of Q^ minus the level of abatement required by the EU.[31] In the third case, the EU requirement falls to the right of Q^. In this case, it is above the full-cooperative level

Figure 6.1. The European Union Constraint on Pollution in Group 1 Countries



of abatement for Group 1 and Group 2 and 3 countries will not be willing to make any side payments in this case. The overall effect of the EU is to even out the geographic inequity among up and downstream groups involved in the unidirectional externality and

[31] Considering that water quality in the Danube-Black Sea System is far from good (see Chapter Three), it

lessen or eliminate the need for side payments, as long as the EU requirement for abatement is higher than the non-cooperative level of abatement for Group 1.

Institutional Constraints

There are other institutional factors that will affect the incentives for side payments, aside from the role of the EU discussed above. One of the most important reasons that side payments are improbable is the unlikelihood of a victim pays regime being acceptable in the Danube-Black Sea System. Maler (1992) points out that victim pays outcomes, while supported by theory for unidirectional externalities, are hard to find in practice. It would be difficult to imagine impoverished Bulgaria paying wealthy Germany to abate its Danube pollution. This might be difficult to justify domestically to the German public, which may in fact have a willingness to pay for improvements in environmental quality in downstream countries. It would also be difficult to justify internationally to other countries and institutions. Such behaviour would run contrary to the polluter pays principle adopted by numerous international institutions such as the OECD (Maler, 1992), as well as two international institutions that have been established to facilitate pollution abatement efforts in the region.[32]

Such behaviour would also be unlikely because of the importance of reputations and reciprocity in international relations. Game theoretic analyses have shown that repeated interaction, or the knowledge that the game will be played again (also known as repeated games), increases the odds of cooperation and decreases the odds of malicious behaviour,[33] a result that makes intuitive sense. If countries know they will have future dealings with each other, they anticipate that good behaviour will be rewarded, and that maliciousness will be punished or will result in retaliation. International relations is not a one-shot game, particularly in the Danube-Black Sea Region where there is a great deal of interdependence among countries in many sectors. Reciprocity and countries' reputations will become even more important with increasing integration in the region,

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is very likely that the EU requirement for abatement will be above Q*.

[32] The polluter pays principle is enshrined in both the Strategic Action Plan for the Danube River Basin and the Strategic Action Plan for the Rehabilitation and Protection of the Black Sea (SAP-BS, 1996 and UNDP/GEF, 1999).

[33] See Axlerod (1984) and Oye (1986).

which is taking place at the behest of the EU, making it even more difficult for upstream countries to ignore the concerns of their downstream counterparts.

Another aspect of independence in the region lessens the likelihood of side payments. On an individual basis, many of the countries involved in the Danube-Black Sea pollution problem play both the role of upstream and downstream country, making many polluters victims of upstream pollution (on a group level this applies to Group 2). These countries may not be concerned with the impacts of their pollution on downstream countries, but their concern with the impact of pollution that they are receiving from upstream countries will likely affect their behaviour with regard to downstream countries. Hungary is a very good example of such a country. Although it is positioned closer to the upstream end of the Danube and is responsible for approximately 10 percent of all nutrients that enter that river (which puts it in the middle of Danube countries in terms of pollution levels), Hungary still receives pollution from many other upstream countries. This is of particular importance considering that 96 per cent of its water comes from catchment areas outside its borders in upstream countries (Vigh and Szilvassy, 2002). Hungary is interested in improving international cooperation within the Danube because it is in its own self-interest to do so.[34] Allowing a de facto victim pays principle to define international environmental relations in the Danube would not sit well with a country that gets 96 percent of its water from upstream countries.

The models in previous chapters have characterized the pollution that flows downstream in the Danube as a unidirectional externality, where the net benefits of abatement for downstream groups depends on the behaviour of upstream groups. While this model captures the cascading effect of the externality on net benefit functions, it does not address the effect that any given country's relationship with its downstream neighbours will have on relationships with its upstream neighbours. For example, if Hungary were to indiscriminately pollute the Danube without consideration of downstream countries, it would have difficulty complaining when upstream countries did the same. At a group level, the same would apply to Group 2. Disregarding downstream countries would, in fact, probably have a negative effect on Hungary's net benefits that are dependent on the behaviour of its upstream neighbours. This demonstrates the rationale to establish norms, rules and other institutions, such as the polluter pays principle, that regulate and mitigate the behaviour of countries. In the case of the Danube-Black Sea pollution problem, these norms and rules serve to weaken the imbalance created by geography and the unidirectional externality, or limit the need for side payments.

The Role of Wealth Disparities

Thus far we have seen that in the absence of the polluter pays principle, downstream countries will have to make side payments to their upstream counterparts to increase abatement upstream because of the unidirectional externality, but also that the EU and other institutional factors might either lessen or eliminate the need for these payments. Assuming there is still a need for side payments to bring about the full-cooperative level of pollution, there is another factor that must be considered. Resource constraints in downstream countries will limit the ability of the Group 3 countries to make side payments. An examination of Table 4.1 reveals the significant differences in GDP per capita and United Nations' Human Development Index (HDI) ranking between the countries in Groups 2 and 3 and those in Group 1. It is clear that the downstream countries are much poorer and have a significantly lower level of human development than their upstream counterparts. This difference means that there is likely a restriction on the ability of downstream groups to make side payments to upstream countries because of a lack of resources.[35] This restriction can be formalized as follows:

Let,

S = the level of side payments actually made by downstream countries

$\bar{S}$ = the upper limit to side payments resulting from the resource constraint

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[34] In a June 2003 interview in Budapest, Péter Kovács, a department head with the Hungarian Ministry of Environment and Water, pointed out that it is in Hungary's best interest to improve international relations in the water field because of Hungary's dependence on water that flows in from abroad.

[35] Frisvold and Caswell (2000) point out that downstream countries that are substantially poorer than their upstream counterparts may be unable to offer side payments for upstream countries to abate pollution.

Several levels of side payments are possible in light of $\bar{S}$. Any amount between zero, where there are no side payments, and $\bar{S}$, which is the upper limit, can be used to move the situation towards the optimal level of pollution. Hence, the constraint associated with side payments 'S' can be formally defined as follows:

$$0 \leq S \leq \bar{S} \qquad (7)$$

The equation above essentially states that side payments can be equal to or lesser than the resource constraint in downstream countries. These side payments, by definition, cannot be negative. It is important to note, however, that one of the potential values of $\bar{S}$ is zero. This would mean that, because of a severe constraint on resources, there is no opportunity for side payments.

An examination of how Group 2 and 3 countries fare in terms of human and economic development in the region, as well as globally, can provide some insight into their ability to make side payments.[36] Analysis of Table 4.1 reveals that the Group 1 countries have an average per capita GDP level that is over three times greater than their downstream counterparts in either Group 2 or 3, and their average HDI ranking is approximately 50 places higher than the averages of their neighbours downstream. The absolute differences in GDP are also striking; Germany's GDP is over 1000 times greater than Moldova's (ICPDR, 1999). With average GDP per capita levels of approximately 5000 USD, and average HDI levels in the 70s out of 173 (UNDP, 2002),[37] Group 2 and 3 countries are not only among the most underdeveloped in the region, but they are also relatively underdeveloped on a global scale. Considering these low levels of wealth and human development gap, it would be reasonable to assume that $\bar{S}$ is in fact zero,

[36] The regional comparison will be particularly important because Group 2 and 3 countries are more likely to look to their neighbours when measuring their development progress and expectation than to distant countries in regions such as Sub-Saharan Africa.
[37] Countries with HDIs in the 70's include Suriname, Fiji, Thailand and the Philippines (UNDP, 2002).

meaning that downstream countries would be unable to deliver any side payments to their upstream counterparts.

Lessons for Downstream and Upstream Countries

As was discussed in Chapters 4 and 5, side payments could be used in the context of the unidirectional externality by downstream countries to convince their upstream counterparts to abate pollution and move the situation from non-cooperation closer to the full-cooperative outcome. The factors discussed above in this chapter indicate that side payments will actually be unlikely in the case of the Danube-Black Sea pollution problem. However, the formal analysis and discussion of the role of side payments offered in this and previous chapters still provides some useful insights for Danube-Black Sea countries. Firstly, they illustrate that the EU and other institutional or resource constraints on countries behaviour can have the same effect as side payments, and therefore lessen or eliminate the need for these payments. These restraints can even out the upstream-downstream polluter victim imbalance associated with the unidirectional externality, and move the situation from non-cooperation closer to the full-cooperative outcome. They are a more realistic and arguably more desirable method for improving the situation than side payments, considering the wealth constraint in downstream countries.

Secondly, examining the Danube-Black Sea pollution problem in the context of side payments and cooperation among the parties involved provides a useful framework from which to draw lessons for policy in upstream and downstream countries. This section will use the results of the formal analysis from previous chapters together with the institutional dimensions discussed earlier in this chapter to draw policy lessons for the countries involved in the Danube-Black Sea pollution problem, as well as the EU.

Lessons for Black Sea Countries

The formal analysis provided in Chapter Five has implications for the choices that Black Sea countries could make to address upstream pollution. While side payments are unlikely, there are a variety of other methods that Black Sea countries could use to reduce upstream pollution, including issue linkage, lobbying the EU to ensure that the WFD is enforced in member states, and insisting that the polluter pays principle be respected. While these efforts could have positive effects for the whole system, Black Sea countries must be aware that reducing upstream pollution will also decrease the incentive for cooperation among themselves, as occurred with side payments in Chapter Five. If Black Sea countries respond to this incentive and do reduce efforts for cooperation among themselves, they may be retarding progress to find a lasting solution to the Danube-Black Sea pollution problem. This is because cooperation among the Black Sea countries will be a critical part of addressing the Danube-Black Sea pollution problem.

Three important factors demonstrate why this is the case. Firstly, as was demonstrated in Chapter Four, the benefits of pollution abatement are higher when Black Sea countries cooperate than when they act in their own self-interest. Cooperation in the management of Black Sea marine resources also ensures that every unit of abatement, whether upstream in the Danube or downstream in the Black Sea countries, yields higher benefits. Cooperation provides a greater incentive to abate, but it also makes abatement more rewarding for the Black Sea countries.

Secondly, cooperation in the Black Sea sends a strong message to upstream countries that their downstream counterparts are serious about addressing the pollution problem, and are not interested in free riding on upstream abatement. This kind of leadership would be particularly compelling considering that the EU WFD requires members to work with non-members to implement the WFD objectives (EU, 2000). Failure to cooperate sends the message that Black Sea countries are simply interested in waiting for upstream abatement instead of working to address the pollution at home. This message may decrease the interest of upstream countries in the consequences of their actions in the Black Sea.

Thirdly, while much of the nutrient pollution that enters the Black Sea comes from the Danube, Black Sea countries account for approximately half (46 percent) of all nutrients that enter the Black Sea (see Table 6.1). This is because Bulgaria, the Ukraine and particularly Romania pollute the Black Sea both directly from their seashores, but also through the Danube Basin. Romania itself accounts for over a quarter (26 percent) of all nutrient pollution in the Danube River Basin (see Table 3.2). Considering that the figures in Table 6.1 measure emissions at the source, the contribution of the Group 3 countries to Black Sea nutrient pollution is probably even higher than 46 percent, because some of the pollution that enters the Danube upstream will be trapped there in wetlands or other nutrient sinks. While there is still a great deal of nutrient pollution that enters the Black Sea from the Danube countries of Groups 1 and 2, an important part of addressing the pollution problem will be encouraging greater cooperation among Black Sea riparian states that are either directly or indirectly the most important source of nutrients. Romania will again be one of the key players in this endeavour because it is responsible for such a large portion of all pollution that enters the entire Danube-Black Sea System, over twice as much as the second largest polluter (Germany) and seven percentage points more than all Group 2 countries combined (see Table 6.1).

The fact that Black Sea countries account for a significant amount of the pollution in the Black Sea means that the incentive to cooperate among these countries is higher than it would be if upstream pollution were more prevalent, and downstream pollution less so. As has been discussed above, increasing abatement upstream through side payments, lobbying, issue linkage or any other mechanism allows Black Sea countries to side step the issue of cooperation among themselves. But because of the importance of pollution in the Black Sea itself, the countries there will still be faced with a significant problem even if upstream pollution is greatly reduced. Referring back to the formal analyses in Chapter Five and the associated discussions, the convergence between the benefits available under the Nash equilibrium and full cooperation (displayed in Figure 5.3) will be restricted by the significant amount of pollution that Black Sea countries emit into the system. Essentially, while convergence between the Nash equilibrium and full-cooperative outcomes will occur, it will not occur to the same extent that it would if upstream groups were responsible for a greater share of the pollution that enters the Black Sea. Despite this fact, upstream abatement may still have a significantly negative effect on the prospects for cooperation in the Black Sea because of the potential difference in benefits between Nash and full-cooperation. The overall conclusion is that Black Sea countries should be careful to ensure that upstream abatement does not jeopardise downstream cooperation.

Table 6.1. Nutrient Pollution by Group in the Danube-Black Sea System

Country	Nitrogen		Phosphorous		Nutrients	
	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total	Total (kt/y)	Percent of Total
Group 1						
Germany	120	10.76%	7	5.77%	127	10.28%
Austria	96	8.61%	6.8	5.61%	102.8	8.32%
Czech Republic	32	2.87%	3.4	2.80%	35.4	2.86%
Slovakia	54	4.84%	5.6	4.62%	59.6	4.82%
Hungary	82	7.36%	13.2	10.89%	95.2	7.70%
Slovenia	24	2.15%	2.8	2.31%	26.8	2.17%
Total	408	36.60%	38.8	32.01%	446.8	36.15%
Group 2						
Croatia	35	3.14%	4.1	3.38%	39.1	3.16%
Bosnia-Herzegovina	37	3.32%	5.1	4.21%	42.1	3.41%
Yugoslavia	106	9.51%	17.7	14.60%	123.7	10.01%
Moldova	13	1.17%	2.2	1.81%	15.2	1.23%
Total	191	17.13%	29.1	24.01%	220.1	17.81%
Group 3						
Bulgaria	109.467	9.82%	7.525	6.21%	116.992	9.47%
Georgia	1.585	0.14%	0.435	0.36%	2.02	0.16%
Romania	276.373	24.79%	28.128	23.20%	304.501	24.64%
Russia	13.491	1.21%	1.037	0.86%	14.528	1.18%
Turkey	38.008	3.41%	5.857	4.83%	43.865	3.55%
Ukraine	76.83	6.89%	10.338	8.53%	87.168	7.05%
Total	515.754	46.27%	53.32	43.99%	569.074	46.04%
TOTAL	1114.754	100.00%	121.22	100.00%	1235.974	100.00%

Source: BSEP, 1997 and ICPDR, 1999

Lessons for Upstream Countries

The formal analyses presented in the previous chapters have important implications for upstream countries as well. The first of these is that upstream countries have an incentive to facilitate cooperation in the Black Sea. In Chapter Five it was demonstrated that Black Sea countries have a greater incentive and more resources to make side payments to upstream countries when they cooperate among themselves, and that they will also have more resources to make these payments. This conclusion has important implications, despite the fact that side payments are unlikely. Half of the Black Sea countries are EU candidates, and receive support from the EU to help them comply with the *acquis communautaire* (see Chapter Three). By pursuing enlargement in the Black Sea region and supporting applicants, the EU has clearly demonstrated that it believes enlargement to be a desirable policy for Europe, and that enlargement is in the EU's interest. Cooperation in the Black Sea moves the countries there closer to compliance with the WFD and closer to accession, and the greater benefits that cooperation delivers to Black Sea countries lessens the need for EU support in the environmental sector, and possibly in other sectors as well. This benefits the EU and its upstream members, and provides them with an incentive to encourage cooperation.

A second lesson for upstream countries comes from the effect of upstream abatement on Black Sea cooperation that has been discussed above. Countries in upstream groups as well as the EU should be cautious when they decide how much to abate in the interests of the Black Sea. The implementation of the WFD in Group 1 countries requires that the effects of their pollution on Black Sea countries be considered by upstream polluters (see Chapter Three). This requirement, however, may actually dissuade the Black Sea countries from cooperating among themselves (see Chapter Five and the discussion above in this chapter). Considering this effect, the EU and its members may be wise to require that any upstream abatement that is aimed at environmental improvement in the Black Sea be conditional on increased cooperation downstream in the Black Sea. This would provide the Black Sea countries with an incentive to cooperate, instead of an incentive to abate to a lower level because of the reduced marginal benefits available to them.

Chapter Seven: Conclusions

The complexity caused by the large number of very diverse countries and the interaction between the unidirectional and reciprocal externalities makes the Danube-Black Sea pollution problem an interesting study in international environmental cooperation. The countries involved range from relatively wealthy EU members, to post communist countries that are on their way to economic recovery and EU membership, to some of the poorest and most troubled countries in Europe. There is also a unique relationship between the Black Sea, which is one of the most polluted water bodies in the world, and the Danube, which is the most international river basin in the world and the most important source of nutrient pollution in the Black Sea.

The Danube-Black Sea pollution problem is characterized by a geographic and economic imbalance, where wealthier upstream countries are polluters involved in a unidirectional externality, and poorer downstream countries are both the victims of the unidirectional externality and involved in a reciprocal externality among themselves. In the case of the unidirectional externality, theoretical analyses suggest that side payments from downstream to upstream countries will be a prerequisite for upstream abatement. This paper provided an economic formalization of the Danube-Black Sea pollution problem in order to uncover the incentives that countries face to abate and pollute. It has also examined how these incentives affect the role of side payments and the prospects for cooperation in the region.

This paper demonstrated that, while side payments may be theoretically probable when the nutrient pollution issue is considered in isolation, it is unlikely that they will occur in reality because institutions and other constraints will diminish the incentive for downstream countries to make payments, or limit their ability to do so. Focussing on side payments also provided a useful framework from which policy lessons could be drawn for upstream and downstream countries, as well as the EU.

Because of its enlargement and environmental policies, the EU is a very important institution involved in the Danube-Black Sea pollution problem. Its approach to enlargement requires that all candidates comply with all EU policies, including its environmental requirements. The Water Framework Directive (WFD), the most important EU policy for the Danube and Black Sea, requires: management based on river basins, good ecological quality in all waters, and that members endeavour to cooperate with non-members to implement WFD objectives. These requirements make it more difficult for upstream members and applicants to ignore the downstream consequences of their pollution for both members and non-members, and they consequently lessen the need for side payments.

The wealth and development gap among Danube-Black Sea states and the interdependence among these countries also reduces the need and likelihood of side payments. Low levels of economic and human development in downstream countries mean that these countries will likely be unable to pay their upstream neighbours for abatement. The fact that a given country's relationship with its downstream neighbours will have an impact on the relationship with its upstream neighbours also limits the extent to which upstream countries can ignore the downstream effects of their pollution.

Examining the role of side payments provided important policy lessons for both upstream and downstream countries alike. Abating pollution in Black Sea countries will be a key part of addressing the Danube-Black Sea pollution problem because of: the amount of pollution that Black Sea countries emit into the system; the importance of demonstrating to upstream countries that Black Sea countries are not interested in free riding on upstream abatement; and the difference in benefits between the Nash equilibrium and the full-cooperative outcome in the Black Sea. But making side payments and increasing upstream abatement lessens the incentive for cooperation in the Black Sea, meaning that these countries must resist the temptation to substitute upstream abatement for cooperation among themselves. Upstream countries should consider linking any upstream abatement that has the objective of improving water quality in the Black Sea to cooperation among Black Sea countries. The EU and its upstream members should also encourage cooperation in the Black Sea as this will allow applicants in the region to accede faster and with less EU assistance.

Suggestions for Further Research

There are a variety of avenues for further research that arise from this study. A particularly interesting, yet extensive avenue, would involve quantifying some the values discussed in this paper to investigate the interaction between the two externalities in an empirical manner. For example, this paper has proposed that upstream abatement decreases the incentive for downstream cooperation; however, little was said about the actual strength of this effect. Because of the potential significance of such an effect in the Danube-Black Sea Region and beyond, further research in this area would be both interesting and useful.

Another interesting avenue would be to research the evolution of the effect of the EU and the WFD in the Danube-Black Sea Region over time. EU enlargement in Eastern Europe is still in its early stages, and the WFD will be in the implementation process for years to come; it will be interesting to see what the actual effect of these phenomena are several years from now.

A final area for further research would involve relaxing the assumptions that marginal benefits of abatement in Black Sea countries decrease with upstream abatement, and that marginal benefits of Black Sea abatement decrease with increasing abatement in the Black Sea. As is discussed above, the Black Sea is very polluted, so these assumptions may not hold at lower abatement levels (see Maler, 1992). Revisiting this research with different assumptions might provide some interesting results.

Appendices

Appendix A: Ethics Approval

SIMON FRASER UNIVERSITY

OFFICE OF RESEARCH ETHICS

BURNABY, BRITISH COLUMBIA
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May 28, 2003

Mr. Alan MacKinnon
Graduate Student
School of Resource and
Environmental Management
Simon Fraser University

Dear Mr. MacKinnon:

Re: An Economic Analysis of Nutrient Enrichment in the Danube-Black Sea System

The above-titled ethics application has been granted approval by the Simon Fraser Research Ethics Board, at its meeting on May 26, 2003 in accordance with Policy R 20.01, "Ethics Review of Research Involving Human Subjects".

Sincerely,

Dr. Hal Weinberg, Director
Office of Research Ethics

Appendix B: Interviews

Interviews Conducted in Budapest, Hungary

Dr. István Ijjas
Institutional Socrates Coordinator
Department of Research and Scientific Affairs
Budapest University of Technology and Economics
Budapest, Hungary
Date of Interview: June 3, 2003

Dr. Zsuzsanna Kerekesné Steindl
Head of Department
Department of Integrated Pollution Prevention and Environmental Monitoring
Ministry of Environment and Water
Government of Hungary
Budapest, Hungary
Date of Interview: June 4, 2003

Péter Kovács
Head of Department
Department for Water and Soil Protection
Ministry of Environment and Water
Government of Hungary
Budapest, Hungary
Date of Interview: June 4, 2003

Dr. Ferenc László
Director, Senior Research Associate, Chemical Engineer
Institute for Water Pollution Control
Water Resources Research Centre Plc. (VITUKI Plc.)
Budapest, Hungary
Date of Interview: June 5, 2003

Interview Conducted in Munich, Germany

Dr. Michael Altmayer
Groundwater Protection
Bavarian State Ministry for Regional Development and Environmental Affairs
Munich, Germany
Date of Interview: June 11, 2003

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