GAINS FROM TRANS-BOUNDARY WATER MANAGEMENT IN LINKED CATCHMENT AND COASTAL ECOSYSTEMS

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Worldwide, coastal and marine ecosystems are increasingly affected by point and diffuse source water pollution originating from rural, urban as well as industrial land uses in coastal river catchments (see for example Rogers, 1990; Elofsson et al., 2003), even though these ecosystems are of vital importance from an environmental as well as an economic perspective (Hodgson and Dixon, 1988; Cesar et al., 2002; Gordon, 2007). Integrated Catchment and Coastal Zone Management (ICCZM) specifically takes into account this inherent relationship between catchment land use, surface and ground water pollution, ecosystem state and associated environmental values.

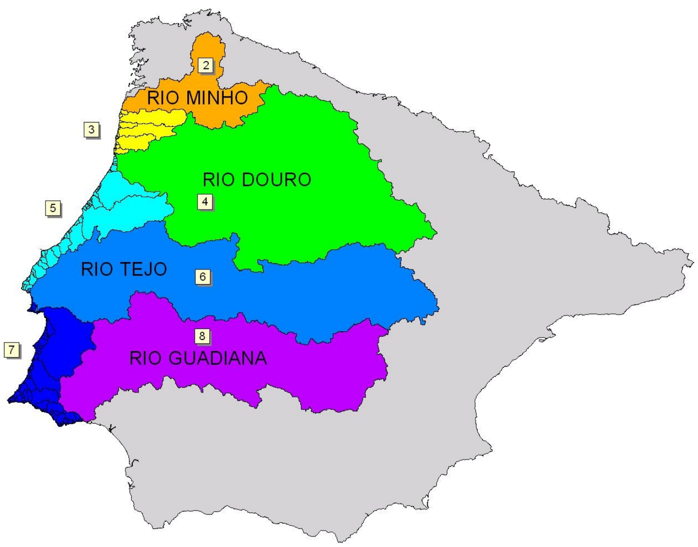
To warrant sustainable economic development of river catchments, we need to balance the marginal costs from catchment water pollution abatement and the associated marginal benefits from coastal and marine resource appreciation (see for example Hart and Brady, 2002; Gren and Folmer, 2003; Roebeling, 2006). In doing so, however, we need to differentiate between intra- and trans-boundary catchments because benefactors and beneficiaries from water quality improvement are not in all cases one and the same (Askari and Brown, 2001; Dirksen, 2002; Ward, 2007). In trans-boundary catchments the private (national) welfare maximizing rates of water quality improvement differ across nations as benefits from water quality improvement typically accrue to one nation while the costs are paid by multiple nations.

Economic incentives and market-based instruments (like pollution taxes, pollution abatement subsidies and marketable emission permits) can be used to internalize these beneficial spill-overs from water quality improvement such that market behaviour could lead to efficient and social welfare maximizing outcomes (Shortle et al., 1998; Perman et al., 1999). This would, however, require international treaties and regulations that allow for international financial transfers of these welfare gains and that are based on verifiable water pollution measures or proxies (Elofsson et al, 2003; Ward, 2007). Provided full cooperation of all involved water polluting countries, market behaviour would then lead to efficient outcomes where marginal abatement costs and marginal abatement benefits are equal and the same across all water polluting nations (Gren and Folmer, 2003).

The importance of trans-boundary catchment management is specifically addressed in the 1999 sustainable trans-boundary catchment water management convention (RAR nº 66/99, 1999), in which Spain and Portugal agree to cooperate in the protection of surface and ground water resources as well as in the protection of aquatic and terrestrial ecosystems that depend on these water resources. In alignment with the European Union Directives 2000/60/EC and 2006/118/EC, this convention focuses on the implementation of activities that promote and protect the good state and use of water resources in the trans-boundary catchments of the river Minho, Lima, Douro, Tejo and Guadiana (see Figure 1).

While approaches for water quality management in linked catchment and coastal ecosystems are fairly recent though existent (see for example Goetz and Zilberman, 2000; Hart and Brady, 2002; Roebeling, 2006), water quality management in trans-boundary catchments poses additional scientific and managerial challenges (Elofsson et al., 2003; Gren and Folmer, 2003; Ward, 2007). The objective of this paper is to develop and apply a deterministic optimal control approach that allows us to explore, analytically as well as quantitatively, private and social welfare maximizing rates of water pollution abatement in linked trans-boundary catchment and coastal ecosystems. For a case study of the Tejo catchment in the Spanish-Portuguese peninsula, we estimate nation-specific water pollution abatement cost functions as well as coastal and marine-based environmental value reductions from water pollution, to determine as well as compare private (national) and social (trans-national) welfare maximizing rates of water pollution abatement.

Figure 1 International river basins on the Spanish-Portuguese peninsula



Notes: Basins comprising river Minho (2), Lima (3), Douro (4), Tejo (6) and Guadiana (8).
Source: Néry et al. (2003).

The presented approach differs from existing approaches in a number of ways. First, we explicitly present an analytical derivation of private (national) and social (trans-national) welfare maximizing rates of water pollution abatement using nation-specific abatement cost functions. Second, the developed analytical optimal control approach provides an elegant, stylized and easily understandable solution concept thus contributing to the development of sustainable water quality improvement targets. Finally, we go beyond the usual cost-effectiveness analysis based on arbitrary ‘tolerable‘ or target levels of pollution as we specifically take into account the negative external costs of increased water pollution in the downstream coastal and marine environment.

Results for the Tejo case study catchment show that, as compared to the current situation, some private (national) welfare gains can be obtained through the adoption of win-win land use practices, leading to a 10% reduction in the annual rate of water pollution and an almost 8% increase in annual regional income. Maximum social (trans-national) welfare gains can, however, be obtained through the adoption of win-win as well as lose-win land use practices across Spain and Portugal, leading to a 50% reduction in the annual rate of water pollution and a 15% increase in annual regional income. Yet, Spain’s hypothetical non-cooperation in water pollution mitigation would only lead to a 25% reduction in the annual rate of water pollution and a just over 10% increase in annual regional income – i.e. social (trans-national) welfare losses from non-cooperation between Spain and Portugal would equate to over 200 million Euros per year.

A number of caveats to this study need to be mentioned. First, while this study shows that social welfare gains can be obtained through a reduction in water pollution as compared to the current situation, continuous population growth and economic development may lead to further increases in water pollution and critical coastal and marine ecosystem thresholds may be reached. Addressing these socio-economic development dimensions requires the inclusion of non-linear water pollution cost functions that reflect rapidly increasing costs from coastal and marine resource degradation beyond specific water pollution threshold values. Second, it must be emphasized that the water pollution abatement cost functions are based on current land use patterns as well as current land use practices in the Tejo catchment and, consequently, do not include land use change and future land use practices. It can be expected that water pollution abatement costs are lower if land use change and future land use practices would be taken into account. Third, the case study is based on aggregate water pollution abatement cost functions because the absence of industry specific land use practice information did not allow for the estimation of agricultural industry specific water pollution abatement cost functions. As a result, at this stage we are not able to estimate private (national) welfare maximizing rates of water pollution abatement for agricultural industries separately. Finally, the welfare maximizing rates of water quality improvement presented in this study are most likely underestimated as re-suspension of water pollutants and uncertainty in benefits from coastal and marine resource conservation have not been taken into account. Consequently and self-evidently, presented results provide a first indication of the gross direction and magnitude of change – not an exact recipe for change.

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