Resource and Energy Economics 44 (2016) 92–117

Contents lists available at ScienceDirect

Resource and Energy Economics

journal homepage: www.elsevier.com/locate/ree

Sustainable agreements on stochastic river flow☆

Erik Ansink[a,*], Harold Houba[b]

[a] Department of Economic and Social History, Utrecht University, The Netherlands
[b] Department of Econometrics, VU University Amsterdam, and Tinbergen Institute, The Netherlands

A R T I C L E I N F O

Article history:
Received 8 September 2014
Received in revised form 14 October 2015
Accepted 23 February 2016
Available online 7 March 2016

JEL classification:
C73
D74
F53
Q25

Keywords:
River sharing
Sustainable agreements
Repeated sequential game
Folk Theorem
Water allocation
Renegotiation-proofness

A B S T R A C T

Many river sharing agreements in transboundary river basins are inherently unstable. Due to stochastic river flow, agreements may be broken in case of drought. The objective of this paper is to analyze whether river sharing agreements can be self-enforcing, or sustainable. We do so using an infinitely-repeated sequential game that we apply to several classes of agreements. To derive our main results we apply the equilibrium concepts of subgame-perfect equilibrium and renegotiation-proof equilibrium to the river sharing problem. We show that, given the upstream–downstream asymmetry, sustainable agreements allow downstream agents to reap the larger share of the benefits of cooperation.

☆ Small parts of this paper are based on a revised version of FEEM Working Paper 73.2009, 'Self-enforcing agreements on water allocation', by the first author. The authors thank Arjan Ruijs, Hans-Peter Weikard, Ralph Winkler, and two anonymous referees for helpful comments and suggestions. Erik Ansink acknowledges financial support from FP7-IDEAS-ERC Grant No. 339647.

* Corresponding author at: Department of Economic and Social History, Utrecht University, Drift 6, 3512 BS Utrecht, The Netherlands. Tel.: +31 205981214.
E-mail address: j.h.ansink@uu.nl (E. Ansink).

http://dx.doi.org/10.1016/j.reseneeco.2016.02.005
0928-7655/

1. Introduction

We extend and apply the theory of repeated games to the river sharing problem. Our main contribution is the design of agreements that are sustainable to stochastic river flow in a dynamic setting. Doing so, we add to the rapidly growing literature on the analysis of solutions to the river sharing problem (cf. Béal et al., 2013; van den Brink et al., 2012; Ambec et al., 2013), which has largely ignored dynamics and stochasticity.

In an international river basin, when water is scarce, countries may exchange water for side payments (Dinar, 2006; Carraro et al., 2007). This type of exchange is generally formalized in a river sharing agreement. The aim of river sharing agreements is to increase the overall efficiency of water use. This increase in efficiency can be obstructed by the stochastic nature of river flow, because countries may find it profitable to break the agreement in case of drought (Dinar et al., 2015; Ward, 2013). A recent example is Mexico's failure to meet its required average water deliveries under the 1944 US-Mexico Water Treaty in the years 1992–1997 (Gastélum et al., 2009). Additional case study evidence on agreement breakdowns because of droughts can be found, for instance, in Barrett (1994) and Beach et al. (2000). Only a minority of current international agreements take into account the variability of river flow (de Stefano et al., 2012). Most agreements do not; they either allocate fixed or proportional shares, or they are ambiguous in their schedule for water allocation. Both the efficiency and stability (Bennett and Howe, 1998; Bennett et al., 2000; Ansink and Ruijs, 2008; Ambec et al., 2013) of such agreements may be hampered. These effects could be worsened by the impacts of climate change on river flow.

In order to accommodate for stochastic river flow, Kilgour and Dinar (2001) developed a flexible river sharing agreement that provides an efficient allocation for every possible level of river flow. This agreement maximizes the overall benefits of water use, after which side payments are made such that each country benefits from cooperation. This flexible agreement assures efficiency, but not stability because it ignores the repeated interaction of countries over time. Countries have an incentive to defect from the agreement when the benefits of defecting outweigh the benefits of compliance. Note that there is no supra-national authority that can enforce this type of international agreements. This implies that a stable agreement has to be self-enforcing or sustainable, in the sense that each agent should have an incentive to comply with the agreement. In such a setting, application of repeated-game theory to the setting of river sharing seems natural, but to the best of our knowledge, this has not been done yet.[1]

Given the asymmetry imposed by the geography of the river, we adopt an infinitely-repeated sequential game, in which upstream agents move before downstream agents.[2] The Folk Theorem for infinitely-repeated sequential games is a limit result on the discount factor. For practical purposes, the issue is firstly, given some discount factor, how to construct sustainable agreements, and secondly whether certain classes of agreements have properties that may be appealing for implementation by policy makers. For instance, we will assess the effects of restrictions on per-period payoffs and we will look at some disadvantages of fixed-payment agreements, which are common in practice.

To derive our main results we apply the Folk Theorem to the river sharing problem using the equilibrium concepts of subgame-perfect equilibrium and renegotiation-proof equilibrium. We will see that, given the upstream–downstream asymmetry, sustainable agreements allow downstream agents to reap the larger share of the benefits of cooperation. This distribution of gains is the opposite of some papers that assess agreements on river sharing in a static setting (e.g. Ambec et al., 2013). Our results provide economic intuition for an empirical result (downstream states managing to negotiate

[1] This paper is therefore a contribution to the challenge raised by Carraro et al. (2007): *"Water resources are intrinsically unpredictable, and the wide fluctuations in water availability are likely to become more severe over the years. Formally addressing the stochasticity of the resource, as well as the political, social, and strategic feasibility of any allocation scheme, would significantly contribute to decreasing conflicts over water."*

[2] This sequence of moves according to the agents' geographical location seems most natural. There are two additional argument to support this sequence. One is that payments to compensate for water deliveries can easily be deferred while water deliveries themselves cannot. The second argument relates to observability of river flow. The logical alternative to a sequential game is a game with simultaneous moves. Such a game, however, is equivalent to a game with sequential moves in which the second agent does *not* observe the action of the first agent. Since, in practice, most transboundary rivers are monitored – meaning that downstream observes the river flow – we prefer the sequential game over its simultaneous alternative.