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Negotiating land for flood risk management : upstream-downstream in the light of economic game theory

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Abstract

This paper discusses the use of game theory as a method to achieve land and water governance for flood retention and resilience on a catchment scale. Therefore, it addresses flood retention in river catchments by using pay-off matrices of game theory. How do pay-off matrices between upstream and downstream change when certain property rights are adjusted or institutional conditions are changed? What if liability issues, responsibilities, and externalities of flood protection measures are reframed? Who should pay and who profit from retention measures? Individual scenarios correspond to some basic games from the game theory. The aim of these thought experiments is to develop rules for upstream-downstream agreements on retention and resilience within a river basin area.

Introduction

Flood protection with dikes alone is not an acceptable solution for increasing risks of river floods. In many cases the use of dikes is perfectly feasible but when used in isolation they are not the best solution. Two alternative options are: Retain floods upstream or adapt land uses downstream (resilient cities). Retention and resilience cannot substitute traditional flood protection by dikes entirely, but their value for reducing flood risk has been acknowledged in the academic debate (Hartmann, 2012) and politics (Directive 2007/60/EC). The main challenge is to implement them on land in appropriate upstream-downstream relations. Usually, flood storage options are implemented on 'cheap' land, for example, where the upstream land has a low value use such as grassland (e.g. polders on the Havel river in Germany).

The situation is more complicated if the land suitable for upstream retention is a valuable area for land uses that would be affected by occasional flooding (i.e. agriculture, settlements, etc.). But also adapting the downstream land uses to flooding can be very expensive. So, the question is on how to decide under such competitive situations between using the potential upstream (i.e. valuable areas) or adapting downstream land uses (which would cost a lot of money) (Scherer, 1990).

The trade-off between upstream-downstream has been addressed in the scholarly debate and in practice for more than 200 years (Jüpner, 2017). Most of the literature on upstream-downstream trade-offs address either technical aspects of emissions or pollutions (e.g. Groll *et al.*, 2015), cross-border aspects (e.g. Bracken *et al.*, 2016), or pursues a catchment perspective on governance (e.g. Rouillard *et al.*, 2015). Fewer scholars have addressed the relationship between upstream and downstream from the aspect of land use planning and trade-off (Scherer, 1990; Hartmann, 2011; Rouillard *et al.*, 2015; Thaler *et al.*, 2016). Economic observations on flooding and the relation between upstream and downstream are also rare (i.e. White, 1936; Lind, 1967). Chang looked for tradable flood mitigation permits, asking the question how upstream and downstream parties can be encouraged to collaborate (Chang, 2008). The economic approach to the evaluation of costs and benefits connected with floods and flood protection is described in many papers and manuals. Among the most comprehensive ranks a new 'Multi-Coloured Manual' (Penning-Rowsell *et al.*, 2014), which provides assessment techniques for flood risk management costs and benefits including useful data for the practical assessment, a manual of the cost-benefit analysis (CBA), indirect benefits, limitations and complications of CBA, to guide decision-making etc. Specific instruments such as control-command and market-based instruments and its application in flood risk management have also been discussed (Filatova, 2014). Although in all current environmental and flood protection planning process, there is a strong emphasis on stakeholder and public engagement, there is almost no discussion on opportunities to utilise negotiation between different groups of stakeholders/upstream-downstream.

In this contribution, the focus lies on the question in which scenarios do negotiations between upstream and downstream lead to what patterns of negotiations. Therefore, different scenarios are analysed with game theory. However, the paper does not provide an answer for upstream-downstream agreements, but develops and discusses the approach of game theory for those cases. It is thus a methodological contribution.

Traditional economic methods in water management

The most common and politically feasible approach is based on neoclassical environmental economics. It uses the cost-effectiveness analysis (CEA) that ranges possible measures depending on their effectiveness and is used for cost minimisation and the CBA that compares the measures at their costs and benefits (WATECO, 2003, Penning-Rowsell *et al.*, 2014). Such methods are regularly applied to justify flood protection measures. However, these approaches are associated with considerable uncertainty especially in the part of the determination of benefits and economic effects (Laurans, 2006; Jensen *et al.,* 2013). Also, the conflict over water issues is not only about costs and benefits, but 'arises from social and political aspects' (Madani, 2010, p. 255). The possibility of including stakeholder's negotiation or other dynamic elements is very limited in CBA. The negotiation could be integrated in CBA as a result of optimisation or in form of scenarios. The solution could be either to combine CBA and CEA with institutional analysis (Ostrom et al., 1999), or to use a method for solving multi-criterial and multi-decision-maker problems such as multi-criterion decision analysis (Elshorbagy, 2006).

Ronald Coase explains that economists have in the past often followed the argument of Pigouvian theory of externalities (Pigou, 1920), who thought the question in terms of which a company A inflicts damage on a company B (i.e. polluter-pays-principle). So, restrictions are proposed to restrain company A (Coase, 1960). But who is A and who is B in our case of an upstream and a downstream party? Coase avoids blaming one party as a polluter; rather he emphasises that 'we are dealing with a problem of a reciprocal nature' (Coase, 1960, p. 1). He regards externalities as a situation of two rival opportunities.

Based on the limitations of CBA and the difficulties of applying the polluter-pays-principle, other schemes need to be found to distribute costs and allocate flood risk management measures. Game theory provides a simple method to combine CBA as an input of costs and benefits with the approach of Coase (Coase Theorem) to also discuss and display the outcomes of different scenarios (Bennett *et al.,* 1998; Madani, 2010; Delille and Pereau, 2014). At the general level, game theory is used to identify and interpret behaviour and interaction of different parties who behave strategically. Game theory is used in location problems in planning or in sharing of natural resources or in reduction of emissions (Basaran, 2005). Floods are suited for the application of game theory because they are predominantly economic disasters; the economic values involved create incentives to look for negotiated agreements. With respect to flooding, Delille and Pereau (2014) used game theory to model the bargaining between agents over the building a seawall. Bennett *et al.* (1998) used the game theory to justify the international agreements and cooperation. Thus, game theory is an appropriate method that allows the researcher to experiment with certain arrangements and break with existing paradigms between upstream and downstream to predict its outcomes (Cooter and Ulen, 2004).

Game theory for flooding

Each game requires players, the strategies of each player, and pay-offs for each player for each strategy (Cooter and Ulen, 2004). Players in a game strive for maximising their utility and income, so that the outcome depends on choice of all groups (Luce and Raiffa, 1957). Each player pursues their interests with regard to the strategies of other players; such a situation can lead to equilibrium(s).

The size of pay-offs for a player depends on each player's behaviour (implementation of flood protection measures versus nonimplementation), his location (upstream versus downstream) and legal liability to pay for damages (Delille and Pereau, 2014). There are a couple of complexities for the game:

- Flood situations usually result from accumulated behaviour of many individuals.
- The land (both up- and downstream) might not be owned by locals, but people or organisations remote from the catchment.
- Asymmetric relationships in catchments (not individuals, but rather complex groups) need to agree on solutions.
- Identifying the beneficiary from an upstream perspective is fairly easy (except in Deltas), but for the downstream there are usually many upstream actors.

Leaving those complexities aside, it is assumed in the following game that there are only two players – one upstream and one downstream.

For the following example, it is appropriate to imagine the players as two cities along a river. In initial situation, new housing projects are planned in floodplains. For the simplicity, only two types of behaviour of each part are considered. This creates a 2 × 2 game. Within the game, 'Upstream' can retain or accelerate floods, 'Downstream' can adapt to flooding or ignore it. This is possible if the players are empowered and able to decide upon the use of the land and if each player encompasses a cohesive area (Hartmann, 2011). Each party acts individually, simultaneously (in the basic scenario) and for its own account. It will be discussed later, if and how the results can be applied to more complicated situations.

The remaining part of the paper discusses different scenarios of arrangements between upstream and downstream. Modelling is done using various types of behaviour including negotiation and conditions (different property values of upstream-downstream, different costs of adaptation). With regard to the flood risks, it makes sense to discuss not only the nature of the game (simultaneous versus sequential; cooperative versus non-cooperative etc.), but also the setting (such as a change of legal liability for damages) and influence of length of the period (increasing occurrence of floods). This leads to a change of the nature of game. The scenarios are demonstrated on practical/hypothetical examples.

Choosing games

Based on analysis of approaches and applications of game theory, for example Bardhan (1993), Dombrowsky (2007), Madani (2010), and Hartmann (2011), in water management investigations mainly used 2 × 2 games. Usually every player had two options for behaviour, each of them led to a different result based on the behaviour of the second player. There are three basic types of nonsequential games which are used in water economics (2 × 2 games): the Prisoner's Dilemma, the Stag-Hunt, and the Chicken game (e.g. Madani, 2010). These games differ in player's strategies (existence of dominant strategy, Nash equilibrium, and Pareto-optimal outcome). The results of the games are influenced by (non-)cooperation. The basis of the Chicken game is a conflict situation in which both players have the same goal. In the event that both meet this goal, the utility of both players decreases rapidly (Colman, 1995). Usually it happens that one of the players succumb to pressure and becomes a coward or a 'chicken'. The interest of the players is also to choose the opposite option than their opponent. The other two types of the game (the Prisoner's Dilemma and the Stag-Hunt) are similar. In the Stag-Hunt game (coordination game), the interest of each player is to do exactly the same as the other player (Skyrms, 2001). In this type of the game, there are two Nash equilibria. This differs from the prisoner's dilemma (Rapoport *et al.,* 1970), which has only one Nash equilibrium, because in this game dominant strategy exists, that means each player prefers constantly certain behaviour. A less frequently mentioned and used game is Deadlock. There are also two dominant strategies similar to the Prisoner's Dilemma, but the equilibrium represents at once the Pareto optimality, which means that there are no possibilities to make any one individual better off without making at least one individual worse off. In the Prisoner's Dilemma, the allocation in Nash equilibrium can be changed to a different that makes at least one individual better off without making any other individual worse off.

It is also possible to apply a series of sequential games. In sequential games, one of the players starts and the other reacts with his behaviour according the maximisation of his pay-off. In relation upstream-downstream, it cannot be clearly determined who would be the player, who chooses their action before the others and who is the second one, who gets some information of the first's choice. In scenarios where there is the dominant strategy by both players, there is no difference between simultaneous and sequential game. Applications games with more players or strategies or as a sequential game are offered as a further possible extension of this article. When designing a laboratory experiment it is also necessary to include this sequential type of game to test and to observe the differences in results.

Depending on the pay-off's distribution, different games can be applied to the issue of flooding. Those games can be created or fostered by manipulating the pay-off matrix, for example, by introducing certain liabilities, property right assignments, or assessment criteria (e.g. appraising residential areas more valuable than, e.g. agriculture, or vice versa). Examples for such agreements are payments for ecosystem services (PES) (Kerr, 2002) or tradable development rights (TDR). Those are normative and political decisions, just depending on the distribution.

Setting of the game

As mentioned above, there are four types of behaviour. Each player has to decide between two options regarding the use of their part of the floodplains, whereas it is assumed that both players profit from housing projects in their own floodplain. Upstream can either build up new housing projects with high dikes to prevent the houses (i.e. 'accelerate' the flood) or withdraw from building in flood–prone areas and instead provide retention volume for the sake of Downstream ('retain' strategy). 'Accelerate' – ultimately will lead to increasing water levels downstream. Downstream chooses between realising housing projects in floodplains disregarding the threat of inundation ('ignore'-strategy) or implement a risk-adapted construction for the buildings ('adapt' strategy).

If both decide to profit most individually (both players maximise their utility), the other party will not be taken into account. This condition means, if Downstream 'ignores' the flood, the housing area looks the same, regardless whether Upstream retains or accelerates the flood. However, Downstream must consider the cumulative probability P of an extreme flood over a predetermined period (whereas the probability also includes a possibility that for example the 'one in hundred-year flood' occurs more often – it is in the end just a statistical probability, but this shall be discussed elsewhere). Moreover, P represents a likelihood of a flood over a predetermined period, not certainty. One could imagine that in reality there is a probability of a flood for each short period, and players need to work with a cumulative probability. Flooding is a random event. The odds of occurring are independent of past occurrences (Cooley, 2006, p. 105). Downstream, therefore, is interested in the probability of an event in a period of y years (depending on the investment calculations for the housing project). If x represents the probability of a flood in a certain year, then, $(1{-}x)$ is the chance that this event will not take place in a given year. The odds that an event will not occur in two successive years would be $(1{-}x)\,(1{-}x) = (1{-}x)^2$. So, if $(1{-}x)^y$ is less than P, Downstream has an incentive to 'ignore'. For the centennial flood, this would mean: $(1{-}0.01)^y = P$. A critical length of a 'no-flood' period can be computed based on the probability assigned. According to the result, the period within which the necessary profit needs to be generated is determined. However, the outcome is not certain and decisions are made based on expected pay-offs. Also, Downstream has to consider that in the end, this is gambling with probabilities.

In the short term, the 'ignore'-strategy is very attractive, but in the long run, the cumulative probability of flooding on one or more occasions increases (precisely: the probability that a flood does not occur for a long period decreases). The longer a project needs to be profitable, the higher is the chance of a flood within the project lifetime. But the 'ignore'-strategy is often applied in practice. Housing areas, industrial areas, and further flood-sensitive land uses are often located downstream to other high-value uses, which are protected by dikes, and thus accelerate the wave: 'urban waterfronts' along the rivers, financed by credit institutes, and promoted with slogans like 'Living near the River' are typical examples. In the long-term of our simple example, the collective benefit of such allocations is zero. A flood would reduce the profit for Downstream. If Upstream decides to 'accelerate' the flood, he does not regard the effects on the Downstream. Rational individual behaviour is able to produce the most individual gain. Upstream is able to realise housing project in the whole floodplain if high embankments protect these areas. Downstream, on the other hand, gains the most if Upstream acts collectively rational despite Downstream acts individually rational. Then, cheap and extensive housing projects can be built.

A major challenge is to assess the pay-offs. Pay-offs consist of the benefits and costs of arrangements between upstream and downstream. Benefits of flood risk management are the avoided damage, whereas different definitions of damage exist (Berg, 1994); costs include opportunity costs connected with land uses of floodplains as well as costs for protection measures (investment and operational costs). The pay-offs are defined as the difference between benefits and costs and with respect to the probability of floods in the equilibrium for 'ignore/accelerate'. For simplification, all transaction costs are disregarded.

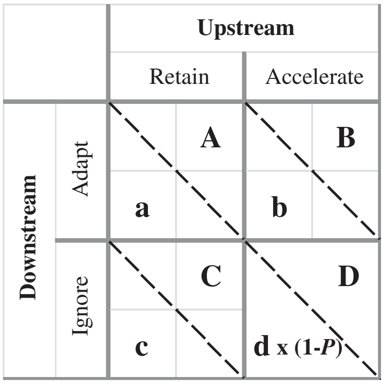
The game

Game theory distinguishes one shot games and repeated games. In case of flooding, it makes sense only to apply the principle of one shot games. Built development floodplains usually are planned to last for many years (over 50 years in the United Kingdom for commercial developments and 100 years for residential development, while the measure is usually considered permanent in the Czech Republic). For that reason, a decision binds the player for a long time. The situation may change if the players are willing to cooperate. Cooperative solutions are those which maximise the common pay-off of both players. Some of the pay-off structure prevents finding the cooperative equilibrium. The model of the game where the Nash equilibrium profit is less than it could be with the cooperation of players is called the Prisoner's Dilemma (Axelrod, 1984). Players in this game choose an action once and for all. Thus, a wise strategy is needed.

Possible players' behaviour can be combined, in case of floods four action profiles come into consideration: retain/adapt, retain/ignore, accelerate/adapt, and accelerate/ignore. The combinations form a 2 × 2 matrix (Figure 1). The behaviour of the first player (Downstream) forms the rows of a matrix. The behaviour of upstream fills the columns of the matrix. Inside each matrix, there are two numbers, which represent pay-offs for each player depending on the behaviour of both players. The right one (capital letter) belongs to Upstream and the left one (lower case) to Downstream. Each player prefers higher pay-offs.

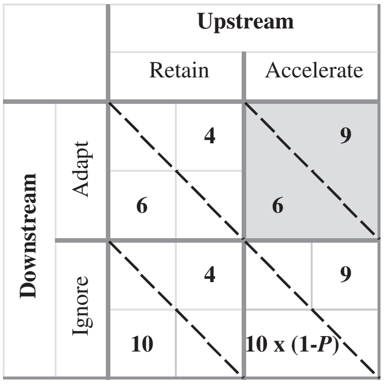
Based on definition of the players' behaviour, there is partial asymmetry regarding the dependencies, since the Upstream's actions fully affect downstream while Downstream's actions have no effect on Upstream. According to the conditions of scenarios the asymmetry will be changed.

Figure 2 shows an arithmetic example of a pay-off matrix, considering the conditions above. The pay-offs are a monetary gain (e.g. millions of Euros). Just for the



		Upstream	
		Retain	Accelerate
Downstream	Adapt	A a	B b
	Ignore	C c	D d x (1-*P*)

Figure 1 Example of the game.



		Upstream	
		Retain	Accelerate
Downstream	Adapt	4 6	9 6
	Ignore	4 10	9 10 x (1-*P*)

Figure 2 Flooding game pay-offs.

simplification of the comparability, simple values are assumed. Upstream gains 4 in case of 'retain' and 9 in case of 'accelerate'. Downstream earns 6 in the case of 'adapt'. Following the asymmetry mentioned above, the gain for Upstream is 9, if Upstream 'accelerates' the flood-wave, regardless whether the Downstream 'adapts' or 'ignores'. On the contrary, for the same reason, a rational decision of Downstream in a short run leads to 10 in the combination 'ignore/retain' and $10*(1 - P)$ in case of 'ignore/accelerate', but in a long run, Downstream's profit decreases to a nearly 0 in the case of combination 'ignore/accelerate' (because P becomes almost 1). The asymmetry explains why the particular maximum of 10/9 can be achieved by rational decisions, whereas only Downstream takes risk of losing pay-offs. Such situations can be observed in practice. In the Netherlands, there is discussion of designs for houses and even greenhouses that float on water and rise and fall as a flood passes. Thus, the Dutch try to gain as much as possible by a risk-adapted behaviour. Germany, France, and Switzerland are the upstream parties. Some similar cases can be found in other catchment, for example, in the Czech Republic in the catchment of rivers Berounka and Vltava. The following combinations of strategies can be played:

Accelerate/adapt

For Downstream, it would be most profitable if Upstream pursues 'retain'. For Upstream, however, it is most tempting to act individually rational as well. Then, however, Downstream's profits depend strongly on the time period that is considered in the economic assessment. So, if Upstream indeed 'accelerates', Downstream should 'adapt' in order to achieve at least a profit of six if he thinks that the flood is coming with probability of at least 0.4. The highest economic welfare of the whole catchment then achieves a pay-off of 15. In case of Germany, France, and Switzerland, retention takes place to some extent, but as a whole, these densely settled upstream parties accelerate flood waves and force the Dutch to adapt their housing projects (whereas it has to be admitted that the adaptive strategy of the Dutch is also owed to sea level rises, not only to river floods).

Accelerate/Ignore: If Upstream accelerates, the 'ignore' strategy pays off for Downstream if he views a probability of the flood as less than 0.4. In that case, namely, the pay-off is $10 \times (1 - 0.4) = 6$, which is equal to the strategy 'adapt'. Downstream then becomes indifferent between the two strategies and strictly prefers 'ignore' if he thinks the probability is below 0.4.

Retain/ignore

The combination 'retain/ignore' achieves the maximal gain for Downstream. However, this opportunity will dissatisfy Upstream, because he carries all the burdens and Downstream gets all benefit. This combination will only result in a situation with a very strong downstream party, which has the opportunity to control or at least influence Upstream extraordinarily. Probably, Upstream and Downstream are within the same administrative borders, and the decision power is with the downstream party. Within the arithmetic example, this combination reaches the second best collective gain, namely 14.

Retain/adapt

It achieves a common profit of 10. From the perspective of efficient allocation, this combination of strategies is not preferable. This is a consequence of implementing both retain and adapt measures when only one of them would be sufficient. It is a result of lack of cooperation.

Finally, in a theoretical world without liability or other legal framings, the combination 'accelerate/adapt' is predicted in long run (with probability of floods $P > 0.4$). The most probable strategies are highlighted in grey in the pay-off matrix. The combination 'accelerate/ignore' emerges if short-term profits dominate decision-makers.

In short term with probability of floods lower than 0.4, the game is similar in structure to Deadlock. Both players have a dominant strategy. Upstream prefers ‘accelerate’-strategy and downstream ‘ignore’. It follows that equilibrium is located in the combination ‘accelerate/ignore’. This situation is in contrast to prisoner’s dilemma, because the equilibrium results in Pareto optimality. It is impossible to make one player better off without making the other one worse off.

In case of $P > 0.4$, Downstream loses the dominant strategy. Downstream prefers ‘ignore’ if upstream retains and ‘adapt’ if upstream accelerates. The dominant strategy of Upstream is maintained. The game has a Nash equilibrium ‘accelerate/adapt’ in pure strategy for given value of P. In this case, the game cannot be likened to any of the basic types.

Playing with different types of games

In our example above, we had only two parties, when introducing many more, almost every party is both an upstream and a downstream – so each has the incentive to ‘accelerate’ and ‘ignore’. Hartmann (2011) describes this situation as one of ‘clumsy floodplains’. The economically best result for the whole catchment is unlikely to happen. Starting from the flooding game, we modify the rules of the game to see how redistributions of gains and losses may generate an economic more efficient allocation in the catchment area.

Scenario 1: introducing upstream liability rule

Assume an authority decides against the reckless Upstream who is affecting Downstream by accelerating the flood. From now, Upstream has to compensate Downstream for the losses. The distribution in Figure 3 is the result (the right column changes). In the case ‘accelerate/adapt’, Downstream claims a pay-off of 10. The remaining five are for Upstream. In the case of ‘ignore/accelerate’, the liability takes away the risk from Downstream. The risk is transferred to Upstream, who has now to estimate the risk. In long-term, Upstream prefers ‘accelerate’ when Downstream plays ‘.adapt’ and ‘retain’ if Downstream prefers ‘ignore’. The liability has another implication: the compensation of Downstream’s losses through the liability rule deletes disadvantages of building in the floodplains. There is no economical reason for Downstream to reduce damage. The risk of flooding has no impact on allocation decisions, Downstream has an incentive to accumulate values, because Upstream takes the risk. Downstream has in this manner an incentive to waste resources, which is inefficient (Baumol and Oates, 1988). The asymmetry is changed. Now, the Downstream has an advantage. Based on the P, in case of high probability ($P > 0.56$) the situation leads to ignore/retain’ and in case of $P < 0.56$ to ignore/accelerate. The pay-offs in adapt/retain’ offers possibility of negotiation.

Ronald Coase describes the problem of indifference of players whether to be compensated for the losses or receiving income from certain goods (Coase, 1960, p. 15). This liability thus creates moral hazards.

In case of high value of P Upstream can offer a payment to Downstream for pursuing ‘adapt’ instead of ‘ignore’, and pursues himself the strategy ‘accelerate’ (Figure 4). Upstream could offer a payment of 0.5 of the original 5 to attract Downstream with the highest pay-off in the matrix (10.5) for ‘adapt’. This makes Downstream to play ‘adapt’ over ‘ignore’ when Upstream plays ‘accelerate’. Initial payment for Downstream was not sufficient. Therefore, Upstream needs to pay additional 0.5 to make the action ‘adapt’ attractive. Then, no damages happen and in sum, the catchment yields a benefit of 15. The most efficient allocation is achieved.

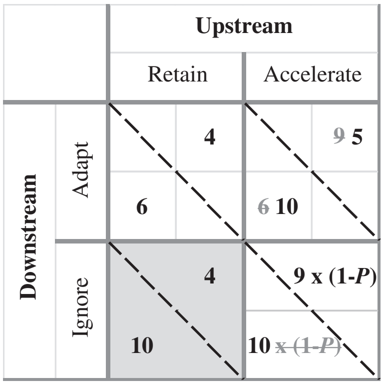


Figure 3 Introducing Upstream liability rule.

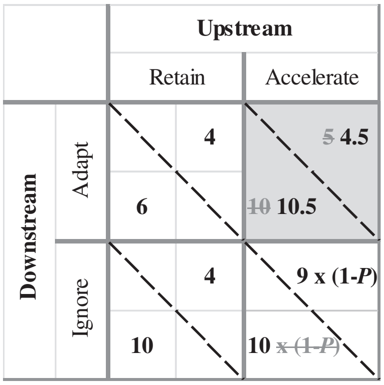


Figure 4 Introducing Upstream liability rule after the negotiation.

Scenario 2: introducing downstream liability rules

What possibilities does Downstream have without the liability rule? Ronald Coase shows that the allocation of resources will be the same. The allocation depends on the benefit and the costs of damage. If the benefit is bigger than the damage, the firm accepts costs of liability the victims are not able to pay the firm off (Coase, 1960).

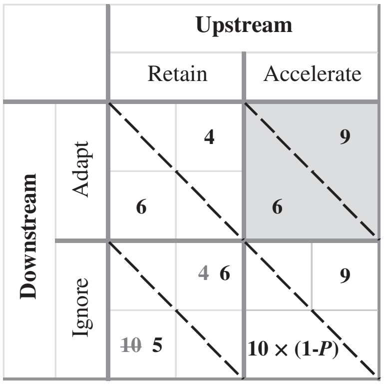


Figure 5 Downstream pays Upstream.

The pay-off matrix changes (Figure 5): Downstream would pay Upstream for pursuing the 'retain' strategy in order to stay in 'ignore'. Upstream will only agree if he is at least not worst off with this option than with the other options. So Upstream agrees on every offer that assigns at least a pay-off of 9 for him. This implies that a pay-off of 5 remains in the combination 'ignore/retain' for Downstream, the payment is about 5. However, this is not a Nash equilibrium. Under these circumstances, Downstream has a dominant strategy 'adapt' in a long run. It earns 6 no matter what Upstream does. In this situation, Upstream prefers strategy 'accelerate', which brings him pay-off of 9. However, if Downstream considers only short-term profits and estimates P lower than 0.4, there is no Nash equilibrium.

Outcomes in a long run are the same no matter who is responsible for flood protection. It corresponds with Coase's theorem and Coase's allocation neutrality (Coase, 1960).

Whether the conclusions of Ronald Coase are transferable to the Upstream-Downstream case, depends very much on the estimation of the P. A sustainable treatment of the situation, however, regarding long-term effects, and in long terms, P increases. Compared to the previous scenario, upstream achieves higher profits in equilibrium.

Scenario 3: valuable upstream

The case will be different if Upstream and Downstream are not equal in their abilities to gain profit from new housing projects. To realise the potential trade-offs, it needs to be demonstrated that the gains are great enough to make it worthwhile to overcome obstacles. The costs of flood damage mitigation in urban areas are (usually) high, whereas costs of flood mitigation measures in rural areas are (usually) relatively low. Imagine one party yields more land rent (because of better infrastructure, better marketing, better conditions for building etc.). How will the parties distribute gains and losses, which allocation results?

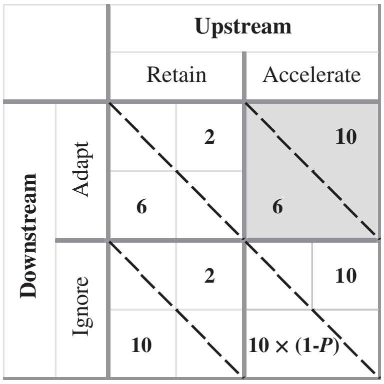
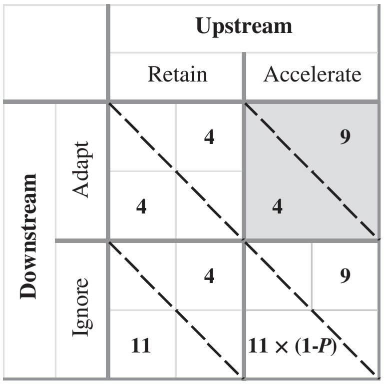


Figure 6 Valuable Upstream.

Figure 6 shows a situation of an Upstream, which yields more benefit from housing projects than Downstream. Upstream yields now a pay-off of 10 maximum in the 'accelerate' strategy; in the 'retain' strategy is able to achieve only 2 based on the higher value of the housing projects in Upstream. This is a result of higher opportunity costs. In this situation, Downstream has no bargaining power to convince Upstream not to play 'accelerate'. In case of lower probability (P < 0.4) both players have a dominant strategy. Upstream prefers 'accelerate' and downstream 'ignore'. This game corresponds to Deadlock with result 'accelerate/ignore'. In long term, (P > 0.4) downstream loses the dominant strategy and would avoid the loss caused by floods. New Nash equilibrium is achieved in the combination of 'accelerate/adapt'. This situation is Pareto efficient with the highest possible social welfare pay-offs (16).

Scenario 4: valuable downstream

Vice versa, if Downstream yields higher pay-off from the housing projects, like in Figure 7, Downstream profits 11 maximum with the strategy 'ignore'; 'adapt' yields even less pay-off. Downstream can realise housing areas and negotiate with Upstream about the costs for the 'retain' strategy. Before starting negotiations, equilibrium is in case of lower probability (P < 0.64) in situation 'accelerate/ignore' based on dominant strategies of both players and



		Upstream	
		Retain	Accelerate
Downstream	Adapt	4 4	9 4
	Ignore	4 11	9 $11 \times (1\text{-}P)$

Figure 7 Valuable Downstream.

type of game Deadlock. In long run, new Nash equilibrium is located in 'accelerate/adapt'. The situation changes in case of negotiation. The highest social benefits is connected with the situation 'retain/ignore'. If the Downstream pays more than 5 (e.g. 6) to Upstream the equilibrium moves to the 'retain/ignore'. Both players reach the higher pay-offs than without negotiation. Both of them profit 1.

Discussion and conclusion

Based on the scenarios presented above, it is not possible to create a universal game solving all the supposed settings. Given that transaction costs are ignored and property rights are determined, the model confirms the allocation neutrality in negotiation. The original rights allocation affects only transfer of wealth (distributional aspect). Negotiation constitutes an important role in the issue of floods. In all cases there was a significant shift in the situation due to possibilities of negotiation. The total pay-off increased using negotiation. Within the modelling, it is possible to solve the situation within transfer of payment as a reduction of money which receives the recipient. In the context of the real world this problem should be solved as pressure to reduce transaction costs. In this regard, the State can contribute, for example through policy, by defining (property) rights and their enforcement.

Among the constraints of the discussed approach are that the probability of floods and risk perception can have a significant influence on the outcomes of the games. Also moral hazard or free-riding have not been considered.

Another important aspect of the above games is the assessment of the costs and benefits, because this is part of a political and normative process. This also incorporates the rather difficult aspect of potential benefits and costs as consequences of particular measures, that is, the question becomes difficult when asking if a party realise a certain benefit because of some measure or if an existing flood protection level inherently leads to certain benefits (White, 1936).

In the real world, where more than one upstream party might provide retention areas, the payments would be a matter of negotiations. We can derive the general conclusion: either find a less-valuable upstream, which you can convince by payments to retain floods, or offer a valuable downstream retention volume for an appropriate payment. In short: pay or swim! This of course, raises interesting issues regarding the notion of justice in flood risk management in practice (Thaler and Hartmann, 2016).

In any real major river catchment the removal of a small volume of storage for a single urban development (e.g. few km^2), has barely measurable influence on downstream flood levels. In our game, we consider only one player in the upstream and one in the downstream for simplicity. Our assumption is a significant impact on downstream correspond to the cumulative impact of multiple floodplains in the upstream. In practice, from the point of view of cities in downstream it would be necessary to negotiate with more cities in the upstream to achieve significant influence.

So, what can we learn from the economic analysis of upstream-downstream relations in the flooding games presented above? The game theory can help to set effective incentives for flood management. Finally, game theory, as discussed above, can help to decide where to take action in catchments – upstream or downstream. The constraints discussed above show that game theory can only contribute one piece for decision. However, as floods have – at least in developed countries – predominantly financial damage (or damage that is relatively easy to monetise, as insurance communities show), this economic approach can be a valuable tool. Such games are not solely applicable to flood risk management, but also to similar problems which are based on arrangements and agreements between landowners within river basin areas. Notably the games for increasing water quality and reducing pollution are similar and in many cases solve the same problem of allocation of measures.

The above discussion excluded the complexity and institutional framing from real-world examples to illustrate basic principles underlying possible negotiations between upstream and downstream on land for flood risk management. To some extent these constraints the applicability, because institutions influence the game substantially, transactions costs are high and political issues of (i.e. across borders) change the setting. Nonetheless, the discussion above also reveals basic economic arguments underlying the layers of complexity that have been disregarded here. It makes explicit to discuss how flood risk management distorts or works with market mechanisms (as simplistic as they are). But the real advantage of using game theory for flooding is not depicting the costs and benefits and making informed decisions on allocation (actually other methods such as CBA might indeed be better suited for this); the benefit of game theory is that it enables experimenting with certain rules such as liabilities, responsibilities, and property right assignments. This is to understand (or even predict) outcomes of negotiations between upstream and downstream under certain regulatory regimes. This can ultimately contribute to better land and water governance for retention and resilience on a catchment scale. The approaches explored in this paper need to be further empirically tested on real-world examples and cases.

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