On Strategic Incentives and the Management of Stochastic Renewable Resources

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Doctoral Thesis
Swedish University of Agricultural Sciences
Uppsala 2005

Acta Universitatis Agriculturae Sueciae
2005:124

ISSN, 1652-6880
ISBN, 91-576-6923-6

Tryck: SLU Service/Repro, Uppsala 2005

Abstract

Magnus Hennlock. *On Strategic Incentives and the Management of Stochastic Renewable Resources*. Doctoral Thesis.

ISSN, 1652-6880, ISBN, 91-576-6923-6.

The thesis consists of four theoretical articles that can be read independently of each other on the common topic - strategic incentives in the management of natural resources. Article I concerns biodiversity conservation of essential species in sustaining the ecosystem. The issue is what forces that may explain why a natural resource stock declines although the government is running a conservation programme in a second-best solution. The focus is on the government's strategic behavior against the industry being a polluter. Ten forces are identified that explains why a resource may decline under a conservation programme. One result is that an increase in the variance of the natural growth process does not lead to an increase in investment in the emission-generating industry in the second-best solution, as in the first-best solution. In article II, a marine natural resource stock is exposed to harvest as well as damage by pollution from N countries. Each country has four decision variables: harvest effort, domestic production (generating transboundary pollution), abatement and research in environmental technology. It is shown that the marine resource is damaged 'twice' as a result of a 'chain effect' in the strategic incentives among the countries. A harvest function is introduced, which results in 'tough' harvest efforts, implying that agents' effort increases the smaller the expected stock size as an extreme case of the 'tragedy of the commons'. In article III, the classical upstream-downstream case is analyzed under the assumptions of the Coase theorem in a dynamic model. Different assignments of rights to determine the level of externality are compared to the case of no-cooperation. It is shown that the 'efficiency proposition' does not necessarily hold. Specifically, a bargaining outcome may not be possible when downstream society has the right to determine the level of externality in the dynamic model as it may violate individual rationality of upstream society. In the fourth article - a technical note - it is shown in a that in most models with private provision of public goods, there exists a simple mechanism determining the reaction functions of the players.

Key words: renewable natural resources, pollution, biodiversity, international environmental problems, bioeconomics, stochastic differential game theory, Coase Theorem, public goods

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Articles appended to the thesis

The thesis is based on the following articles. Article I is accepted and published in the *Swiss Journal of Economics and Statistics 141 (3) 2005*, the article is reproduced here with permission by the Editor. Article II is in submission to *Natural Resource Modeling* and article IV is in submission to *Journal of Public Economic Theory*.

I A Differential Game on the Management of Natural Capital Subject to Emissions from Industry Production

II An International Marine Pollutant Sink in an Asymmetric Environmental Technology Game

III The Coase Theorem in a Stochastic Growth Model

IV Technical Note: Response Aversion in Games Involving Private Provision of Public Goods

Contents

On Strategic Incentives and the Management of Stochastic Renewable Resources

Articles I–IV

1 Introduction

The theme of this thesis is the analysis of strategic incentives when several economic actors either have open access to a natural renewable resource for harvest and/or may influence the growth of an open access resource due to other private activities. There are several examples of transboundary natural resources e.g. marine resources, animal species habitats, water resources, and fisheries where the benefits are shared by many regions or nations and where conflicts of interests occur in the decision of policies, such as harvesting, environmental policies, and rehabilitative means. Several policies integrate ecosystem rehabilitation through more sustainable productions in agriculture, forestry, fisheries and through sustainable management of renewable resources. In a broader context, biodiversity and ecological relationships are transboundary. Management of 'local resources' such as rural water, land, agriculture, forests, sanitation and energy in one country or region will often affect sustainability also in neighbor countries or regions due to ecological relationships as well as transboundary pollution that harms renewable resources. Thus, initiatives in the field of sustainable development management and biodiversity conservation often need to be international and/or interregional. This makes the analyze of strategic incentives and cooperation a central issue in sustainable development. Consequently, there are growing problems faced by many countries and regions bordering transboundary resources arising from lack of effective policies, instruments, and mechanisms for managing resources. It may be issues concerning over-harvesting, pollution, groundwater shared by regions, building dams for hydroelectric power.

The coexistence of stock externalities, uncertainty and several independent regions or social planners suggests stochastic differential game theory as a tool to analyze the decision-making problems. This approach is essentially a combination of game theory and optimal control. The first steps in the development of differential game theory were taken by Rufus Isaacs during 1951-1954 in four RAND working papers.[1] During 1960s and 1970s several articles were written on the topic. Lancaster (1973) was an early application of differential game theory on economic growth theory. During the 1980s and 1990s, differential game applications began to be used in natural resource economics e.g. Clemhout and Wan Jr (1985), Kaitala (1989), Jorgensen and Sorger (1990), Yeung (1992), Kaitala (1993), Kaitala and Pohjola (1995), Jorgensen and Yeung (1996) and Maler et al. (2003).

A drawback of stochastic differential game theory is the problem of finding analytical tractable solutions. The functional structures that yield analytically tractable solutions are very limited beyond the linear-quadratic approach, i.e. a linear dynamic system and quadratic objective functions. It is well known that the closed-loop concept requires specific structures of the functions to yield analytically tractable solutions in the Isaacs-Bellman-Fleming equation such as the linear-quadratic approach e.g. Starr and Ho (1969), the linear state games or the logarithmic models e.g. Reinganum (1981). A common approach as in e.g. Clemhout and Wan Jr (1985) is to use square-root functions in the dynamic system as well as the objective functions. This may imply that the state variable cancels in the product of the

[1] Isaacs (1965)

shadow price function and the dynamic system leaving a constant in the maximized Isaacs-Bellman-Fleming equation. I was inspired by Yeung (1998) as I found that this method easily could be generalized to include constant returns-to-scale Cobb-Douglas functions in the dynamic system with the control variable and the stock variable as arguments. Specifically, in the simplest case, say that the objective function contains the term $x^{\alpha}(t)$ with $x(t)$ as the stock variable, then the dynamic system may contain the terms $x^{1-\alpha}(t)$ or $x(t)$ as the shadow price function contains the term $\alpha x^{\alpha-1}(t)$. This concept may then be extended by introducing cross-products between state variables and the control variables in 'proper' ways in the functions to generate 'block recursive' maximized Isaacs-Bellman-Fleming equations with analytically tractable solutions. Since the functions of x can be transformed to linear functions the models can often be transformed to linear state games or an extension of these games in the presence of cross products. The transformation to linear state games is useful in stochastic differential game theory as the second derivative term of the value function cancels in the Isaacs-Bellman-Fleming equation (Dockner et al., 2000). Variations of this approach are used in this thesis in articles I, II and III. There were relatively few papers that presented models with explicitly identified nonlinear feedback Nash equilibria that were not degenerate. However, in the last decade there has been an increasing discovery and use of the latter. Moreover, in e.g. Yeung (1998) an overview of papers are presented and it is also shown that some differential games such as Sorger's game of competitive dynamic advertising (Sorger, 1989), Clemhout and Wan Jr's game of dynamic property resources (Clemhout and Wan Jr, 1985) or Reinganum's game of race in research and development (Reinganum, 1982) belong to a class of games which has linear value functions. Even though, differential game theory models have been developed, the textbook literature on differential game theory has been rather sparse. A classical book is Basar and Olsder (1999), which also covers difference games, however it is not until recently that other books have appeared, such as Petrosjan and Zenkevich (1996) and Dockner et al. (2000). A more recent development is cooperative differential game theory although there are some classical literature on the topic such as Leitmann (1974), Haurie (1976), Petrosjan (1977) and Haurie et al. (1994). Recently, cooperative stochastic differential games with time consistent rules for distribution of the gains from cooperation have been developed e.g. Petrosjan (1997), Yeung and Petrosjan (2001), Yeung and Petrosjan (2004) and Yeung (2004).

The thesis contains four articles. Three of the articles use stochastic differential game theory techniques to explore strategic incentives when uncertainty is present. The first and second article, use non-cooperative stochastic differential game theory while the third article uses techniques from stochastic cooperative differential game theory. Finally, the fourth article is a technical note on the determination of reaction functions in static public good models though the results transform to dynamic models.

2 Article I - A differential game on the management of natural capital subject to emissions from industry production

The topic of article I concerns biodiversity conservation of ecosystems that have indirect-use values such as essential species in sustaining the ecosystem. The issue is what forces may explain why a stochastic natural resource stock declines when the government is running a conservation programme in a second-best solution. A model is developed where a government makes tax-financed investments in a downstream renewable resource stock that is damaged by upstream industry pollution. The analysis focuses on the situation where the government and the industry act independently of each other in a second-best solution, though it is the government incentives that are of primary interest in the game-theoretic analysis. While the industry only receives profit from industry production, the government receives benefit from industry production as well as the renewable resource stock that is to be restored and conserved. Moreover, the government faces a budget constraint implying that the investment must be financed by taxing the industry.

The article introduces five concepts. Firstly, the essential focus is on the renewable resource stock - not pollution *per se* normally occurring as damage in the objective function. The issue is rather how pollution damages the renewable resource stock and how this fact conveys to the shadow prices and costs of the stocks in the optimization problems. The damage of current pollution is modelled as future damage on the natural resource stock. Technically, this is modelled by introducing an endogenous decay rate of renewable capital determined by the ratio of current emissions flow and current renewable resource stock size. The result is that the smaller the current renewable resource stock is for a given current emissions flow, the greater is the damage to the growth of renewable resource stock. This means that the *actual* carrying capacity may differ (be lower) than the *natural* carrying capacity without industry pollution. It therefore takes time for the resource stock to recover from current emissions flow. However, the government may increase the speed of recovering by investments in the renewable resource stock such as restoring and arranging habitat, land, wetlands or food supply. Secondly, the natural growth function is a concave function which introduces an elasticity measure $\varepsilon \in (0, 1)$ of growth representing how 'resistant' the resource stock is to reductions in its own stock level. The greater is ε the less will natural growth fall as the current stock size falls. If $\epsilon = 0$ the growth function is a linear function with positive slope. If $\varepsilon = 1$ the growth function is a linear function with negative slope and a positive intercept with the vertical $\dot{k}_N$ axis, implying that the natural growth rate cannot go down to zero. For all values $0 < \varepsilon < 1$ the natural growth function exhibit a smooth concave function of the logistic growth function type. The benefits of the introduction of this growth elasticity measure in the natural growth function is that it can generate a wider range of natural growth rate patterns that apply to different species. Moreover, the functional form can be transformed to fit the limited structures that are known to generate analytical tractable solutions in dynamic programming solutions. Thirdly, the smaller the natural resource stock size, the greater amount of investment is needed to increase growth by a given amount. Technically, the investment in the natural resource stock is defined by a constant-returns-to-scale Cobb-Douglas function with investment and stock as arguments. The smaller the resistance ϵ of the resource stock, the less effective is a given amount of investment. Fourthly, the damage from emissions flow is determined by an endogenous decay rate function, determined by the ratio between emissions flow over the resource stock size, suggesting that a given emissions flow generates a greater decay rate if the current stock size is small. However, a great resistance ϵ of the resource stock counteracts this effect. Fifthly, a common approach in the literature using differential game theory is to use square-root functions in objective functions and the dynamic system. In this article, I solve the model without specifying the functions completely and thereby make explicit the type of inherent structure that results from this kind of technical restrictions in the literature. From an economic viewpoint, the technical restriction is here plausible as it implies that the social planner derives a greater utility from a natural capital stock that is 'more resistant' to emissions, i.e. the growth of natural capital falls less from a given reduction in stock size due to damage from emissions flow.

Comparative statics around the second-best solution shows ten Forces, or caveats, that may explain why a stochastic natural resource stock declines even though the government is running a conservation programme in the second-best solution. Some caveats are an industry sector with *long-term* preferences, a low depreciation rate of physical capital beyond uncertainty in the natural capital stock. Moreover, in the second-best solution, the industry's investment path is independent upon the variance of the stochastic process. However, this was not case in the first-best solution when the government is in charge of industry investments; the greater the variance of natural resource's growth process the greater is the government's investment in the emission-generating industry. Hence, even though the second-best solution implies greater investments in the emission-generating industry *per se*, it hampers the government's increase of investments in the emission-generating industry resulting from an increase in uncertainty of the natural resource stock.

3 Article II - An international marine pollutant sink in an asymmetric environmental technology game

Heretofore, the issues of harvest and pollution have usually been treated separately in different models. An overview of the models on e.g. fishery is found in Bjorndal et al. (2000). In the 1990s, differential game theory has also been introduced in international environmental issues. Often these models are based on national consumption or production, which generate transboundary pollution, for example de Zeeuw and van der Ploeg (1991), Kaitala et al. (1992), Tahvonen (1994), Haurie and Zaccour (1995), Maler and de Zeeuw (1998), Jorgensen and Zaccour (2001*b*), Jorgensen and Zaccour (2001*a*). This article allows for harvest and pollution to appear together in a model with N countries. Several marine resources are subject to transboundary pollution (e.g. being used as pollutant sinks) as well as harvest, such as the Baltic sea, where biomass is harvested at the same time as there is overfertilization from agriculture. The stock of biomass is then affected by both these measures. It could be argued that the damage from using a renewable resource as a pollutant sink could be seen as another kind of 'harvest', however, there is one important difference - harvest is a flow that can be changed quickly while pollution is often a stock, which takes time to change. Thus, the damage effect from harvest on renewable capital should therefore be of different character compared to the damage effect of pollution. Rehabilitative means after a damage from pollution requires the reduction of a pollution stock not just the reduction of harvest flows. Not only is pollution long-lived *per se* but also the damage to the resource stock.

Technically, the article brings together ideas from several areas: IO theory and the approach of 'tough' strategies from Fudenberg and Tirole (1984), extended to international environmental problems in Copeland and Taylor (1990); differential game models on international pollution such as Kaitala et al. (1992), Tahvonen (1994), de Zeeuw and van der Ploeg (1991) and de Zeeuw and Maler (1998); bioeconomics with open access e.g. Clemhout and Wan Jr (1985), Kaitala (1993), Jorgensen and Yeung (1996) and de Zeeuw and Maler (1998) and endogenous horizontal innovation growth models from growth theory e.g. Romer (1990) and Jones (1995). The game is solved by using the Isaacs-Bellman-Fleming dynamic programming technique, identifying the subgame perfect Nash controls of investment rates, harvest efforts, abatements and environmental research efforts for N countries. The solution is then compared to the social optimum solution solved with stochastic optimal control theory.

The features introduced in the model are as follows. Firstly, each country has four decision variables, harvest effort, investment rate in domestic industry (generating emissions), abatement, and finally, environmental research efforts that improve the abatement measures. Secondly, a harvest function is introduced where the damage of the N countries' harvest efforts are measured as a decay rate with a damage parameter. The point is that harvest activities, beyond the caught individuals, may cause further damage of different degrees to habitats and disturbing reproduction and this degree is reflected by the damage parameter. Thirdly, the damage from pollution is measured as a concentration rate between the current pollution stock and natural resource stock. The greater the pollution stock is over the natural resource stock the greater is the current decay rate and the greater is the future loss of natural resource stock. Beyond this, there is also a toxicity parameter reflecting different degrees of toxicity of the pollution. Fourthly, the paper introduces endogenous growth that are asymmetrical across the N countries. The research sectors and the accumulation of environmental knowledge follow a simple accumulation process similar to the Romer (1990) growth model with the same result that the research effort (in each country) is constant over time. There is also a cost of doing research that may differ between the countries. Fifthly, the paper introduces a pollution stock with a sum of N Cobb-Douglas functions determining the total growth of the pollution stock in the sea. The arguments are pollution flow by each country and the present pollution stock size. The growth of pollution is decreasing by the degree of toxicity. The latter could be discussed, as it is rather a result of technical convenience to keep the solution analytically tractable. Sixthly, the total abatement effort is determined by a sum of N Cobb-Douglas abatement functions. The natural growth function, the domestic production sectors and the physical capital accumulations are adopted from article I.

A major result of the harvest function is 'tough' or 'aggressive' harvest efforts. In many dynamic models on renewable resources, harvest efforts decrease as the stock size decreases. In this model, the agents' effort increases the smaller the expected stock size as an extreme case of the 'tragedy of the commons'. Such harsh competition about what is left of a valuable resource has been seen for commons in the developing world, e.g. the Lake Manzala in Egypt where poor fishermen desperately increase efforts by fishing during spawning/breeding seasons, using illegal fine mesh nets and even dynamite or poisons in the competition for a declining food resource. In the model, it is seen that the aggressive harvest effort signals a credible threat by one agent to other agents: If any other agent increases harvest effort, emissions or reduces abatement effort (and thereby reduces the expected stock of renewable resource), the agent in question will also speed up harvest effort as a credible threat to protect its claims on what is left to harvest of the resource. This rational reasoning holds for every agent. Due to strategic incentives in the subgame perfect Nash equilibrium, the resource stock is exploited and damaged twice, firstly, by increased emissions, and then secondly, by increased harvest efforts. Each agent harvests the resource earlier in time in order to get as much of the resource before the concentration rate (pollution stock per unit of renewable resource stock) grows and increases the depreciation of the resource.

There are two alternatives for an agent to reduce the world's pollution stock, by abatement or by exploiting the transboundary renewable resource as a pollutant sink (assimilation). The former alternative incurs two *private* costs to the agent, a cost for abatement effort and a cost for environmental research effort. On the contrary, the latter alternative incurs a sunk cost of forgone future resource for *all* agents as pollution decreases current reproduction capacity. In the Nash equilibrium, each agent performs less abatement and less environmental research effort, therefore shifting over the burden of pollution to all the other agents by using the transboundary renewable resource as a pollutant sink rather than investing in environmental technology compared to the social optimum. As a result, the concentration of pollution absorbed by the renewable resource stock grows at a higher rate in the subgame prefect Nash equilibrium, which creates further incentives to each country to speed up harvest effort as the efficiency of harvest effort falls with the increase in concentration of pollution. The strategic incentives in abatement, harvest efforts and investments in emission-generating industry as well as environment research, all originate from the same source - the externality connected to the open access of the marine resource. Another result, which is expected, is that volatility in the renewable resource stock slows down agents' environmental technology growth in the Nash equilibrium. Every agent prefers to harvest the resource too much and too early in time as the concentration of pollution stock per unit of resource stock rises faster and damages the stock earlier in time. The greater the volatility, the greater is the incentive for the agent to shift over the burden of pollution to the other agents by using the resource as a pollutant sink rather than investing in domestic environmental technologies that improve domestic abatement efforts.

4 Article III - The Coase theorem in a stochastic growth model

This article illustrates the Coase theorem in a dynamic model with stock dynamics. The essential difference, compared to the static models that have been launched hitherto, is that the initial Coasean bargaining not only concerns an externality level with a corresponding lump sum reallocation, but rather a 'plan' of Pareto optimal controls and a liability payment flow to the agent that has the right to determine the externality level. The latter flow is, technically, a side payment flow to 'bribe' the agent having the legal rights to reduce the externality level. This implies that one may look at techniques used in cooperative differential game theory e.g. Petrosjan and Zenkevich (1996), Petrosjan (1997) and Filar and Petrosjan (2000). There is also a literature on (time consistent) side payments in upstream-downstream e.g. (Jorgensen and Zaccour, 2001*b*) and Haurie and Zaccour (1995). Recently, a literature has emerged on the issue of finding payoff distributions between participants in cooperative stochastic differential games, e.g. Yeung and Petrosjan (2004) and Yeung (2004).

The article does not deal with aspects of imperfections within the Coase bargaining process but will assume that the bargaining process takes place with no transaction costs and result in a Pareto optimal bargaining outcome. The contribution of this paper is rather that it illustrates the Coase theorem in a dynamic model with upstream and downstream stock dynamics. A very simple model, which is a transformation of a linear state game, is used for illustration. However, the dynamic programming is used to find the solution just as in the two other articles. A phase portrait of the Coasean vector field illustrates the results. The assignment of property rights will not affect the Coasean steady state and the surrounding Coasean vector field. The agent that has the right to determine the externality level has the advantage to choose initial conditions in the Coasean dynamic system. i.e. whether the process starts in upstream society's or downstream society's private equilibrium steady state. It is found that the corresponding liability payment flow is proportional to the production volume of upstream society. The Coasean bargaining solution policy then involves a move from any of these initial conditions towards the Coasean steady state. The unique Pareto optimal transition paths connecting each private equilibrium steady state and the Coasean steady state are identified. When the contracting parties reach the Coasean steady state, the party that lacks the right to determine the externality level has to continue paying a steady state liability flow forever to the party that has the right to determine the externality level. The effect of increased volatility in the stock enters the dynamic system in the same way as increased time preferences or depreciation rates since uncertainty reduces the shadow price at given stock levels. The growth in downstream society is further delayed by a low downstream technology level and/or high downstream depreciation rate and/or high volatility of downstream stock and a high pollution parameter. Even though both societies will gain in the long-run, downstream society has to wait longer than upstream society before it can collect the gains in terms of higher growth.

Another major result is that the efficiency proposition that the initial assignment of rights does not affect the Pareto optimal solution does not hold in this model.

When downstream society has the right to be free from pollution, individual rationality (at each instance of time) is not satisfied for the upstream society. The disagreement shadow price of upstream capital is too low as the upstream society enters the bargaining process. This result probably stems from the naive relationship between emissions and production in the upstream society. The downstream society would not allow any upstream emissions at all, and hence, upstream society are forced to zero production and the disagreement shadow price of upstream society is zero as bargaining commence.

5 Article IV - Response aversion in public goods models

The slope of a player's reaction function reveals her willingness to 'exchange' a unit of own activity for a unit of other players' activity. In other words, the slope of the reaction function reveals the player's 'response aversion' to changes in other players' activities. Article IV is a technical note that presents a mechanism, which may mitigate analysis and improve understanding of subgame perfect behavior in public good models with private provision. Specifically, the mechanism shows how a player may be response averse, response neutral or even a response lover depending on the relationship between her marginal benefit and marginal cost functions. By translating a player's strategic behavior to terms of her marginal benefit and marginal cost functions, the mechanism enlightens the way policy instruments, economic instruments in agreements and institutions affect the strategic behavior of an actor.

However, the mechanism only applies to public good models. The mechanism may e.g. be applied on public goods in coalition theory where the slope of a player's reaction function is a proxy for her incentives to free-ride on other players' increase in activity levels beyond non-cooperative levels. Carraro and Marchiori (2002), present a summary of the last decade of developments of theory of coalition stability. They conclude that the slope of the reaction function is one of four major features (the other being membership rules, order of moves, and players' conjectures) that are conclusive for the stability of coalitions and agreements. The mechanism derived in this note then enlightens the way policy instruments, the level of congestible services, economic instruments stated in agreements and institutions that punish free-riding will affect free-rider incentives in public good models.

6 Drawbacks and Further Research

The purpose with this section is to give some support to those who should view this thesis from a critical standpoint. A second purpose is to bring forward suggestions for further research. There are several simplifications, restrictions and drawbacks in the four articles and the author do not claim that these are all drawbacks or shortcomings of the articles. The supervisors and external reviewers gave professional support and the author is therefore solely responsible for all shortcomings in the articles of this thesis.

6.1 Article I

A serious restriction, or drawback, of the first article is that the industry has no strategic response to changes in the government tax in the second-best solution, and hence, the model, as it stands, cannot be used to analyze Pigovian taxes. However, the purpose of the article is to focus on the government's strategic response to the industry behavior when it is running the conservation programme of investing in the natural resource stock. By making the model more complex and introducing an industry response to a change in taxes, the effect of Pigovian taxes could have been analyzed as well. This would most likely also change the result that there is no change in investment in the emission-generating industry from an increase in uncertainty in the second-best solution.

Another extension would be to use robust control to analyze possible precautionary behavior of the government as the natural resource stock size become low (Roseta-Palma and Xepapadeas, 2004).

6.2 Article II

A conclusive simplification in this model is the common parameters in the abatement function, decay function and growth function of pollution. These restrictions derive from the priority to find analytically tractable solutions. In some cases, the restrictions may be plausible; however, the appearance of the pollution toxicity in the growth function of pollution is questionable. Unfortunately, I have no suggestions for improvements if we are looking for analytically tractable solutions and this is, no doubt, a weakness of this part of the model.

An extension to this model would be to add research in a traditional sector and let each country allocate resources between the two domestic resource sectors. However, the technical problems may be extensive. Another extension would be to solve the model (and the model in article I) for subgame consistent cooperative solutions with time consistent payoff distributions between the actors. Technical achievements in cooperative game theory with stochastic processes have been made recently in papers by Yeung and Petrosjan (2004). Their approach could likely be used to find analytically tractable solutions to the models with a structure of the kind in this paper.

6.3 Article III

Article III illustrates the Coase theorem in a very simple model, which is, as far as I can see, a transformation of a linear state game. It would be interesting to extend this model to a non-linear approach as well as abandon the naive relationship between the upstream capital stock size and the upstream emissions such that upstream society can hold a stock that is invested elsewhere without generating emissions as well as engaging in environmental research changing the relationship between capital size and pollution flow. This would change the disagreement condition of upstream society in a way that may make it possible to fulfil the efficiency proposition. Furthermore, one could look for weaker individual rationality conditions rather than the using the strongest condition (rationality satisfied at each instant of time). Until then, the question remains, is it possible to reproduce the Coase theorem's 'efficiency proposition' in a dynamic model with stock dynamics?

6.4 Article IV

This note was sent to the previously mentioned journal and came back from the associate editor saying that the paper makes a "technical point whose contribution is difficult to understand". There is a request for adding an application as an illustration or an explicit discussion that motivates what we learn from this technical note.[2] However, reviewers seem to agree that the mathematics is correct, though two reviewers asked, "What is Young's theorem?" (answer: the cross-derivatives of a function f are identical if f is twice continuously differentiable, see e.g. Chiang (1984)). Anyway, the author is inclined to say that all we may learn from this technical note is already there in the note. The theorem just presents a mechanism that holds in public goods models. That's it.

[2]Such an application could be to use the mechanism in the analysis of private provision in public good models with coalition theory. Besides this, the mechanism can sometimes also be used to simplify calculation of the reaction function.

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