Journal of Environmental Economics and Management 70 (2015) 1–16

Contents lists available at ScienceDirect

Journal of
Environmental Economics and Management

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

Equilibrium resource management with altruistic overlapping generations

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ARTICLE INFO

Article history:
Received 19 August 2013
Available online 19 December 2014

JEL classification:
C73
D64
D90
Q01
Q22
C61

Keywords:
Overlapping generations
Time inconsistency
Hyperbolic discounting
Markov perfect
Renewable resources

ABSTRACT

We imbed a classic fishery model, where the optimal policy follows a Most Rapid Approach Path to a steady state, into an overlapping generations setting. The current generation discounts future generations' utility flows at a rate possibly different from the pure rate of time preference used to discount their own utility flows. The resulting model has non-constant discount rates, leading to time inconsistency. The unique Markov Perfect equilibrium to this model has a striking feature: provided that the current generation has *some* concern for the not-yet born, the equilibrium policy does not depend on the degree of that concern.

Introduction

To what extent does the degree of our concern for unborn generations affect the equilibrium management of a resource? We address this question using a fishery model, both because of fisheries' intrinsic importance, and also in order to provide focus. However, the research question is central to many resource problems where current decisions have long-lived consequences. These resource problems are intergenerational, but the standard approach studies them using an infinitely lived agent model. That model cannot distinguish between two types of intertemporal transfer, the first between the same agent at different stages of her life, and the second between two different people living at different times. The pure rate of time preference (PRTP) is appropriate for evaluating the first type of transfer, but there should be no presumption that society uses the same discount rate to evaluate the second type of transfer. We imbed a two-parameter discounting model in an overlapping generations (OLG) model. One parameter is the agent's PRTP for their own utility, having the standard interpretation. The second parameter, reflecting intergenerational altruism, measures society's willingness to forgo current utility for the sake of future generations. We study the role of altruism by showing the relation between the altruism parameter and the equilibrium in the natural resource problem.

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http://dx.doi.org/10.1016/j.jeem.2014.12.001
0095-0696/

The Millennium Ecosystem Assessment identifies fisheries as a critical environmental stock (United Nations, 2005). Due to overfishing, loss of habitat, and climate change, at least 30% of the world's fisheries are at risk of population collapse (Sumaila et al., 2011). Fisheries support nations' well-being through direct employment in fishing, processing, and ancillary services amounting to over US$ 220 billion annually (Dyck and Sumaila, 2010). Fish provide nearly 3.0 billion people with 15 percent of their animal protein needs; including post-catch activities and workers' dependents, marine fisheries support nearly 8% of the world's population.

The actual fishery management problem is intergenerational: agents alive today have to decide how much of the stock to retain for future generations. Agents currently alive have a standard optimization problem if they do not care about the not-yet born, or if they discount the future utility flows of the not-yet-born at the same rate as they discount their own future utility. In all other cases, their implied discount rate is non-constant, either decreasing, as with hyperbolic discounting, or increasing. In these cases, the current generation's optimal policy trajectory is not time consistent.

The current generation cannot reasonably believe that it can choose actions that subsequent generations will implement. We therefore consider a particular class of time consistent equilibria, in which the harvest decision at a point in time is conditioned on the fish stock – the state variable – at that point in time. We obtain a Markov equilibrium to the dynamic game amongst the sequence of policymakers. Each policymaker in this sequence is the representative agent at a point in time. The Markov Perfect Equilibrium (MPE) is a subgame perfect Nash equilibrium to this sequential game: the policy rule chosen by each representative agent is optimal, given her beliefs about the policy rule future generations will use.

For general functional forms, this game provides few insights into our research question. Most natural resource problems, like most optimal control problems in other areas of economics, rely on particular functional forms to provide insights. Perhaps the model most widely used to propose target fishery stocks, and certainly the model most widely used to explain the management problem, is linear in the harvest rate (Clark and Munro, 1975; Clark et al., 1979; Clark, 2005). With this model, the benefit per unit of harvest is constant and the cost per unit of harvest is a decreasing convex function of the fish stock; harvest costs increase as the stock falls. The equation of motion equals the natural growth rate of biomass minus the harvest. This model provides a plausible, elegant, and easily interpreted recommendation: the stock should be driven as rapidly as possible to a steady state. The solution is "bang-bang", i.e. it involves a Most Rapid Approach Path (Spence and Starrett, 1975). The steady state depends on the per unit benefit of harvest, the growth equation, the harvest cost function, and importantly, on the discount rate used to evaluate future benefits.[1]

We imbed this linear-in-control model into the sequential game described above, and obtain a striking conclusion: provided that the current generation has *some* concern for the not-yet born, the equilibrium policy rule, and thus the stock trajectory and the steady state, are all independent of the *degree* of concern for future generations. The steady state depends on the agent's pure rate of time preference and the population growth rate, but not on the altruism parameter.[2]

This independence result has an alternative interpretation: the equilibrium policy depends only on the time-0 value of the time-varying discount rate used by the social planner who aggregates agents' preferences. This time-varying discount rate depends on agents' pure rate of time preference, their mortality rate, and their altruism with respect to future generations. However, the time-0 value of this discount rate depends only on the pure rate of time preference and the population growth rate. Thus, in our setting, the statement that the policy depends only on the time-0 value of the discount rate implies that the policy is independent of intergenerational altruism. This alternative interpretation leads to a simple comparison between the MPE and the equilibrium of the planner who can commit to future actions. The former depends only on the initial value of the time-varying discount rate, and the latter depends only on the asymptotic value (as time goes to infinity) of the discount rate.

With more general functional forms, we expect that the MPE depends on all of the discounting parameters. In a MPE, the current planner directly controls current actions; she can influence future actions only by manipulating the state variable upon which future equilibrium actions are conditioned. It is plausible in this setting that current actions are especially sensitive to short run (compared to long run) discount rates. In the linear-in-control problem, we see an extreme form of this relation: the MPE depends only on the short run discount rate.

We use the fishery model throughout, but it is worth emphasizing that our fundamental result applies in all optimization problems with this linear-in-control structure. Spence and Starrett (1975) consider two natural resource applications and three other (non-resource) capital accumulation problems. Their first natural resource application is the fishery model that we also use, and their second application involves a stock pollutant. Our proofs rely on the linear-in-control structure, but not on the fishery context. Therefore, one could also apply our results to stock pollutant and other problems.

Discounting assumptions are important in most of these settings. For example, discounting is central to an ongoing debate about climate policy; greenhouse gasses are the quintessential stock pollutants. Important contributions to this debate include Stern (2007), Nordhaus (2007), Weitzman (2007), and Dasgupta (2008). Although the prevailing view is that climate and other environmental policy is very sensitive to discounting assumptions, the evidence for this view is based on numerical results or on special functional forms. The relation between equilibrium environmental policy and discounting is

[1] For readers who are concerned that the linear-in-control model is not general, we note that many insights into difficult problems are generated using specific functional forms. The log-linear and linear-quadratic dynamic models, along with the linear-in-control model, are the most obvious examples.

[2] We find one exception to this strong result. If the current generation has literally no concern for future generations (i.e., it discounts those generations' benefits at an infinite rate), then the steady state is different: there is a discontinuity in the equilibrium decision rule, in the limit as the current generation's concern for the not-yet born vanishes.