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ScienceDirect
Journal of Economic Theory 138 (2008) 237–261
JOURNAL OF Economic Theory
www.elsevier.com/locate/jet

Comparative dynamics in a productive asset oligopoly

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Received 10 January 2005; final version received 29 October 2006
Available online 12 July 2007

Abstract

We build a subgame perfect Nash equilibrium of a common property productive asset oligopoly and analyze separately the impact of a change in the implicit growth rate of the asset and a change in the number of firms exploiting the asset. We show that the steady state level of asset can be a decreasing function of the asset's implicit growth rate. This phenomenon arises when the initial stock of asset is *below a certain threshold*. In the short-run we show that firms' exploitation rate can be a decreasing function of the implicit growth rate. We study the impact of a change in the number of firms that share access to the asset. Reducing the number of firms can result, in the long-run, in higher industry production. In the short-run, it can result in an increase of the industry's exploitation *and* a decrease of the level of the asset's stock.

JEL classification: D43; L13; Q34; C73

Keywords: Productive asset; Oligopoly; Dynamic games

1. Introduction

We consider a common property productive asset that is exploited by a fixed number of firms. The equilibrium path of the stock of asset depends on several parameters that characterize the nature of the asset as well as the market conditions. In this paper we study separately the sensitivity of the equilibrium paths of the stock of asset to the implicit growth rate of the asset and to the total number of firms that share access to the asset. We use an oligopoly model, where firms exploit the asset and compete in the output market by choosing quantities.

An important parameter that impacts the long-run stock of asset is the asset's implicit growth rate which can be considered as an indicator of its fertility rate. It is intuitive to expect that, the larger the implicit growth rate of the asset the larger the stock of asset. We show that this intuition

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0022-0531/$ - see front matter
doi:10.1016/j.jet.2006.10.012

may be wrong: the steady state level of asset can be a decreasing function of the asset's growth rate. A productive asset with a given implicit growth rate can converge to a smaller steady state level than a productive asset with a smaller implicit growth rate. This possibility arises when the initial stock of asset is *below a certain threshold*. The additional productivity gives an incentive to firms to increase their exploitation. If the stock is below a certain threshold, the impact of the overall production expansion outweighs the impact of an increase in fertility and the asset converges to a stock level that is smaller than the level it would have reached under a smaller implicit growth rate. Although firms benefit from the increase in the implicit growth of the asset, from a conservationist's viewpoint the effect of such an increase in fertility is negative. We also show that, in the short-run, an increase in the implicit growth rate of a productive asset can induce, a more frugal exploitation on behalf of firms. This can happen because the increase in the implicit growth rate increases the asset's rent which induces firms to temporarily reduce their extraction rate despite the fact that the asset is under common property.

In the second part of the paper, we fix the implicit growth rate and study the impact of a change in the total number of firms that share access to the resource. In sharp contrast with a static framework, in an oligopoly model with a productive asset we show that with less firms there can be also higher industry production. Moreover, reducing the number of firms can have, in the short-run, a negative impact on the asset's stock. More precisely, we show that in the case of a productive asset oligopoly, the industry's total production path when the number of firms $M > 1$ can (initially) exceed the industry's production path when the number of firms is $N > M$. This is because the reduction in the number firms affects both the competition at the level of the output market and the interaction at the resource level. We show that a decrease in the number of firms having access to the resource stock reduces the resource rent and thus induces firms to expand their production. Such an incentive of production expansion due to a decrease in the number of firms from N to $M < N$ can outweigh the reduction in the total sales that would occur in an imperfectly competitive market without resource rents.

To conduct our study we use a differential game framework (see Dockner et al. [7]) and focus on closed-loop strategies: the strategy of a firm is a production rule that can depend on time *and* on the asset's stock. The differential game framework has been a useful tool to study the exploitation of a productive asset by a fixed number of agents. In a continuous time framework, [1] Dockner and Long [8] showed that in a transboundary pollution game between two countries there exists a continuum of closed-loop Nash equilibria and that as the interest rate tends to zero the equilibrium long-run stock of pollution converges to the equilibrium stock of pollution under cooperation. Dockner and Sorger [9] studied the joint exploitation of a productive asset by two agents and constructed a continuum of closed-loop Nash equilibria all of which result in the long-run in over-exploitation of the asset. Moreover, they showed that as the interest rate tends to zero the steady states generated by the closed-loop Nash equilibria converge to the first-best level.

In this paper we use a continuous time framework where the time horizon is infinite, future utility is discounted and the strategies considered do not depend on the history of the game and do not allow for the use of triggered punishment. Unlike in Dockner and Long [8] and Dockner and Sorger [9], in this model, each agent's instantaneous utility depends on all agents' exploitation rates. This is due to the fact that firms are oligopolists in the output market. The model we use extends the duopoly model in Benchekroun [2] to an oligopoly. Benchekroun [2] determined the impact of *a marginal* unilateral production restriction. Starting at a closed-loop Nash equilibrium

[1] Discrete time differential games are often referred to as difference games. For discrete time frameworks, see for example Levhari and Mirman [15], Benhabib and Radner [3], Dutta and Sundaram [10,11].