



Does productive capital affect the order of resource exploitation?[☆]

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Abstract

The purpose of this paper is to show that in a general equilibrium framework it is not always optimal to exploit resources in strict sequence, beginning with the lowest cost deposit, even if it is possible to accumulate productive capital. Indeed if there is an exogenous upper bound on the flow of the substitute, it is always optimal to consume it simultaneously with a lower cost stock. Moreover, it may be optimal to consume the high-cost substitute before using a lower cost resource. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Kemp and Long (1980) are the first to question the “folk theorem” that low-cost natural resource stocks should be exhausted before using a high-cost

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substitute,¹ when agents discount the future. They show that in a general equilibrium framework if the marginal cost of extraction and of using the substitute are both constant then it may be optimal to use the high-cost substitute before exhausting a low-cost natural resource. Simultaneously extracting a resource and using a high-cost substitute smooths the utility path. More recently, Amigues et al. (1998) show that it may be optimal to exploit a high-cost substitute strictly before using a lower cost exhaustible resource, if the *flow* capacity of the high-cost substitute is limited. They suppose that the marginal utility of this limited substitute is strictly positive at the steady state, when the stocks have been exhausted. So the flow of the substitute is scarce and since this flow is unstorable, delaying the start of the exhaustible resource exploitation is a method of saving.

Lewis (1982) modifies Kemp and Long's model by allowing the extracted resource and high-cost substitute to be costlessly converted into capital. He finds that a sufficient condition for restoring the folk theorem in this model is that capital has a positive rate of return. In his conclusion he conjectures that in a general equilibrium analysis, it is optimal to use the least cost energy sources first whenever the extracted resource can be converted into productive capital.

If Lewis' conjecture holds, then the inclusion of productive capital in the Amigues et al. model would restore the folk theorem. The latter paper claims that the inability to save implies the failure of the folk theorem. I will show below that Lewis' conjecture does not hold when the flow of substitute is bounded and scarce in the sense described above. It is always optimal to consume simultaneously the high-cost substitute and one of the stocks. Moreover, it may be optimal to use the high-cost substitute before beginning to extract from a lower cost stock.

Since the Amigues et al. result holds even if the economy can accumulate productive capital, their explanation for the result (based on the desire to save) is incomplete. In fact, extending their model by including the possibility of capital accumulation decreases but does not suppress the incentive to use the high-cost substitute before exhausting lower cost stocks. The critical assumption is that the substitute is scarce, i.e. at the steady state the capacity constraint on the flow of the substitute is binding. The shadow value of this constraint is thus positive. The decision maker reduces the cost of this constraint (i.e. chooses its optimal shadow value) by investing and does so by using the low-cost stock early in the program and delaying the date at which he uses the substitute. The ability to invest in productive capital provides an additional means of reducing the cost of the constraint. By extracting the low-cost stock, and investing some of the

¹ The high-cost substitute could be a natural resource or produced with a natural resource, i.e. it could be a high-cost inexhaustible resource.

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