Essays on Resource Exploitation under Fixed Costs

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Abstract

This dissertation consists of three essays on resource economics. In these essays I analyze the implementation of fixed costs for activities with a finite amount of production. I assume that the fixed costs are a characteristic of an activity and the continuous costs must be incurred for not losing the activity permanently. I show that, if the economic activity is finite in its duration, fixed costs induce minimal scales and also discrete effects on market outcomes. I show further how such discrete effects influence, for instance, the exploitation paces, the exploitation order and the price path.

The first essay concentrates on the efficient solution of exploiting exhaustible deposits of a commodity under fixed costs. In contrast to the previous literature, the efficient solution is well defined. I derive the characteristics of an efficient solution, and show that it cannot be decentralized as a competitive allocation, because the price-taking agents would act strategically. The efficient order of exploiting the deposits, which is a classical resource economics question, depends both on the deposits' stock allocations and on their cost structures.

The second essay describes strategic interactions for private deposit owners under fixed costs. I show that there are equilibria in open-loop strategies, in which deposits are exploited concurrently, and others, in which they are exploited sequentially. I show further that agents do not exit simultaneously and that there are no symmetric equilibria.

The third essay introduces the entry. I limit my attention to economic activity where the projects have each a fixed production time, and also a given and discrete impact on other projects executed concurrently with them. I describe an entry game where the entrants influence other entrants' entry decisions by pre-empting. I show that the entry order and the level of industry concentration are distorted when compared to the efficient solution.

Keywords resource exploitation, finite production, fixed costs, game, open-loop strategy, entry

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Tämä väitöskirja koostuu kolmesta esesseestä, jotka kuuluvat ressursitaloustieteen tutkimusalaan. Tutkin niissä kuinka kiinteät kustannukset vaikuttavat tuotantoon, kun tuotannon kokonaismäärä on äärellinen ja kun kiinteiden kustannusten jatkuva maksaminen on edellytys tulevalle tuotannolle. Kiinteiden kustannusten takia tuotannolla on minimiskaala, ja siksi tuotannon päättyessä hinta ja tuotannon taso muuttuvat diskreetisti.

Ensimmäisessä esessessä keskityn teokkaaseen ratkaisuun ja kuvaan sen ominaisuuksia. Sosiaalisen suunnittelijan ongelma on hyvin määritelty toisin kuin aiemmassa kirjallisuudessa, jossa kiinteät kustannukset riippuvat tuotannosta. Osoitan myös, että kilpailevalla allokaatiota ei ole olemassa, koska hinnan ottavaan kilpailijat käyttäytyisivät strategisesti. Resurssin varantojen teho laskee hyödyntämisjärjestys riippuu sekä resurssien varantojakaumasta että niiden käytön kustannusrakenteesta.

Toisessa esessessä tutkin äärellisiä varantoja, jotka ovat yksityisessä omistiessa. Oletan, että resurssien omistajat toimivat strategisesti ja pelaavat open-loop strategioita. Osoitan, että on olemassa tasapainoja, joissa resurssin eri varantoja käytetään yhtäaikaa, ja toisaalta tasapainoa, joissa varanne käytetään peräkkäin. Osoitan myös, että omistajat eivät tasapainossa lopeta tuotantoon samanaikaisesti ja ettei symmetrisiä ratkaisuja ole olemassa.

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Dear Ilona and Hilda, on purpose have I kept you slightly away from this. The reason is that you serve for the greater good. I wrote a dissertation, but you are writing a different story that is more colorful and important. I am the most pleased of all that I have a role in it. Thank you for being there.

Eero Sillasto
Helsinki, June 2019
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List of Essays

This thesis consists of an introduction and the following essays.

(1) Exploiting Deposits with Fixed Costs
   *Unpublished manuscript.*

(2) Oligopolistic Resource Exploitation under Fixed Costs
   *Unpublished manuscript.*

(3) A Game of Entry and Exit – Fixed Length Projects
   *Unpublished manuscript.*
Introduction

A fixed cost is a basic concept in economics. The story typically goes that assuming a given entry level, only the variable costs affect the economic activity level. The fixed costs, accordingly, affect only the revenue from this activity. This is valid when the activity is, for instance, reproducible. In my essays I analyze the implementation of fixed costs for activities with a finite amount of production. I assume that the fixed costs are a characteristic of an activity and the continuous payments of them are a requirement for not losing the activity permanently.

As an example, consider an offshore rig operating an oil deposit in the seabed. The oil rig has high fixed costs, for instance, due to the rent of having the rig on the spot. To be profitable and to cover both the fixed and the variable costs, the deposit owner must hold a strictly positive exploitation pace. Oil deposits are, however, finite. Each of them one day exhausts and exits from production and such an exit with a positive exploitation scale creates a discrete price effect. Hence, if the economic activity is finite in its duration, fixed costs induce minimal scales and also discrete effects at the exits. In these essays I show how such discrete effects influence, for instance, the exploitation paces, the exploitation order and the price path. In the first two essays I concentrate on the problem of exploiting exhaustible deposits of a commodity under fixed costs. Problems with such temporal economical activities are simple to handle, because all deposits contain the same commodity and, consequently, there is a single price at all times.

In the literature on resource exploitation the handling of fixed costs has shown cause problems which my approach avoids. The fixed cost structure typically applied was introduced by Smith (1961). He describes avoidable fixed costs that are altogether avoided over a time interval by choosing not to exploit the resource during that interval. Eswaran et al. (1983) show that such cost structures cause technical difficulties, as there are solutions in which the activity changes at a high frequency between phases of exploitation and no exploitation in order to reduce the average fixed costs level. However, such models are not properly specified according to the critique of Romer (1986), since they lack adjustment costs that would smooth
out the frequent discontinuities in activity. Recently, Bommier et al. (2017) motivate their analysis by a cost structure similar to what I use here, but, in the end, it is not used in their analysis. In my essays the continuation of paying the fixed costs is a requirement for the continuation of the exploitation. This removes the frequent discontinuations in the exploitation activity of which the previous studies suffered. Moreover, in the limit where the firms are atomistic, the existence of the equilibrium is restored while the fixed costs continue to have an impact on the equilibrium path. Outside the limit, I show that with such fixed cost structures the competition is strategic. The strategic interaction literature misses issues the fixed costs introduce. For instance, Lewis and Schmalensee (1980) and Loury (1986) describe exploiting deposits of a resource that have pure linear costs. I extend their work by including also the fixed costs. Finally, throughout the discussions in these essays, there is an analogy to the occupational choice, which Makowski and Ostroy (1995) describe. The choice to continue paying the fixed costs can be seen as an occupation, and stopping these payments is like retiring from that. Hence, if the choices affect the others discretely, a finite occupational choice is always strategic, and distorted to an efficient solution.

This dissertation is a collection of three essays. In the first essay, titled *Exploiting Deposits with Fixed Costs*, I derive conditions for an efficient solution for exploiting deposits with fixed costs, and show that there is no competitive allocation for price-taking agents owning the deposits. To overcome the lack of a competitive allocation, in the second essay titled *Oligopolistic Resource Exploitation Under Fixed Costs*, I describe the agents’ strategic interaction in a differential game, in which they apply open-loop strategies, and show that the exploitation share ratios of the concurrently exploited deposits equal to their mark-up ratios. Finally, in the third essay titled *A Game of Entry and Exit – Fixed Length Projects*, I describe the entries of the projects that could be, for instance, projects to exploit deposits of a resource, each of which has a limited lifetime and a given impact on other projects’ profits.

**Essay 1: Exploiting Deposits with Fixed Costs.** In this first essay I concentrate on the efficient solution, and show that it cannot be decentralized as a competitive allocation when the deposits are characterized by unavoidable fixed costs. I begin by describing the difference between the unavoidable and avoidable fixed cost structures. I show that, when applying the concept of unavoidable fixed costs, there are no technical or economical issues in the efficient solutions,
for instance, relating to the frequently changing activity levels, which appear in
the solutions of Eswaran et al. (1983) with the avoidable fixed cost structure. I
derive the characteristics of an efficient solution, and show that, if the deposits
are exploited concurrently, their marginal costs, which include both the out of the
pocket marginal costs and the opportunity costs, are equal. The order of exploiting
the deposits, which is a classical resource economics question, depends both on the
deposits’ stock allocations and on their cost structures. I show further, that there is
no competitive allocation, because the price-taking agents would act strategically
at the exit of a deposit with a strictly positive scale as the exit induces a price
jump. However, at the limit, when the stocks of the deposits are minuscule, and if
the unavoidable costs are low enough, a competitive allocation exists.

In the first essay I showed that there is no competitive allocation for exploiting de-
posits with fixed costs. To recover a competitive solution, in the second essay I
introduce strategic interactions for private deposit owners under fixed costs, subse-
quently characterizing the outcome in the game. There are equilibria in open-loop
strategies, in which deposits are exploited concurrently, and others, in which they
are exploited sequentially. I extend the results of Lewis and Schmalensee (1980)
and Loury (1986) including both the fixed costs and a more general variable costs
structure. I show that the deposits’ exploitation shares’ ratio equals to the ratio
of their mark-ups, where the marginal costs include both the out of the pocket
costs and the opportunity costs. This is a deviation from the efficient solution. I
show also that agents do not exit simultaneously and that there are no symmetric
equilibria. An equilibrium with a sequential exploitation order may be, however, a
Pareto improvement to the simultaneous exploitation equilibrium.

Essay 3: A Game of Entry and Exit – Fixed Length Projects. In the
first two essays there are no entries. In the third essay I introduce the entry. I limit
my attention to economic activity where the projects have each a fixed length, and
also a given and discrete impact on other projects executed concurrently with them.
These projects may be, for example, deposits of a resource that are exploited at a
fixed exploitation pace. Anderson et al. (2014) describe Texan oil wells and show
that the oil pressure in the well defines their exploitation pace. If the oil pressure
could be kept constant, the oil wells would produce at a constant pace over time,
and they would be suitable as projects for this essay. I describe an entry game for
fixed length projects where the entrants influence other entrants’ entry decisions by pre-empting. I show that the entry order and the level of industry concentration are distorted.
Bibliography


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