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The role of price expectations and legal uncertainties in ocean mineral, exploration activities ☆

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ABSTRACT

In this paper, a standard exploration activities model is modified and applied to time series, data from deep seabed mining of a group of minerals where the number of patents is used as a proxy, for the level of mineral exploration activities. In addition to the rational expectations model, price, expectations formation for mineral prices is decomposed into trend and cyclical components using the, HP-filter method. Estimated parameters from the supply and cost functions are used to determine the, shadow price of the minerals. The non-linear instrumental variables estimator is employed to estimate, the exploration activities function. While the rational expectations model shows the importance of, current prices on exploration efforts, the HP-filter model suggests that firms concentrate on the trend, in prices rather than the short-run cyclical fluctuations. Also, while the U.S. refusal to ratify the LOSC, has increased the legal uncertainties surrounding the management of ocean resources and reduced the, incentive to engage in exploration activities, the passage of the ISA's main legislative accomplishment, regarding regulation of the explorations for polymetallic nodules appear to have made a positive effect.

Introduction

This paper deals with the determinants of exploration efforts aimed at the discovery and extraction of ocean minerals such as manganese, nickel, copper, cobalt, and phosphate. In effect, we test for conditions conducive to the commercial production of marine minerals. Most models of resource extraction and exploration efforts are developed so that the firm's incentive to incur exploration expenditures is to prevent an otherwise rising extraction cost, resulting from depletion and degradation of reserves (Pindyck, 1987; Livernois and Uhler, 1987). However, models that analyze exploration expenditures as an investment deal with other factors that influence the level of exploration efforts. For example, Uhler (1976), Ramsey (1979), and Mason (1986) introduced the problem of accumulated knowledge and information uncertainty. The capital market imperfection argument is also applied in some exploration models (Attanasi, 1981; Griffin, 1988). Among various sources of funds, internal sources are the cheapest for the firm. Thus, during high cash flow periods, typically when the demand for minerals is strong, exploration activities are likely to rise. Attanasi also believes that large firms, due to their bigger cash flows, incur more exploration expenditures than small firms.

The significance of future demand for minerals is also acknowledged in studies, such as Pesaran's (1990), where price of minerals is one of the determinants of exploration effort. In an empirical analysis of petroleum exploration and extraction on the United Kingdom (UK) Continental Shelf, based on quarterly data for 1978–1986, Pesaran finds a positive correlation between exploration activities and expected petroleum prices and a negative correlation between exploration activities and exploration costs. In a similar short-run study of the petroleum industry in the UK, Favero (1992) confirms Pesaran's findings with regards to the significance of the shadow price of oil and exploration costs. However, inclusion of taxes in the Favero model reverses the sign of the coefficient for the post-tax shadow price for the last four observations in his sample.

Since this study uses patents as an indicator of the level of research activities, it is notable that several studies in the past have also made similar use of patent statistics. For example, Griliches (1990) finds a strong relationship between patents received and R&D activities and argues that only successful patent applications are good indicators of inventive activities. Popp (2002) applies patent information to investigate the effect of energy prices on energy-efficient innovations. An early study of seabed mining patent activity by Hoagland (1986) addresses the cyclical nature of the mining industry exploration activities due to fluctuations in mineral prices. He also points out the importance

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of the seabed mining legal regimes in exploration activities decisions. Hoagland believes that examination of the timing of the patent activities help understanding the nature of the cycles. He also maintains that the industry has increasingly engaged in joint venture to reduce exposure to the risk of investment in seabed mining R&D.

In this paper, first the extent of potential marine minerals available and the legal as well as technological complexities surrounding their extraction are described. Then, a standard exploration effort model is modified and applied to marine mining of a group of minerals. While estimates of the exploration effort typically concentrate on a single mineral, here a composite of minerals is considered, which is more consistent with the interests of the extractive industry in ocean mining. We also examine the significance of uncertainties regarding ownership structure of the sea floor minerals to exploration activities. In addition to the rational expectation approach, the shadow price of minerals is decomposed, using the HP-filter decomposition method, in order to separately investigate the effect of the price trend and short-term fluctuations in prices. Concluding comments follow the discussion of the statistical results.

Marine minerals

Potentially exploitable marine minerals are vast in number and in variety. There are approximately 90 different mineral commodities in the marine environment, including: oil and gas; heavy mineral placers containing gold, chromium, platinum-group minerals, tin, and titanium; phosphorus; manganese nodules and crusts containing cobalt, nickel, copper, and manganese; polymetallic sulfides; and sand and gravel. This section of the paper is focused on some non-hydrocarbon marine minerals. Scientific ocean explorations have proven the existence of significant amounts of many non-hydrocarbon marine minerals (McKelvey et al., 1983; Clark and Clark, 1986; Rowland, 1985; Manheim, 1986; Office of Technology Assessment, 1987; Thiel and Schriever, 1993; Daessle and Fischer, 2001). A comprehensive review of the potential world ocean mineral resources by Broadus (1987) identifies cobalt, nickel, manganese, copper, zinc, hafnium, zirconium, and limonite among seabed material commodities constituting from 25 to as high as 220 percent of the total land-based resources in their group. Anderson (1991) maintains that the average grade for cobalt and manganese in manganese nodules is higher than in the land-based deposits, which are currently mined.

In the 1970 s, there was an increasing interest by large companies and governmental organizations from various industrialized countries in the commercial exploitation of seabed minerals, particularly manganese nodules. This interest was indicated by the millions of dollars spent on exploration activities and technological development, and the high number of patents granted during this period (Broadus, 1987). The rising trend in the number of patents for marine mining explorations is typically a reflection of changing demand for minerals and the size and quality of the land-based reserve. However, there have been fundamental obstacles to deep seabed mining including technological, economic, environmental, and legal.

Technologically, various mining methods are available for the recovery of marine mineral resources. For example, mechanical mining systems such as dragline, clamshell, and bucket-ladder dredges have been commercially used to recover sand, gravel, and gold placers. The mining of seabed minerals is also currently feasible with hydraulic slurry technology. Although recently this technology has been commercially used for sulfur mining, it is yet to be tested on a large-scale commercial basis to recover manganese nodules.

After the 1970 s, most experts believed that commercial production of most marine minerals would not occur in the near future because of unfavorable economic conditions (Office of Technology Assessment, 1987; Broadus, 1987). Later, Hoagland (1993) used the average grade and recoverability of the minerals in manganese nodules to develop a weighted price trend for manganese nodules and predicted their commercial production well into this century. These pessimistic expectations regarding commercial production of manganese nodules could be true in spite of a higher grade of some seabed resources in comparison with the land-based minerals, which are currently mined. For example, a geological review of phosphate resources within the U.S. continental shelf concludes that the offshore phosphate resources of North Carolina have a high quality, which makes them potentially competitive with the existing land-based resources (Marvasti and Riggs, 1987). A significant quantity of highly concentrated phosphate is also found in the surficial glauconitic sands on the Chatham Rise, off the east coast of New Zealand (Kudrass, 1984). Another example of valuable seabed resources is manganese nodules. The metal content of these nodules is reported to be high; however, their estimated extraction cost is currently higher than the cost of land-based mining. More recently, 250 sulfide deposits have been identified worldwide creating a wave of interests in their commercial extraction (Halfar and Fujita, 2007).

Although the extraction of marine minerals is becoming an attractive choice again, the cost of initiating commercial mining is still an obstacle. In the economic literature, it is commonly assumed that firms invest incrementally and continuously. But, capacity choice and investment decisions of such firms are more complex. Following pioneering work by Arrow and Fisher (1974), Pindyck, 1988, 1991, argues that most investments are lumpy and largely irreversible. Therefore, most of the investment expenditures are sunk costs. According to Pindyck, firms may also delay irreversible investments in order to wait for new information about prices, costs, or market conditions. The existence of sunk costs and an uncertain future diminish optimum investment expenditures. Recently, Gianluca and Gianmaria (2011) show that, in a dynamic duopoly condition, when investment projects require a significant amount of R&D expenditures with spillovers and there are uncertain cyclical demand conditions, the leader's optimum strategy is to delay its investment. This is consistent with Pindyck's argument that a much higher internal rate of return is required to stimulate the expansion in an industry subject to large irreversible investment. Décamps et al. (2006) also establish this point in their theoretical model. Irreversibility of investment and sunk costs in extractive industries, in particular, are also theoretically analyzed (Cairns and Lasserre, 1986) and empirically documented (Lasserre, 1985).

Another economic issue that is as relevant today as it was in the 1970 s is the possible gap between the pre-entry and post-entry prices for some deep seabed minerals. Since the deep seabed mining of minerals will not be profitable unless it takes place on a large scale, ocean mining will be profitable only if the price of minerals is high. This is because large scale mining of deep seabed minerals is likely to severely reduce the price of some minerals such as cobalt (Adams, 1980; Marvasti, 1988). Therefore, the quality of the existing land-based minerals must drop much further before ocean mining takes place on a commercial basis. The mining companies consider the post-entry price of the minerals in their decision to enter large-scale exploitation of ocean minerals. Consequently, a large gap between the pre-entry and the expected post-entry price of minerals can be an effective entry barrier to ocean mining for some time.

Environmentally, deep-sea mining has a potentially adverse effect on the ecosystem because of benthic disturbances, sediment plumes, and toxic effects on the water column, which might