The Dynamics of Relative Attractiveness : Minerals exploration in the developing world

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Abstract: The high mobility of mining investment is often frequently in the literature. Consequently, the concept of relative attractiveness is particularly important. In a free market, a mining firm concentrates its exploration investment in countries that present the most attractive investment opportunities. This creates a positive feedback loop within a country towards further exploration activity, until, eventually, some limit is reached, thus reducing that particular country's relative attractiveness. In times of shrinking mineral markets, firms have shifted their investment to regions that are perceived to have more stable mineral policies, reflecting the fact that, in their opinion, these countries have become relatively more attractive as the firms themselves become more risk averse. This is an important point, as it shows that the concept of relative attractiveness is a dynamic concept. A government can control the minerals policy within its own boundaries but, in order to remain competitive, policies must constantly evolve to be at least equally attractive as those of other countries. This paper examines the dynamics of relative attractiveness and its impact on the decision-making processes which guide a mining firm's exploration efforts in developing countries.

Keywords: *Modelling; Mining; Environmental Policy*

1. INTRODUCTION

The growing demand for minerals coupled with the depletion of the highest-grade ore deposits has led to an increase in the average size of mining operations and an increase in the average amount of waste generated per tonne of mineral recovered [Down *et al*, 1977, p9 and Meadows *et al*, 1992, p87].

Because of the possibility of large environmental and economic losses from mining accidents, mining activity is heavily regulated in most developed countries and this environmental policy is seen as an important factor in the decision making process of mining firms when allocating mineral investment funds. One of the consequences of the growing costs of environmental regulation in developed countries has been the influx of exploration investment to developing countries. In the short run, the less stringent environmental regulations in these countries may give mining firms locating in them a cost advantage. However, regulations tend to converge in their stringency in the long run [Ballance & Forstner, 1992, p147] and this may benefit firms that have developed cleaner processes.

The aim of the research underpinning this paper was to explore the complexity and interdependence of the factors impacting the relative attractiveness of a country as a location for minerals exploration and development.

2. MODELLING EXPLORATION AND INVESTMENT DECISION

To provide a mechanism whereby the relative attractiveness of competing mineral policies can be exposed, the model developed here simulates a number of mining firms working various mineral deposits in four different countries over a fixed time period of 60 years. Model behaviour is a complex function of initial conditions and changing policy over the simulation period. To increase variety, and so better simulate reality, countries and firms are assigned different initial conditions regarding their geology and strategic management policies, as outlined in Table 1.

Figure 1 divides the mineral supply process into exploration, development and extraction phases. Modern mining requires considerable monetary investment during each of these phases. At the exploration phase, investment decisions are based on expected values and are funded by paid-in capital in the case of new firms or internal funds when the firms are established. Development decisions are determined on the basis of Net Present Value (NPV) and funded by retained earnings, equity and borrowings. Extraction, which is funded internally, is driven primarily by the difference between price and operating costs. The model discussed here is structured around a set of discrete decision points facing each mining firm. Each decision point acts as a flow of investment funds that, after a delay, channels minerals throughout the system. It is beyond the scope of this paper to consider each of the major investment decisions. Instead, emphasis is placed primarily on the exploration and development decisions.

	Country 1	Country 2	Country 3	Country 4
Geology	Developing Country	Standard	Standard	Favour-able
Political Stability	Unstable	Stable	Stable	Stable
Env Reg. & Planning Req	Undeveloped	Standard	Standard	Mature
Cost of Local Inputs	Low	Standard	Standard	High
Explor-ation Costs	High	Standard	Standard	Standard

	Firm 1	Firm 2	Firm 3	Firm 4
Growth Goal	Strong	Weak	Standard	Standard
Extraction Policy	Price Sensitive	Price Sensitive	Price Aggressive	Price Passive
Risk Averse	Low	Standard	Standard	Standard
NPV Cutoff	Low	Standard	Low	Standard

Table 1: Individualisation of simulated countries and mining firms

Both exploration spending and its location are driven by a mixture of push and pull effects [Crowson, 1999]. The booming market conditions of the late 1980s increased the internal funds available to mining firms and expectations about future market conditions. This led to an increase in investment in the mid 1990s in both new and existing mines. However, exploration had been cut back during the base metals recession of the mid 1970s to mid 1980s and there were no discoveries of large economic deposits in the countries which had traditionally been regarded as politically stable.

This turned the focus towards the developing countries. Up until the late 1980s, most exploration investment was directed towards North America, Canada and Australia that together accounted for 70% of exploration spending [Crowson, 1999]. As existing technologies had been applied in these regions and they had become mature exploration sites, new discoveries became progressively harder to find and the success ratio began to decline. Also, the mineral policies were becoming more bureaucratic and delays that were long and costly, particularly with respect to environmental considerations, became more common. There were also increasing conflicts over land access and the rights of indigenous people.

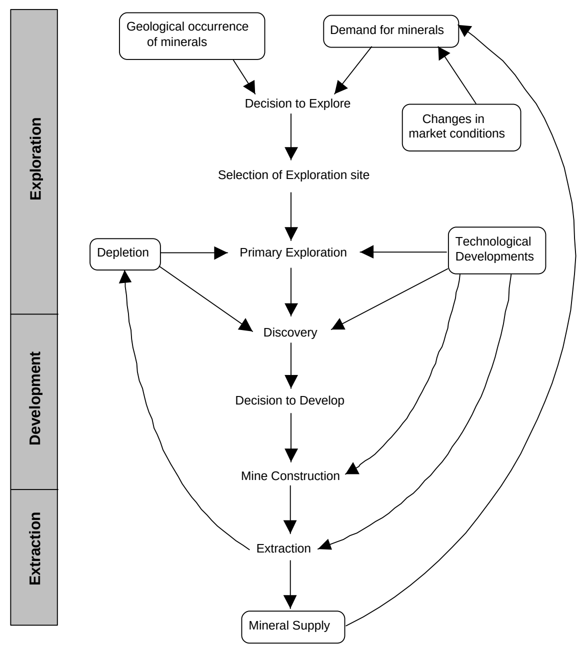

Figure 1: The mineral supply process [adapted from MacKenzie & Woodall, 1988, p365]

The globalisation of the world market since the collapse of communism and the reduction of government interference in the mining industry has resulted in many countries introducing new mineral policies to attract investment [Otto, 1994(a)]. As a result, the combined share of exploration spending in North America and Australia declined from 70% in 1989 to 56% in 1993 and 37% in 1997. Most of this decrease occurred in North America, while investment in Australia dropped by under 3% over this time. Investment in South American countries increased to 13% in 1993 and 29% in 1997, the South Pacific, accounted for 9% in 1993 and 11% in 1997, and investment in African countries grew from 5% in 1993 to 13% in 1997.

The allocation of exploration funds depends on the expected value of deposits in potential exploration sites, the degree of risk associated with each location and the firm's attitude to risk [Lesser *et al*, 1997]. More specifically, assuming the firm wishes to maximise the expected value of exploration by exploring the 'best' deposits first, the decision on where to allocate exploration funds will depend on the expected cost of exploration (the finding cost), the expected geology (ore grade, tonnage, deposit type) and costs of mining any discovery (planning, capital, operating and environmental costs, as well as taxation). This expected value is adjusted for the risks associated with each location as mining firms discount proposed developments in countries where the perceived risk is high relative to other countries.

3. EXPECTED VALUE OF EXPLORATION

The geological potential of a country is the single most important factor in determining the attractiveness of that country to mineral exploration and investment [Johnson, 1990, p180 and Eggert, 1992, p24]. Worldwide, governments are the main source of geological information. In 1994, 120 countries had Geological Survey Organisations whose purpose is to collect, organise and disseminate information on the geological potential of the country [Otto, 1994(b), p2].

When ranking possible exploration sites, mining firms will make an estimate of the probable size and type of a deposit in each site. This estimate is affected by the number and size of any discoveries already made in that region and, if there are no discoveries, then the firm will use the concept of a model deposit. This information is used, along with expectations about costs, to make an estimate of the expected value of a discovery in each country.

The costs of finding a deposit are termed the exploration costs. These are broken down into the cost of the exploration licence and the cost of physically carrying out the exploration, that is, the labour, drilling and equipment costs.

To arrive at these estimates the firm draws on its own experiences and those of other mining firms, as well as industry-wide forecasts. To estimate the value of a deposit, the firm must first estimate its likely physical characteristics. This is based on discoveries already made by the firm in the particular exploration site or, if the firm is deciding whether or not to invest in a country for the first time, on any discoveries made by other firms. Based on this estimate and on commonly used industry rules, as well as its own experience and knowledge about the country, the firm estimates the planning, capital and operating costs for that deposit. The expected revenue from the deposit is the product of the estimated tonnage of recoverable mineral and the expected price for that mineral. The costs are subtracted from the revenue to give the expected value of the deposit [MacKenzie & Woodall, 1988, p368].

The environmental protection requirements of the country also have a significant impact on costs. Increasing environmental regulatory and planning requirements reduces the relative attractiveness of potential deposits. This is because increased planning and regulatory costs reduce the expected net value of exploration, thus shifting exploration funds elsewhere in the short term. See Table 1 for details of Country characteristics. This can be seen in Figure 2 in which relatively high planning and regulatory requirements in Country 4 increased the environmentally related proportion of planning, capital and operating costs by 50%. This results in a short-term reduction in exploration spending in Country 4, as it reduces the expected return on investing there. However, after the more favourable (highest expected values) deposits of Country 2 and Country 3 are explored, Country 4 again becomes a target for exploration funds (in the late 1990s of the simulation run).

Initially, scarce exploration funds, in the form of paid-in capital are distributed between potential countries, favouring those that show higher expected net value of exploration. Later, when the more favourable locations are explored, profits from initial exploration/development efforts can be reinvested in other less favourable locations or countries. By the year 2040 of the simulation, Country 1 (developing country) has secured almost twice the exploration funding of

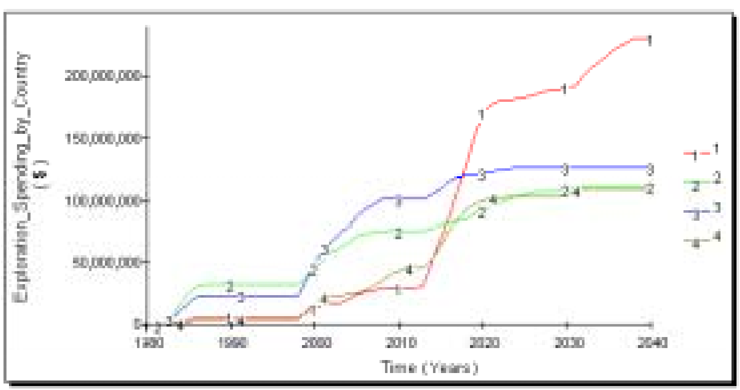

Figure 2: Exploration spending by country (1 to 4 in the legend)

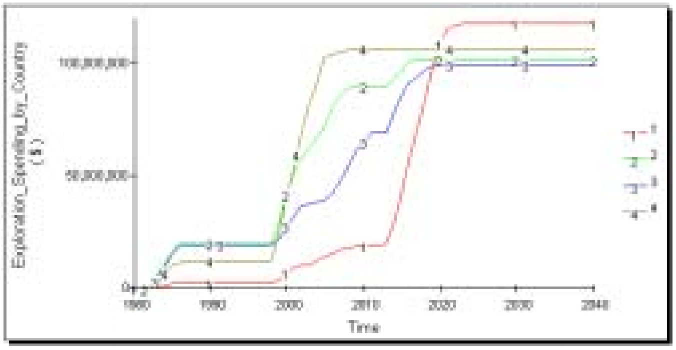

Figure 3: The effect on exploration spending of worldwide coincidence of environmental regulatory and planning requirements

each of the other countries, but this is because the cost of exploration is higher in the developing country (Country 1), thus explaining why it is left until last to explore.

In effect, tightening environmental regulations, as in the case of Country 4 in this example, results in shifting the country's potential deposits down the rank. Indeed, this effect is not specific to environmental parameters. Increasing or decreasing one parameter while holding all others constant will have an obvious effect on exploration expenditure in the country in question. The use of a simulation model is not necessary to expose this behaviour.

In practice, however, the situation is more complex. Regulatory requirements change over time, both within and between countries, shifting the relative attractiveness up and down in a dynamic fashion. For example, tightening environmental regulations need not necessarily reduce the relative attractiveness of exploration sites in a particular country if it is combined with changes to other important policies.

Figure 3 shows the effect on exploration spending of increasing world-wide regulatory and planning requirements to the level of the developed country (Country 4). In this instance, Countries 2 and 3 secure most exploration funds initially as Country 4 still has higher local input costs and Country 1 has higher exploration costs. There is then no exploration activity during the next 15 years as exploration funds have been exhausted. However, once the initial development phase becomes profitable, further exploration funds become available and are directed primarily towards Country 4 in the first instance, reflecting its increased perceived geological potential resulting from the initial round of exploration. Remember that Country 4 is initialised with a more favourable geology along with more stringent regulatory and planning requirements and higher cost of local inputs (Table 1). Knowledge of the more favourable geology is not available to firms in advance and so the model deposit size is used as a basis for determining the net value of exploration, until more accurate information becomes available. The effect of making this knowledge available from the outset is reflected in Figure 4.

Figure 4 shows the importance of providing firms with accurate geological information as a means of securing exploration funding. The expectation of increased tonnage has a positive effect on expected net value of exploration calculations, thus increasing the relative attractiveness of Country 4 for exploration investment. Therefore, improving geological information facilities is an example of how a country with a favourable geology may compensate for the effect of applying more stringent environmental regulatory and planning requirements.

4. PERCEIVED RISK

As exploration and development take such a long time, there are risks associated with any possible investment location. During this time, many important factors such as the mineral policies, the government itself and the public attitude to mining within the country may alter significantly. These risks must be factored in to decrease the expected value of the exploration investment. As the firm is attempting to predict events over a very long time period, the estimates that are made at this stage of the mining process are very uncertain [Astakhov *et al*, 1988, p220].

For example, clear and transparent terms under which tenure rights are granted and terminated at all stages in the exploration to development process are very important to mining firms. Johnson [1990] identified the right to mine any deposit as the most important non-negotiable factor before a mining firm will consider investing in a country. The economic argument for security of tenure is that exploration risk should only be assumed if there is an expectation of obtaining subsequent mining rights.

Figure 5 shows the output for a deposit from two simulation runs, one where construction commences as planned in simulation year 2008 and the other where the mining licence is refused.

Figure 6 shows how this refusal not only affects

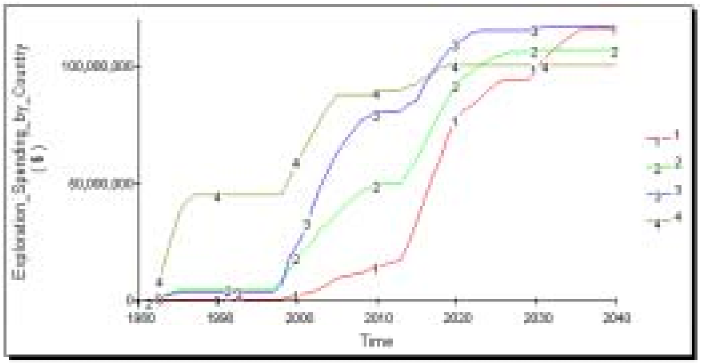

Figure 4: The effect on exploration spending of the availability of accurate geological information

the development of the deposit in question, but also has negative feedback on the future expected net value of exploration in the country in question, in the short term. More specifically, the perceived security of tenure is adversely affected immediately on refusal to grant the mining licence. This, in turn, impacts the perceived risk, for all mining firms, of carrying out further exploration in that country.

However, a firm's perception of security of tenure (and other risk factors) will return to normal over time if there are no other unexpected policy changes. For this reason, the expected net value of exploration is only affected for a short period, until approximately 2015. Nevertheless, if there is a second refusal of a mining licence in Country2, as happens in 2064, then the effect on perceived security of tenure is compounded and so it takes longer for the perception of risk to return to normal. This underlines the need for consistency over time in government policy if the inflow of minerals investment is to be maintained.

Firms tend to invest in countries where there has been prior successful investment by multinational mining firms. For example, most zinc exploration is focused around existing zinc mines. This is seen as an indication that there is a workable minerals policy, support industries and suitable infrastructure as well as geological potential. Results of a survey of the investment policies of 39 multinational mining firms indicate that 40% of these firms will not invest in exploration or development in countries where other similar firms have not invested [Otto, 1994(a), Table 4]. Mining firms also tend to be conservative in their investment decisions and often reinvest in countries in which they have already made discoveries and developed mines [Otto, 1992, p28]. This is because the perceived geological potential of the country increases as discoveries are made, the firm is familiar with the mineral policies, and it may already have offices and employees *in situ*.

Political risks affect the profitability of mining investment. Although some developing countries remain politically unstable, the more developed countries have growing problems of access to land and more stringent environmental legislation. Political changes which might affect the operation or profitability of a mining or exploration investment may occur even in a country widely regarded by investors and political observers to be politically stable. All countries have some element of risk as well as some potential to produce profits. However, the difference is in the degree of risk that is present.

Also, there is the fear that as the developing countries begin to industrialise there may be a problem with exporting minerals, as they will be needed to supply development [Hargreaves *et al*, 1994, p5]. These difficulties increase the uncertainty associated with exploration and subsequent development of any mine, and consequently alter the risk-reward balance [Anon., March 3, 1995, p165]. It must be recognised that while political risk cannot be avoided completely, it may be managed. The methods of managing and reducing political risk, besides avoiding high-risk countries altogether,

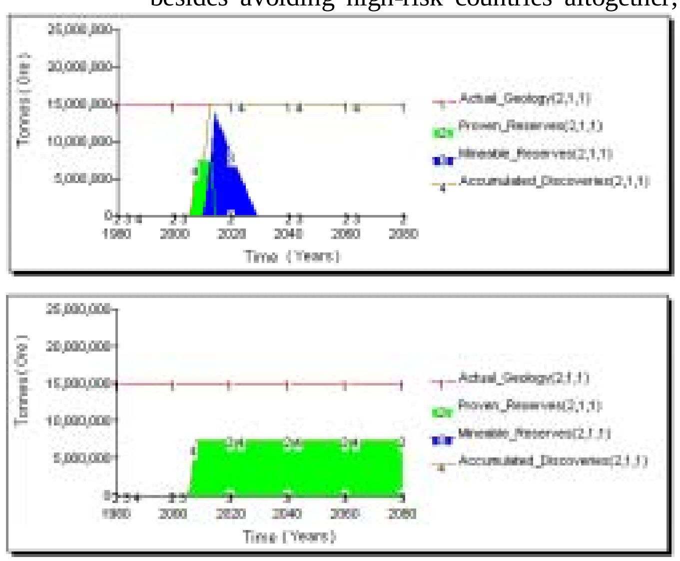

Figure 5: Effect of government refusal of mining license

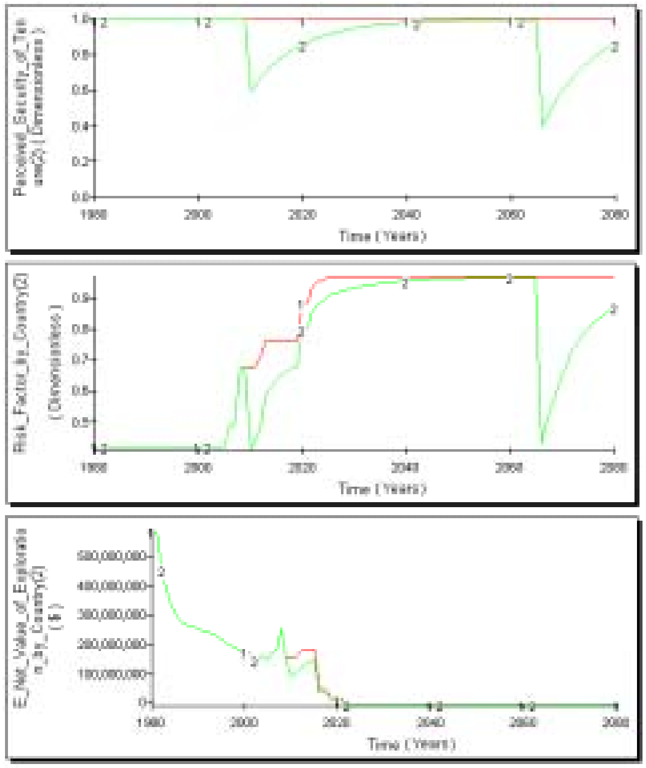

Figure 6: Security of tenure, perceived risk and expected value of exploration

are by having a fair and flexible contract which contains a reference to international law and arbitration, by insuring the investment either with a public or private investment insurance scheme, risk spreading through joint ventures involving international institutions, and investing in more than one country [see Kolo, 1997].

Information regarding the risks associated with a particular country is available from international mining agencies (such as MEG). This is used by mining firm to assess the risks associated with each potential investment location. A mining firm will typically assess the risks associated with each country and attach a weighting to these risk factors. This weighting is determined by the firm's attitude to risk and its strategic objectives [Otto, 1992, p3]. Therefore, each potential investment location may be rated differently by individual mining firms [Otto, 1994(a)].

5. CONCLUDING COMMENTS

It is only possible in this paper to provide a brief overview of a detailed model for examining the impact of environmental policies on each stage of the mineral investment process from exploration through to development, operation and closure. For further information the reader is directed to O'Regan & Moles, 2001.

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