Economic theory and the valuation of mineral assets

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ECONOMIC THEORY AND THE VALUATION OF MINERAL ASSETS

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INTRODUCTION

The value of any mining or oil firm is derived from the value of its mineral assets (reserves). In this paper, I will focus on approaches to valuing these individual reserves, a task which, due to certain aspects of mining and oil extraction, provides challenges for appraisers and valuators. The paper reviews those challenges, and offers an economist’s suggestions as to how they may be overcome. That is, I come at the problem of value from an economic science standpoint, which may be at variance with traditional appraisal practice.

I begin the paper with the general concepts and practices of mineral asset valuation, and then move on to selected valuation issues that concern the industry. In the final section of the paper I touch briefly on the link between mineral asset valuation and mineral firm equity valuation as viewed through the lens of real options.

WHAT IS VALUE?

It is important at the outset to define what I mean by value. Economists speak of value in terms of fundamentals. For example, economists advocate fundamental analysis of shares on the stock market using discounted earning projections, rather than using

* I would like to thank Jim and Ellen Hodos of Onstream Resource Managers for their helpful comments on an earlier draft. This does not imply that they necessarily endorse any of the ideas contained in this paper.
technical analysis that takes market psychology into account. In mineral asset valuation, economists use this same paradigm, valuing an asset using projections of discounted benefits expected to be received by its owner. In turn, we presume that owners are informed and rational, and are not subject to emotional or irrational behavior. Owners also are assumed to set in place incentives to cause the asset operator to act in an optimal way, making value-creating decisions on behalf of the owner using the owner’s risk preferences.

Typical definitions of fair market value, a term used in appraisal and valuation standards, contain some of these same concepts. Buyers and sellers are assumed to be willing, knowledgeable, and at arm’s length, implying that there is a detached and informed valuation process undertaken by each party. But, as I read it, fair market value aims at getting at the transaction price likely to be negotiated by a typical buyer and seller, each having reasonable but not absolute knowledge about the asset, and each with possibly different information sets. Fair market value also takes into account vagaries of the market, such as lack of competition for an asset or widespread psychological effects. Economic theory assumes away such vagaries, and therefore finds no difference between fundamental value and fair market value.

In practice, bubbles, strategic behavior, and differing assessments of value between buyer and seller do exist. In these cases the difference between fundamental value and fair market value, put succinctly, is the difference between the value that an asset will generate and the value that an asset will trade for. For example, during the height of the dot-com bubble, I have the impression that these shares were trading at their fair market value, even though they were trading well above their fundamental value.

This difference has important implications for mineral asset valuation. Transactions of mineral assets are often between parties with emotional, strategic, or other interests in the properties that may cause them to price the assets at more or less than their worth. Furthermore, the buyer and seller may have different opinions about the value, and may be negotiating in a non-competitive market. Economists have difficulty modeling such behavior, and so create assumptions that force transaction value to equal the income ultimately expected to be generated by the asset under optimal management, in effect causing fair market value to equal fundamental value. Appraisers and valuators, on the other hand, are often interested in real world transaction values, and are forced to recognize that transactions are between flawed individuals in non-competitive markets, causing a divergence between fair market value and fundamental value.\(^1\)

Whether fundamental or fair market value is the better value, when there is a difference, depends on the purpose of the valuation exercise. If we are asked to predict what property X would have transacted for in the absence of some restricting event, such as a takings, I think we need fair market value. After all, we want to see what the owner

\(^1\) Economists are catching up, though, with game theory and the new field of behavioral economics attempting to address some of these issues.
of the asset would have received from a buyer given the realities of the market. If we want to determine the wealth that will be ultimately created by the productive use of the asset, we need fundamental value. An example of a need for fundamental value might be an assessment of asset value for property tax purposes.

**TYPES OF MINERAL ASSETS**

Mineral assets can generally be classified into four types of properties: speculative, exploration, development, and producing. Speculative properties have very little assurance of mineral potential. Exploration properties have enough potential that expenditure of exploration dollars is warranted. Development properties are the outcome of a successful exploration exercise, and warrant development into a producing asset. Producing assets are those that are in production.

Economists would have each type of property valued via a fundamental analysis, discounting a projected stream of future income. This becomes difficult, however, for speculative and exploration properties, as information on production potential and the timing of that production, if any, is so poor as to render projections of income largely meaningless. In addition, these properties are seen by the market as options on information, in that owners have an option to spend money to obtain more information about the nature of the asset. Traditional discounted cash flow income approaches are inappropriate when valuing such options, and so we either need to use real options or decision analysis techniques in valuing these types of properties, or look to actual trades to infer their values. The latter suggests a comparable sales approach, in which case the resultant values will be fair market values and not fundamental values.

In sum, economists have very little to offer on the fundamental value of speculative and exploration properties. For this reason, most economic (fundamental) analysis begins when properties are in the development or production stage. The advent of real options and decision analysis has allowed us to move back to valuing properties at the exploration stage, but this is a new type of analysis that is still finding its feet, and is not yet well accepted by industry or the Courts.

**THE VALUE OF A MINERAL ASSET EQUALS THE VALUE OF ITS IN-GROUND RESERVES**

For all property types, asset value is a joint product of any potentially extractable mineral located beneath the earth’s surface and any installed capital that is used to extract that mineral. One can arbitrarily divide the mineral asset’s total value between the two types of assets, typically deducting the cost of installed capital (a drill hole, for instance) from the total asset value to derive the value of the extractable mineral. But such accounting

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2 Another type of mineral asset is a royalty interest, which I will not discuss here.
is arbitrary — the extractable mineral is worth nothing without the installed capital, and the installed capital is worth nothing without the extractable mineral. That is, there is nothing inherently valuable about a drill hole, and so one cannot necessarily value its contribution to the total asset value by using that drill hole’s cost.³

Another valuation principle, and the primary focus of this paper, is that the total value of the joint asset, which I will for convenience call the mineral asset, is derived solely from the prospect of ultimately extracting the mineral for a profit. This principle holds regardless of the valuation technique used, be it income-based or comparable sales, and of the purpose of the valuation, be it fundamental value or fair market value. If the mineral asset is never expected to generate a penny, it has no value.

In this vein, many logically presume that the value of a mineral asset is simply the current mineral price, \( P_0 \), multiplied by the mineral reserve quantity expected to be ultimately extracted, \( Q_0 \):

**Model 1**

\[
V_0 = P_0E[Q_0]
\]

where the subscript 0 indicates time 0 (today). I denote the forecast of reserves by the term \( E[\bullet] \), for expectation.⁴ By this model of value, an expectation of one million ounces of gold buried one mile under the earth’s surface has a current value of some $300 million, since the price of gold is roughly $300/ounce. I have often heard this valuation argument used by environmental groups who claim that the Mining Law of 1872 is giving away mineral reserves worth millions of dollars, yet charging miners only a fraction of this for access to the reserve. The rule ignores the fact that each ounce of gold will need to be recovered, often at great expense, and this valuation model is clearly inappropriate.

Another “value equals profit” model presumes that the value of a mineral asset is its current mineral price, \( P_0 \), less per unit after-tax extraction cost, \( C_0 \), multiplied by the mineral reserve quantity expected to be ultimately extracted \( Q_0 \):

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³ The value of a drill hole in my back yard is zero; even though it may cost $1 million to drill, it adds no value to my property.

⁴ An expectation is the mean of a random distribution. For normal distributions, the actual outcome will be below the mean 50% of the time, and above the mean 50% of the time. An expectation is therefore an unbiased prediction which is never exactly correct, but is as likely to be too low as too high.
Model 2

\[ V_0 = (P_0 - C_0)E[Q_0] \]

This model correctly takes into account extraction costs, and allows for the fact that high extraction costs can make the value of some assets negligible or negative, but it ignores the fact that extraction requires the ongoing investment of capital in the form of exploration and development expenses. It therefore still overvalues the asset.

A third model correctly deducts the present value of remaining expected exploration and investment costs, \( I_0 \):

Model 3

\[ V_0 = (P_0 - C_0)E[Q_0] - E[I_0] \]

This is still not the asset’s value, though, as it misses the fact that \( Q \) cannot be extracted instantaneously — the average gold reserve takes 12 years to extract once developed, and so all units of the mineral should not be priced at today’s net value per unit, \( (P_0 - C_0) \). That is, while those units extracted today can be valued at \( (P_0 - C_0) \), units extracted tomorrow must be evaluated at tomorrow’s net value per unit, \( (P_{t+1} - C_{t+1}) \), and discounted to the present. Model 3 may or may not overvalue the asset, depending on the path of prices and costs over time, although it is my experience that it tends to overvalue producing assets (Cairns and Davis 1998, Davis and Cairns 1999).

A fourth model views a mineral asset as a \( T \)-period extraction project, and values the asset as the after-tax present value of the expected cash flows, including an appropriate deduction for any necessary periodic capital expenditures, \( I_t \), and abandonment costs net of salvage value, \( A_t \):

Model 4

\[
V_0 = E \left[ \sum_{t=0}^{T} \frac{(P_t - C_t)q_t}{(1 + radr)^t} - \sum_{t=0}^{T} \frac{I_t}{(1 + radr)^t} - \frac{A_t}{(1 + radr)^T} \right]
\]

where \( q_t \) is period \( t \)’s quantity extracted, \( T \) is the final period of operation, and \( radr \) is a risk-adjusted discount rate. This equation is an algebraic representation of the standard Net Present Value (NPV) discounted cash flow model. The method clearly identifies mineral assets as an ultimate extraction project, with risk and future economic and technical factors being the drivers for today’s value. Inherent in the method is the need
for forecasts of prices, operating costs (inclusive of all taxes), reserves, production, investment costs, and abandonment costs. Economists assume that expectations are unbiased and uniform across the parties valuing the asset, and that competition between buyers will bid the transaction value up to the fundamental value indicated by Model 4. The particular expectations of the buying and selling parties may in fact be different and biased, and will be reconciled only via some negotiating process in an imperfectly competitive market. Fair market value assesses the impact of these negotiations.

Aside from requiring a forecast of the future, Model 4 also requires the use of the appropriate risk-adjusted discount rate (\(radr\)). Of course, the higher the discount rate, the lower the asset value, and so discount rate plays just as important a role in mineral asset valuation as prices and costs.

Model 4 can technically be used to fundamentally value all types of mineral property. For speculative and exploration properties, it would include remaining exploration and development expenditures, and \(q_t\) would be zero for several years while these activities are underway. The expectation over annual output \(q_t\) would include the large probability that reserves may not exist. This uncertainty may also warrant a very high discount rate. However, as I noted above, the uncertainty of information at this stage of the project’s life, combined with difficulties in adjusting for risk, makes the valuation produced by Model 4 highly uncertain — it will be unbiased, but the value will ultimately be revealed to be either much higher or much lower. There is also a problem with valuing the option-like characteristics of the asset using a Net Present Value approach. It is likely that values obtained by comparable sales will have a lower margin of error, but they, in turn, may be biased estimates of fundamental value since they may include pricing factors such as lack of competition for the asset.

For development and producing mineral properties, Model 4 in most cases produces a reasonable estimate of the fundamental value of the asset. Fair market value will approach this fundamental value when the asset trades in rational and competitive markets. This is likely to be the case for large properties sold at arm’s length. Small properties, on the other hand, are likely to transact at values other than their fundamental values for reasons that I have touched on.

Despite the fact that Model 4 produces fundamental value, it is very similar to a model used by mineral industry appraisers in the estimation of fair market value. In the royalty income approach to valuation, mineral appraisers value the royalty income that a mineral lease owner would expect to receive from the mining or oil firm. Before proceeding, let me therefore briefly discuss mineral royalties and this valuation approach. Mineral extraction often takes place from reserves that are not owned by the extraction firm. In many cases, at least in the United States, the reserves are owned by the federal

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5 Cases where it is not reasonable include those where \(V < 0\), where waiting to extract the mineral is optimal, and where there are real options to alter investment plans and extraction patterns as price, cost, and technical uncertainty resolves. See Davis (1996, 1998).
government. All land owners, including the government, charge the extracting firm a royalty, a percentage of gross or net revenues, for the privilege of extracting the mineral. A well-designed royalty will tax all of the excess economic profits away from the extractive firm, leaving them with a barely positive NPV project. In this case, the value of the asset to the extractive firm is zero — all of the value has been transferred to the royalty holder.

One can then see the relationship of Model 4 to the royalty income approach via the following equation.

**Model 5**

\[
V_0 \text{ (royalty owner)} + V_0 \text{ (extractive firm net of royalty)} = V_0 \text{ (asset)}
\]

If all of the asset value is transferred to the royalty owner via royalty payments, the NPV of the cash flows net of royalty payments would be zero, making \( V_0 \text{ (extractive firm net of royalty)} = 0 \). The present value of the royalty stream will then equal \( V_0 \text{ (asset)} \). One can therefore get at the fundamental value of the asset either via Model 4 with no deduction for the royalty payments in the cash flows, or via calculating the present value of the royalty stream. I prefer the former route, as most royalty streams are not well designed, and take too much or too little value away from the extractive firm. That is, the royalty income approach is, in my mind, a quick and dirty method of calculating an asset’s fundamental value, and is based on the strong assumption that the royalty owner has managed to tax away a value of \( V_0 \), not more and not less. I find this highly unlikely. My main point, though, is that the royalty income approach determines a fundamental asset value, which is only equal to fair market value under the restrictive assumptions that economists usually make.

Now, if one wanted to value a royalty owner’s position in the asset, without regard for what the asset is worth, one would, naturally, take a present value of the expected royalty income. This technique is valid no matter how poor the royalty design. To help matters, these royalty streams are often traded in the market, and so there is some market information as to the value of royalty position.

**MINERAL ASSET VALUES CHANGE FROM DAY TO DAY**

Whether valuing the royalty owner’s position, the extractive firm’s position, or the asset, the volatility of mineral prices means that value will vary widely from day to day, week to week, and year to year. In an interesting study of gold mining assets, Peter Tufano (1998) of Harvard University measured the sensitivity of gold company value to changes in gold price. He found that a 1% change in gold price typically caused a 2% change in mining company equity value. Gold prices are highly volatile, with daily changes of 1% a common occurrence. In valuations, therefore, especially for purposes of litigation, it is
vital to establish a date on which to value the asset, and to use the market’s (in the case of fundamental analysis) or buyer’s and seller’s (in the case of fair market value) forecasts as of that date in the valuation.

**THE VALUE OF A MINERAL ASSET IS HIGHLY DEPENDENT ON RESERVE CERTAINTY**

The quantity of ultimately recoverable reserves is only known upon permanent abandonment of the asset, and at the date of valuation the final amount of reserves is always uncertain. This provides a challenge for valuation, as not knowing the amount of reserves means that the productive life of the asset must be estimated. Nevertheless, in order to perform a fundamental valuation, we must have some *ex ante* estimate of the quantity of valuable material that can be extracted. The uncertainty surrounding the estimate of extractable reserve is called reserve risk.

The mining and petroleum industries each have their own reserve uncertainty classification systems. The mining industry uses the terms Inferred Resources, Indicated Resources, and Measured Resources to indicate increasing geological confidence. Standard definitions are given in Figure 1. The first thing to take away from these definitions is that the most uncertain category of reserves, Inferred Resources, is so uncertain and so unlikely to translate one for one into more certain reserves that no income projections can reasonably be made. This is not to say that these types of reserves have no value, but that their value is highly speculative, and are worth little per unit until upgraded to the Indicated or Measured categories via additional exploration work.

In the oil and natural gas industry, reserve uncertainty is denoted by the categories of Proven Reserves, Probable Reserves, and Possible Reserves, with Possible Reserves coinciding roughly with Inferred Resources. The mining industry also uses these reserve classifications: “Probable” mineral reserves are the currently economic portion of Indicated Resources, and “Proven” reserves are the currently economic portion of Measured Resources.
Figure 1: Widely Accepted Definitions of Mine Reserve Uncertainty (CIM 2000)

**Inferred Mineral Resource**: that part of a Mineral Resource for which quantity and grade or quality can be estimated on the basis of geological evidence and limited sampling and reasonably assumed, but not verified, geological and grade continuity. The estimate is based on limited information and sampling gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes.

**Indicated Mineral Resource**: that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics can be estimated with a level of confidence sufficient to allow the appropriate application of technical and economic parameters, to support mine planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes that are spaced closely enough for geological and grade continuity to be reasonably assumed.

**Measured Mineral Resource**: is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, physical characteristics are so well established that they can be estimated with confidence sufficient to allow the appropriate application of technical and economic parameters, to support production planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes that are spaced closely enough to confirm both geological and grade continuity.

Table 1: Transaction Values and Market Factors for Various Classes of Gold Reserves

<table>
<thead>
<tr>
<th>Resource Category</th>
<th>Average Price per Expected Ounce</th>
<th>Market Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven and Probable Reserves (Producing)</td>
<td>$60.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Proven and Probable Reserves (Development)</td>
<td>$34.10</td>
<td>0.56</td>
</tr>
<tr>
<td>Measured and Indicated Resources (Exploration)</td>
<td>$10.30</td>
<td>0.17</td>
</tr>
</tbody>
</table>

In general, Resources and Probable Reserves must be “proved up” to the category of Proven Reserves, the most geologically and economically certain category, before an extraction program can begin. This requires expenditure on drilling (information gathering) at the site. These additional costs, in and of themselves, will make assets in the
category of Resources and Possible Reserves less valuable than Proven Reserves, and we observe the market discounting non-Proven Reserves quite highly. Table 1 shows, for major gold property acquisitions during the 1990s, the average transaction price, on a per expected ounce basis, for each category of reserves and resources. The market factors, which simply convert the difference in transaction prices to a percentage, show that there is a significant premium paid for operating mines, where reserve and cost uncertainty has been reduced. Properties ripe for development trade at a 44% discount, with the difference coming largely from investor distaste for uncertainty. Measured and Indicated Resources are valued at a 83% discount, with no value being attributed to Inferred Resources.

Table 2: Market Factors for Various Classes of Oil and Gas Reserves

<table>
<thead>
<tr>
<th>Reserve Category</th>
<th>Average Market Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven Reserves (Producing)</td>
<td>0.97</td>
</tr>
<tr>
<td>Proven Reserves (Shut In)</td>
<td>0.85</td>
</tr>
<tr>
<td>Proven Reserves (Undeveloped)</td>
<td>0.56</td>
</tr>
<tr>
<td>Probable Reserves (Producing)</td>
<td>0.32</td>
</tr>
<tr>
<td>Probable Reserves (Undeveloped)</td>
<td>0.22</td>
</tr>
<tr>
<td>Possible Reserves (Producing)</td>
<td>0.09</td>
</tr>
<tr>
<td>Possible Reserves (Undeveloped)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

The comparable market factors for oil and gas reserves are given in Table 2 (SPEE 1999). Here we can clearly separate out the market factors for development costs from the market factors for reserve uncertainty. Proven Reserves that require development expenses trade at roughly 60% of the value of developed and producing reserves of the same risk category. Yet Probable Reserves at an undeveloped field trade at roughly 20% of the value of developed and producing Proven Reserves, with the additional 40% discount coming from reserve uncertainty. Once again, we see that reserves with high uncertainty are highly discounted.

I have often wondered why these high market factors exist. If the estimate of Possible Reserves is unbiased, and given that the risk is purely technical, the only discount should be for the additional drilling costs. The market factors, however, discount for much more than this. One explanation is that the market factors are correcting for bias in the estimated

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6 These figures are taken from Ludeman (2000), based on my interpretation of the resource categories of the various transactions he reports.
amount of non-Proven Reserves, as geologists tend to be optimists regarding the mineral potential of a property in its early phase.

WHAT IS THE CORRECT RISK-ADJUSTED DISCOUNT RATE (RADR) TO USE?

This is the most common question posed to me when I present a paper at a mining industry conference. The discount rate for mineral asset valuation performs the same function as with the valuation of any asset — it accounts for the time value of money and project risk. As such, one would think that standard financial theory, such as the Capital Asset Pricing Model (CAPM), could be used to determine the appropriate discount rate for a given discounted cash flow approach. However, I am finding it increasingly difficult to answer this discount rate question. For example, gold is often thought to be a “zero beta” asset, and as such, according to the CAPM, producing gold projects with proven reserves should be discounted at the after tax risk-free rate. Yet gold projects with proven reserves are typically evaluated at a radr of 14% on a nominal, after-tax basis. Other producing mineral projects are discounted at up to 19% (Bhappu and Guzman 1995). Oil is also a zero beta asset, yet producing reserves here, too, are evaluated at a nominal radr of 15% before tax (SPEE 1999).

Whenever I see a disconnect between theory and practice, I tend to question the theory rather than the decisions of those practitioners whose careers rest on their decision making. Finance theory, in my mind, fails to take into account the lack of diversification of many mineral extracting companies, whose managers and employees are exposed to mineral price risk. Any one bad project outcome can force the company into bankruptcy. Decision makers in these companies therefore add a significant insurance premium to their discount rate to ensure that they only take on projects that carry a substantial chance of success. Even with this cushion, though, the extractive industries have not managed more than a modest return to their shareholders; mining has returned only 5% to investors between 1973 and 1999 after adjusting for inflation (Humphreys 2000). Oil has done only slightly better, at 8%. I have a hunch that this may be related to real options analysis, which I will comment on below.

What about discount rates for projects with less certain reserves? Finance theory says that reserve uncertainty is unsystematic, and so, as long as reserve estimates are unbiased, no additional discounting for this risk should take place. This is clearly not what happens in practice. Reserve risk is penalized highly by decision makers in these firms. The approach, which seems reasonable to me, is to value each class of reserves separately, first calculating the NPV of the class as if the reserves were proven and producing, and then applying the above market factors specific to each class. Another way to get the same impact of reserve risk is to use a higher radr for risky or non-producing reserves, with the premium reflecting the undesirable unsystematic risk that is not supposed to concern decision makers. However, since finance theory gives us no advice as
to the appropriate increment to the radr, there is no way of knowing what radr should be used. I, therefore, prefer to value uncertain reserves (Probable Reserves, and Measured, Indicated, and Inferred Resources) at the typical 14% – 19% nominal radr for proven and producing properties and then adjust the resulting NPV downwards for resource risk using the market factors that we see industry applying.

I would like to make one more comment about risk-adjusted discount rates. Since individual mineral assets have finite lives, it is inappropriate to use a capitalization rate as a radr when valuing these assets. Capitalization rates are rates that convert a perpetual income stream to a present value (or convert a one-time investment into a perpetual income stream). Typically, if one observes a perpetual firm annually generating $1 million in after tax cash flows to all providers every year, and observes that its market value is, say, $5 million, one would calculate the firm’s capitalization rate as 1/5 = 20%/yr. If a firm of comparable risk were being valued, and if that firm was expected to generate a perpetual annual stream of $3 million, an NPV analysis would value that firm at 3/0.20 = $15 million. This capitalization rate approach cannot be used for mineral property valuation because of the finite life of reserves; to use a capitalization rate would be to overestimate value, as it presumes that production continues indefinitely. Mineral firms, on the other hand, who have an intellectual capital that produces perpetual income by identifying new projects to replace old ones, may be valued using a capitalization rate.

THE USE OF COMPARABLE SALES WHEN VALUING MINERAL RESERVES

Comparable sales, since they measure transaction values, produce fair market valuations rather than fundamental valuations. However, publicly quoted arm’s length transactions of mineral assets are rarely available. And where they are, the information becomes dated very quickly due to the volatility of mineral prices. As a result, sales comparisons must be adjusted, sometimes radically, if they are to be made comparable to the subject property at its date of valuation.

As I mentioned earlier, comparable sales are indispensable for valuing speculative and exploration properties, where there is not enough information to perform a reasonable fundamental NPV analysis. For development and producing properties, comparable sales can provide a benchmark when calculating the fundamental value of the asset. They also take into account the market factor for reserve and other risk. While comparable sales will not necessarily reveal an asset’s fundamental value, they introduce discipline into the valuation process.

WHAT ABOUT POLITICAL RISK?

Many mineral assets are located in developing countries, where political and financial instability detract from the value of the asset. Analysts often estimate an annual probability
of mineral asset loss of up to 50% in some countries, the high value being a result of the
tendency for nations to show force by nationalizing and “returning to the people” the
mineral assets of foreign corporations operating within the country. I would suggest,
however, that political and financial risk is in this day and age an unlikely event. The
insurance rates charged by insurers of political and financial risk typically indicate a risky
event probability of less than 2% per year. My own work shows that markets placed at
only 1.4% the annual probability that the African National Congress, in the early 1990s,
would carry out its threat to nationalize mining assets in South Africa (Davis 2001).
Incidentally, don’t waste your money purchasing political risk analysis from the various
companies that offer it. Their track record in predicting risky events is horrible.

A typical approach to dealing with this risk is to add a political risk premium to the
\[ \text{radr} \]. As ad hoc as it sounds, there is theoretical support for this approach, but only if the
following rules apply: the project has a long life, the risk is of permanently losing the
entire cash flow stream, and the annual probability of losing that cash flow stream is
constant. While this may sound like a lengthy laundry list, it applies in some cases, and
when it does, the appropriate impact of political risk on valuation is taken into account
when the \( \text{radr} \) is increased by this annual probability of permanent cash flow loss (Davis,
2001).

The next issue is the amount by which to increase the discount rate. For fully
diversified owners of the asset, if the annual probability of permanent cash flow loss is
2%, then the discount rate should be increased by two percentage points. Fully diversified
equity owners, for example, would wish that mineral asset managers use this increment
when assessing foreign projects. Undiversified asset managers, on the other hand, will
use a higher risk adjustment factor, the same project insurance premium effect that I
discussed earlier. Here, again, fundamental value recognizes the diversified nature of
shareholders, and recommends a relatively small premium in the discount rate for political
risk. Fair market value, on the other hand, will take into account that the transaction
value of the asset is impacted by managerial risk aversion on the part of both buyer and
seller, which will lead to a higher discount rate and lower asset value.

**DEPLETION ALLOWANCES AND TAX CALCULATIONS**

Since those who have claim to the cash flows emanating from a mineral property pay
taxes, all NPV and income approaches must be calculated using after tax cash flows. In
mineral asset valuation, just as depreciation of capital is a tax shield, so is extraction of a
mineral. Most mineral property operators are allowed this tax write-off as they produce,
which is known as depletion, and thus depletion effects must be taken into account in
calculating the taxes operators will pay (Stermole and Stermole 1993, pp. 298-307).
Depletion, just as depreciation, is a non-cash flow item, and must be added back to the
cash flow analysis after taxes have been calculated.
SMALL OWNER-OPERATOR DISCOUNT

When performing a fundamental valuation of a mineral asset, economists assume that the operator will follow an extraction plan that maximizes the value of the asset to the owner. This, in turn, requires that the optimal amount of capital be installed at the commencement of production. Generally, capital costs increase with the size of the reserve, as shown in Figure 2. Any investment pattern that deviates from the solid line is suboptimal, causing asset value to be destroyed.

Large firms tend to have access to financial markets such that they are able to install the appropriate amount of capital. Small owner-operators, however, are often severely capital constrained, and tend to invest in less costly and mis-sized used equipment (see Figure 2). This and the lack of skilled management and staff in these operations causes production inefficiencies which lower the present value of the receipts from extraction.

One might presume that larger extractive firms will buy these properties at a discount and create value by installing properly sized equipment and managing the asset more skillfully. Indeed, this is an assumption that economists make, and so their NPV analyses are based on optimal investment and extraction plans. Large companies, however, are not interested in these small deposits, and so we see small deposits trading at a significant discount to what they might be worth under the management of a large firm.
Figure 2: Optimal Investment Levels as a Function of Reserve Size

Valuators estimating either the fundamental or fair market value of small mineral properties or firms can take this destruction of value into account by directly modeling the suboptimal extraction program in an NPV calculation such as Model 4, or by applying a small operator market factor to the Model 4 NPV calculated assuming optimal asset management. It is my experience that 80% or more of an asset’s fundamental value is destroyed by small owner-operators, implying a small property market factor of 0.20. Differences between fundamental and fair market value are then created by unique buyer/seller dynamics that must be layered on top of this discounted value.

REAL OPTIONS, MINERAL ASSET VALUATION, AND EQUITY VALUATION

Real options is the application of financial option pricing theory to the valuation of real assets. It is all the rage, and its first application, in 1979, was to the valuation of mineral assets. In theory, at least, real options serves to describe the attributes of all classes of mineral properties much more appropriately than NPV analysis. The reason for this is that mineral properties contain within them option-like opportunities that cannot be valued by NPV analysis. It is well known within the industry, for example, that well-conducted NPV analysis tends to undervalue mining company equity (Davis 1996).7

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7 I define well-conducted NPV analysis as that which appropriately treats risk within the complete markets,
The result is that a mineral asset’s fundamental value usually is worth more than its NPV. This added value can only be uncovered using real options techniques.

In practice, however, calculating this added value is extremely difficult. There are shortcuts that the business schools are teaching their MBAs, but these shortcuts create so much valuation error that we really can’t rely on the numbers. Beware real options consultants bearing simple solutions!8

Real options theory does, however, solve a conundrum that I raised earlier. Mineral investments are generally valued using a 15% or so discount rate, and yet the return to holders of traded equity (shares) is on the order of 7%. How can this be? One answer, which I don’t think is correct, is that firms either pay more than the fundamental value for properties, or that the projects undertaken are less productive than originally thought. A better answer is that well-diversified equity holders of listed mineral firms recognize that mineral assets contain real options that significantly lower the risk of their investment. For example, equity holders face limited liability, yet get full participation in profits from the mineral asset. There are also options to shut-down or abandon loss-making properties, which again limits equityholders’ downside losses. These option characteristics add value, and equity holders, recognizing this, bid the equity up to its “real options” value. In addition, they also recognize that the options reduce risk, and only require a return of 7%, the required rate of return for assets (options) of this lower risk class.

All of this means that the link between mineral asset fundamental value and mineral firm equity value is indirect. Fundamental mineral asset valuation via NPV misses some of the value inherent in the flexibility afforded to mineral asset operators, and yet the equity markets reflect this value. Fundamental valuation via NPV also misses the reduction of risk that this flexibility brings to a project, and yet equity markets are aware of and take this reduction into account. For this reason, traded mineral company equity would appear to be worth more than the sum of its parts — the aggregate fundamental value of the underlying mineral assets — but this is not the case. The underlying assets are simply undervalued by decision makers who demonstrate their risk aversion using very high discount rates. I am not advocating that valuators jump on the real options bandwagon, but am merely suggesting that real options may explain these puzzling differences between fundamental asset valuation at the level of the project and equity valuation in the market.

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8 I have seen countless uses of the financial Black-Scholes model to value real options, an inappropriate shortcut that the business schools are teaching their students. The valuation result is absolutely meaningless.
SUMMARY

I began this paper by saying that the valuation of any mining or oil company is based on the value of its mineral assets. As such, as a starting point, one must begin with an accurate valuation of the mineral asset. I have noted here several valuation issues that are relevant to the extractive industries. One of the most prominent is that the management and staff of large mineral companies tends to be superior to that of small operators, and their capital investment decisions are closer to optimal. The result is that small mineral assets will tend to have a lower fundamental and fair market value, on a per unit basis, than that of larger assets. Another issue that I would like to emphasize is that if one wants to value a traded firm’s equity, we need to go further than a simple additive exercise and realize that traditional mineral asset valuation may not uncover all of the value seen by the market. This is partly because of the real option value of flexibility, partly because this flexibility reduces the riskiness of the underlying assets, and partly because equity holders face limited liability. All serve to enhance the equity holder’s position, causing most listed mineral companies to be worth more than the (apparent) sum of their parts.

References


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