What are in-situ gold resources worth? An empirical study

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Abstract

The sale prices of 226 gold mining projects throughout the world reflect the expectation that, at some stage, they may support a profitable mining operation and the magnitude of their potential future cash flows. The sales price is a function of the size (Moz) and grade (g/t Au) of the resource, which affects the type and scale of a possible operation, its likely capital and operating costs, and of the level of country risk (measured by a combined OECD – Fraser Institute index). The dynamic relationship between these parameters was used in a 3D block-model to predict prices for future transactions in various geopolitical environments given any size and grade combination. This analysis suggests that in all environments the market attributes preferential value to grade over size and in high-risk environments large low-grade assets trade at significant discounts to comparable assets in safer environments. In medium-risk environments gold resource transactions generally trade at premiums in relation to comparable assets in different risk environments in a manner that can be likened to the optimisation of debt/equity funding in project finance. Furthermore, it is noted that in medium-risk environments, the market liquidity is polarised between high-grade or very large resources, and on a relative discount basis suggests that medium-size/grade resources may be comparatively cheap. The block-model method adopted in this study has the potential to inject some comparability and objectivity in the otherwise somewhat arbitrary application of 'rule-of-thumb' in determining transaction prices for in-situ resources. Furthermore, when used with reference to liquid markets (ie small, low-grade resources in Australia), the block-model method can be used to estimate the sovereign risk discounts implicit in transactions occurring in other sectors of the market.

Introduction

The valuation of mineral assets is a complex process which requires the valuer to take into account, besides tonnages and grades, factors such as sovereign risk, commodity prices, exploration and economic potential, mineralisation-style, metallurgical and engineering qualities. Whilst data gathering and fairly objective expert advice represent a large proportion of the technical requirements of a valuation, ultimately the valuer has also to rely upon largely subjective judgement to derive a market value. The sovereign risk factor is the least quantifiable factor yet it can have a significant impact upon the market value of mineral assets.

There are currently a number of techniques which attempt to quantify the sovereign risk discount implicit in market transactions. These techniques generally rely upon a linear analysis of mineral assets with comparable deposit characteristics located in countries of different risk profiles and may make use of the capital asset pricing model ("CAPM") in estimating appropriate risk premia [Peirson et al., (2004)]. Reliability, of course, depends on whether the market is liquid and includes directly comparable assets, and on investors behaving in a rational manner devoid of excessive speculation. However, mineral assets are infrequently traded and tend to be unique in their styles of mineralisation. As a consequence, a directly comparable market-based approach is rarely possible and valuations will, in most cases have to rely on subjective expert opinion and 'leaps of faith'.

Valuation approach

The model presented in this paper has two main objectives and applications:

1. Estimating the value of an ounce of gold in any geo-political environment given the size and grade of a deposit and a prevailing gold price.

2. Estimating the country risk discount implicit in any transaction given the size, grade and price per ounce of gold equivalent received from the sale of a deposit.

There are essentially three generally accepted approaches that can be used to derive the market value of a mineral asset [Lawrence (2001)]. Each approach has certain advantages over the others when applied to specific stages of the mining cycle and consequently a valuer is required to critically assess which approach is the most suitable for the asset being valued [Spence. et al (2003), and Australian Institute of Mining and Metallurgy ("AusIMM") (1994b)]:

- **Income-based valuation** – derives the value of a mineral asset under the assumption that economic returns are achievable. The income-based approach is suited for the valuation of individual assets for which a large amount of technical data has already been collected or can be preliminarily estimated. An income-based valuation generally involves the construction of a discounted cash flow ("DCF") model of a project based on a preliminary or more advanced development concept and may include sophisticated risk analysis and simulation [Thomson (2000)]. However, the income-based approach is of limited use for broad market analysis of mineral projects at the exploration to pre-feasibility stages as it:

    - is laborious and requires specific technical detail for each mineral asset (the type of which is rarely available at the early stages);
    - provides a positive value only for mineral assets that can be economically exploited under the prevailing economic conditions even though the asset may command a price in the market;
    - doesn't fully reflect the marketable value (eg the market may attribute a discount or premium to the income-based value);
    - excludes numerous transactions with lower levels of development; and
    - is not conducive to comparing a large number of projects in a timely manner.

- **Cost-based valuation** – may apply a multiplication factor to reported historical exploration expenditure to derive a value estimate. The cost-based approach is suited to mineral assets which have limited technical data pertaining to them (eg early-stage exploration projects) and represent unique or infrequently traded styles of mineralisation [Ellis (2000)]. Public domain documents rarely outline valuation details and therefore this technique is impractical for broad market analysis. Consequently, cost-based valuation approaches are often used by state agencies in regions where free market forces are relatively new.

- **Market-based valuation** – transaction prices of projects in similar geographical, geopolitical and geological environments are used to derive a 'comparable' market value in a process similar to that used in real estate [Lawrence (2001)]. The market approach accounts for intangible aspects of a transaction; includes relevant market premium appropriate for the geographical domain; and is intuitive, easily understood and readily applied to the majority of projects. However, the market-based approach is reliant on a liquid, arbitrage-free market, relatively stable commodity prices and the assumption that mineral assets are comparable despite significant geological, metallurgical and engineering considerations. A more thorough discussion on the limitation of the market-based approach is presented in Lawrence (2001).

The market-based approach is considered the most suitable for the purposes of estimating the value of in-situ resources in various countries or their sovereign risk discount rates as it:

- requires limited and/or property specific knowledge;
- can be applied to a large number of transactions;
- is easily calculated;
- is intuitive;
- is insightful; and
- inherently accounts for sovereign risk, discount rates and geological diversity.

The methodology of the market-based approach used in this paper includes (Figure. 1):

- conversion of all by-product metals to gold-equivalents based on spot commodity prices at the date of each transaction announcement;
- grossing up the value of partial project sales to that of a 100% equity basis; and
- inflating transaction prices to a common basis, eg in this study 31 May 2007 US dollar equivalents.

Assumptions

A number of assumptions need to be made in deriving a value using the market-based approach and this may introduce interpretive variance into the findings of a valuation process. Given the global context of this analysis the following assumptions were unavoidable:

- **Time frame** – this report uses selected transactions that range from 11 September 2001 to 31 May 2007. This timeframe covers a period during which the market was buoyant and the gold price had a relatively low level of volatility compared to those of other metals. Significantly, this period predates the financial turbulence experienced in August 2007 which may represent a change in market volatility and the time when new floats on the Australian Stock Exchange ceased trading at significant premiums to their listing price.

- **Public domain information** – it is assumed that all transactions recorded are based on gold as their primary commodity; are principally valued as in-situ mineral resources; estimates are representative of the mineral resources irrelevant of whether they meet Joint Ore Reserve Committee ("JORC") Code reporting standards [AusIMM,(1994a)]; and the full value of the transactions is disclosed.

- **Efficient market** - As mineral assets containing mineralisation with potential economic value are infrequently traded, it is assumed that the market has efficiently differentiated between the varying Reserve, Resources and historical estimate classifications in the data set.

- **Consideration** – currency conversion to US dollar equivalent has the effect of preserving the value of the transaction. It is assumed that the consideration is representative of the market value of the mineral asset (ie transactions are conducted at arm's-length and are free of compulsion). In some cases consideration includes components other than cash, like shares and/or exploration and development expenditure commitments that are reasonably easy to value in cash terms. Securities that are issued without a stated value are deemed to have a price equivalent to the share price as at the opening of trading at the date of announcement. In other cases consideration may include components which are harder to value in cash terms such as derivatives and some types of future royalty payment obligations. To simplify the analysis, derivatives were deemed to have a strike price equivalent to the spot price of the underlying shares at the time of the announcement and as such to have no value; future royalty payment commitments based on Net Smelter Return ("NSR") based or other royalty bases were ignored due to their uncertainty and difficulty in estimating their economic value; and tenement holdings and supporting infrastructure were also assumed to have little comparative value. The authors realise that these assumptions have the potential of decreasing the total price paid for the resources although this potential distortion is not considered significant in the context of the current analysis and could be overcome if or when better information becomes available.

- **Mineralisation style** – it is assumed that mineral assets with the same gold-equivalents have similar market value to pure gold mineral assets; non-gold by-product minerals do not attract discounts or inflationary factors outside of those calculated by gold-equivalent factors (eg a gold and copper mineral asset is not valued above the sum value of its constituents); spot commodity prices used in the determination of gold-equivalents are representative of the value attributed to a property [ie the acquirer has no strong views regarding market futures (contango or backwardation)]; and mineral assets where gold comprises only a small portion of the apparent market value of a mineral asset can be excluded.

- **Dollar terms** – to adjust for inflationary effects the property values identified are inflated into US dollar terms at 31 May 2007 values. The official US inflation rate is used as a proxy for a standardised international inflation rate (http://www.bls.gov).

- **Commodity prices** – to account for gold price volatility between 11 September 2001 and 31 May 2007, the nominal implied transaction prices are adjusted relative to the differential between the prevailing and the gold price on 31 May 2007.

Block-modelling

Data definition

As a complement to the directly comparable valuation approach, it is proposed that a three dimensional analysis can be used to estimate the sovereign risk discounts implied by the market for any transaction or to obtain an estimate of the likely price for an in-situ resource, given its size and grade in any geopolitical environment.

To carry out a three dimensional analysis of mineral assets at any prevailing price of gold (ie dollars per contained ounce of gold equivalent metal), the X and Y axes were used to represent the magnitude of the grade (g/t AuEq) and size (Moz AuEq) variables respectively, while the Z axis was used to represent the country risk. Aside from expert opinion, measures of country risk can be derived from a number of publicly available surveys and indexes or be based on quantitative financial analysis (ie number of loan defaults). An example of the former is the Fraser Institute Annual Survey of Mining Companies '*Mineral Potential Assuming Current Regulations/Land Use Restrictions'* ("Fraser Survey") index and of the latter the Organisation for Economic Development and Co-operation's ("OECD") credit risk rating. While fundamentally different, both approaches have merit, for instance:

- In 2006/2007 the Fraser Survey was based on the opinion of approximately 330 survey participants and accounts for a broad spectrum of considerations, such as mineral prospectivity, regulatory conditions and sovereign risk [McMahon et al (2007)]. Given the relatively low number of respondents an element of bias cannot be categorically excluded.
- The OECD credit risk rating, by contrast, is statistically derived and more specifically based on the financial risk irrespective of the mineral prospectivity and/or regulatory attractiveness of a country [OECD, (2007)]. This may result in the OECD credit risk rating overstating a country mineral risk. For example, Tanzania is considered fiscally risky yet the general perception in the minerals industry is that Tanzania is not as risky as implied by the OECD credit risk rating alone.

For the purpose of this paper the Fraser Survey and OECD credit risk rating are combined using an equal weighting to derive a combined Fraser-OECD ("CFO") index. The CFO index has an advantage in that it accounts for mineral prospectivity, the regulatory environment and the financial risk (which is important when seeking debt funding arrangements). The CFO index is given a high to low-risk range of 0 to 1 (where 0 is the highest risk and 1 is the lowest risk). Although the authors' preference has been for a 50/50 weighting, a different weighting may be adopted by analysts to emphasise either the prospectivity/regulatory elements (ie higher Fraser Survey weighting) or the credit worthiness of a country (which may affect project financing). While the CFO index is a somewhat crude compromise, in the authors' opinion it does not seriously undermine the overall validity of the analysis in terms of market perceptions of country risk and related value adjustments.

The fourth dimension against which this XYZ model is cast is the sales price of a mineral resource estimated using the market-based approach at a given gold price (ie 31 May 2007). In the author's opinion, an analysis of gold is possible using this methodology because:

- it is a commodity and therefore the market generally does not differentiate between the source of the gold when sold as a refined product on a terminal bullion market;
- potentially economic significant gold deposits are found in a large number of countries;
- gold has a highly liquid market compared to many other mineral commodities;
- gold developments generally require relatively low capital investment requirements when compared to other commodities such as iron;
- gold mines typically sell a highly refined product (ie gold doré), which requires limited refinement and incurs minimal refining penalties;

- gold is not an industrial mineral and has limited use other than as a store of wealth and therefore is not generally influenced by stockpiles held by governments and commodity traders;
- historically the gold market has not been excessively influenced by supply and demand constraints (although there are aberrations); and
- the gold price has stayed relatively stable.

Whilst the above points are not literal truths, the authors consider that they have enough merit to validate the use of gold as a suitable medium for inclusion in the block-model method.

Dataset

The dataset comprises a total of 226 transactions sourced from the public domain, including the Australian, Toronto, London, New York and Johannesburg Stock Exchanges. Each of the transactions used in this paper satisfies the following criteria:

- Assets:
  - 168 (74%) involve gold only mineral assets;
  - 22 (10%) involved gold-silver assets;
  - 21 (9%) involved gold-copper assets; and
  - 15 (7%) involved gold-lead-zinc assets.
- Grade:
  - 65 (29%) have grades >6 g/t AuEq;
  - 58 (26%)have grades <6 but >3 g/t AuEq; and
  - 103 (45%) have grades <3 g/t AuEq (refer to the 'Data analysis' section for discussion on the selection of these grade categories).
- Mineral estimates:
  - 33 (15%) include Reserves;
  - 66 (29%) include at least Measured Resources;
  - 92 (41%) include at least Indicated Resources;
  - 30 (13%) have only an Inferred level of confidence; and
  - 67 (30%) contain estimates that do not meet the minimum reporting criteria of the 2004 JORC Code. Reason for exclusion from the JORC Code classification ranges from estimates that pre-date the current reporting standards and those reported in accordance with the Chinese or the former Soviet Union classification systems. Conceptual targets based on limited technical data were excluded from this analysis.
- Classification:
  - 159 (70%) were reported using the minimum reporting requirements set out in the JORC Code guidelines;
  - 14 (6%) were reported under the former Soviet Union classification system;
  - 2 (1%)were reported under the Chinese (1999) classification system; and
  - 51 (23%) concerned 'historical estimates' that did not conform to any current classification.

The distribution of the transactions on a grade versus total metal basis is shown in Figure 2.

Due to the paucity of detailed information relating to many of the transactions it was impossible to consistently discriminate with confidence between shallow resources amenable to open-cut mining and deeper ones suitable to underground mining methods. Based on explicit statements or descriptive terms and professional judgement (e.g. low grade mineralisation less than 100 m below surface), only 94 transactions (42%) could be clearly identified as being amenable to either open pit or underground exploitation, but often with little additional information such as mining technique or production costs. The differential in price of in-situ resources of similar size and grade can thus be attributed largely to country risk (including differences in mining costs in different countries), but also to different perceptions of the possible cost of mining for individual deposits in the same country (eg deep, high-grade gold mines in South Africa).

This limitation could of course be overcome if or when the transaction database underpinning this study is adequately populated allowing discrimination between relatively cheap and expensive-to-mine resources without excessive loss of confidence in the block-model. Similarly, as Reserves and Resources and historical estimates are juxtapositioned within the dataset, the resulting analysis must be treated with the same caution required in any other market-based approach.

Data analysis

Due to significant variability between the mineral assets in each transaction (principally size and grade), a transformation was required to more evenly distribute the data. For the 226 transactions used in this analysis the following transformations were used to distribute the data within a volume defined as 6.5 units by 6.5 units by 10 units in X, Y and Z dimensions respectively:

- **X** = 1.1[ln(grade) + 1.65]
- **Y** = 2[ln(size) – 9]/3
- **Z** = CFO x 10

The transformed data from the 226 transactions were spatially analysed using variograms to determine the continuity of the price variable within the spatially located dataset. For this paper continuity was determined for directions along the X, Y and Z axes and the following ranges of continuity were interpreted:

- 1.5 for direction 1 (X-axis);
- 2.0 for direction 2 (Y-axis); and
- 5.0 for direction 3 (Z-axis).

Furthermore, the analysis of the variograms indicated that variability (the 'nugget-effect') of is relatively low at around 20% which suggests that the market is relatively efficient at attributing value according to the economic potential and risk associated with a diverse range of resource transactions.

In order to populate a block-model with representative values an ordinary kriging estimation technique was used. The ordinary kriging technique has broad industry acceptance and uses the direction and distances determined in the variogram analyses to gather influence for any given point within the block-model [Isaaks et al., (1989)]. A block-model was generated with 24 sub-divisions of 0.25 in the X and Y axes and 3 sub-divisions in the Z axis. The X and Y axes extended from 0 to 6 units and the Z axis extended from 0 to 10 units. The entire data set of 226 transactions was used for estimation of the price variable into the blocks. For the illustrative purpose of this paper this model was re-blocked into a simple 3 by 3 by 3 model based areas of low, medium and high for each variable.

The simplified blocks are defined by size and grade combinations that are arbitrary in nature, however in the authors' opinion they are representative of the market's perception of what would be defined as low medium or high-grade and small, medium or large assets. On this basis, the size and grade dimensions of the blocks are, relative to the original data:

- **high-grade** – greater than 6.0 g/t AuEq:
- **medium-grade** – between 3.0 and 6.0 g/t AuEq;
- **low-grade** – less than 3.0 g/t AuEq;
- **small** – less than 1.00 Moz AuEq;
- **medium** – between 1.00 and 4.75 Moz AuEq; and
- **large** – greater than 4.75 Moz AuEq.

Ideally, the authors would have preferred the definition of a large asset to be anything greater than 5.0 Moz AuEq, however due to limitations of the reblocking used in this model, a value of 4.75 Moz AuEq is used as it represents the nearest 'best fit'.

The risk dimension is arbitrarily divided by thirds. Each transaction in the dataset was reviewed to ensure that this division is generally consistent with industry perception. On this basis, the blocks are defined as:

- **high-risk** – CFO index of less than 0.33
- **medium-risk** – a CFO index value between 0.33 and 0.67; and
- **low-risk** – a CFO index value greater than 0.67.

The distribution of the transformed dataset is shown Figure 3**,** from which it can be seen that there are few transactions which are defined as being large and high-grade or as small and low-grade. Consequently, the lack of data in the large, high-grade and small, low-grade areas results in an extrapolation of the dataset and caution must be exercised in the interpretation of these results. The size-grade categories in each to the risk domains are shown in Figures 4 to 6, from which it is noted that the medium-size, medium-grade combination is relatively illiquid.

Some of the weakness of this methodology are attributable to the scarcity and quality of the transaction information available and will progressively be addressed as the relevant databases are gradually populated.

On the basis of the discussion outlined in the preceding sections, a block-model was created, the stylised results of which are presented in Figures 7 to 9. The blocks are colour coded into the categories of:

- cheap (blue diagonal stripes) – less thanUS$25/oz AuEq;
- average (green dots) – between US$25 and US$35 AuEq; and
- expensive (solid red fill) – greater than US$35 AuEq.

For illustrative purposes, the above price categories are based on an even distribution of the block values (rounded to the nearest 5) such that cheap blocks represents 37%, average blocks 30% and expensive blocks 33% of the block-model. Relative to the original dataset, the cheap asset comprise 64%, average assets 7% and expensive assets 29% of the population. The difference between the dataset and block-model proportions is attributable to the natural asymmetry of the dataset (ie there are numerous inferior assets relative to superior assets) which is unrelated to the number of blocks in the model. Whilst the definition of cheap and expensive assets is largely subjective, the definitions used in this paper are of similar magnitude (allowing for inflation and increase in gold price) to those presented in Lawrence (2001).

Discussion

In-situ value

Based on an analysis using grade, size, and country risk (mineral potential and credit worthiness) of publicly disclosed transactions, the mineral market is shown to be reasonably consistent in the way it attributes value to mineral assets (Figures 7 to 9).

The block-model developed on the basis of 226 recorded gold project transactions indicates the following points.

- **In all risk environments, the market values are based preferentially on grade rather than size** (eg US$34-38-34/oz AuEq for small high-grade assets vs US$25-38-19/oz AuEq for large low-grade assets). The preference for high-grade assets may be attributable to the speed at which they can be exploited and the reduced capital investment requirements, therefore minimising the time/risk exposure. In addition, the favourable sentiment towards high-grade assets may be a reflection on the ability of such assets to remain economically viable under a wide range of macro-economic conditions. The latter observation is not surprising given that most projects are more sensitive to factors that affect the revenue function rather than those affecting the cost function (ie a change in the prevailing gold price or the grade of the material being processed has a greater impact than one in the operating and capital costs).

- **Low-grade assets in high-risk environments trade at significant discounts to analogous assets in safer environments** (eg US$25 vs US$19/oz AuEq for large low-grade assets in safe and risky blocks respectively). This low-grade aversion suggests that the market is unwilling to accept exposure to high-risk for assets that may not have a reasonable expectation of being economically exploited (ie sub-optimal grade-size combination) or those that are capital intensive.

- **Medium-risk environments attract some of the highest implied market values for some size/grade combinations relative to comparables in safer or riskier environments** (eg US$32-45-29/oz AuEq for small medium grade assets from low to high-risk blocks respectively)**.** The preference for medium-risk environments suggests that the benefit outweighs the cost of assuming some (but not excessive) risk. Based on this observation, it appears that the market values country risk in a similar fashion as to how it values the optimisation of financial risk introduced by increasing borrowing in the funding mix of a project:
    - projects that rely on little debt have less volatile cash flows but also no leverage on the return on equity (eg the NPV of a base case ungeared project). This is analogous to a low sovereign risk environment;
    - projects that rely heavily on debt may be able to achieve significant leverage above an ungeared project but attract significant additional financial risk (ie the expected NPV is significantly higher but also riskier

than that of the base case ungeared model). This is analogous to a high sovereign risk environment where the returns are potentially higher but attracting investment is difficult; and
  - projects funded with a balanced level of debt and equity may satisfy some of the investors' desire for balance between risk and returns, thus optimising their expected NPV in terms of their risk attitudes as well as the company's weighted average cost of capital [Guj et al., (2006)]. This is analogous to a medium sovereign risk environment.
  - The qualitative similarities between the implied transaction values and project gearing suggest that the market is consistent in the way it attributes discount to quantifiable risk (ie from financial gearing) and harder to quantify risk (ie sovereign risk).

- **In medium-risk environments, large low-grade assets trade at significant premiums in relation to comparables in low-risk environments** (e.g. US$38 vs US$25/oz AuEq). The relatively favourable sentiment towards large-low grade assets compared to small low-grade assets may be a reflection of the potentially large cash flows better satisfying minimum corporate target constraints (ie they are 'company makers' irrespective of geographic location).

- **In low-risk environments, small low-grade assets are relatively expensive compared to larger or higher grade assets** (ie US$35 vs US$21 or 32/oz AuEq)**.** The relatively high-cost of inferior assets may be a reflection of the demand by a large number of participants at the junior end of the market. Such competition for inferior assets may in part be driven by the necessity to establish a revenue stream; the capital required to purchase superior assets beyond the means of a junior company; or marketing considerations (ie wanting to be viewed as having the potential to make the transition from explorer to producer).

Implied risk

Although the absolute values determined in the block-model are representative only in relation to the price of gold applicable at a given time, the discount/premium relationship between size, grade and risk is likely to be of relevance for different gold prices and therefore at different points in time.

By selecting a particular block as the reference point, prices in other blocks can then be expressed as a percentage of the reference block. A reference block within the low-risk market should be preferred as this is generally the most liquid and therefore efficient (accurate) segment of the market. Reference blocks within high or medium-risk environments should be treated with more caution as these markets are less liquid and may not contain comparable assets. Furthermore, the block values of high-risk environments may rely on a greater degree of extrapolation of the dataset and therefore may be less accurate. For the purpose of this analysis, the small, low-grade and low-risk block has been used as a reference as it is easier to use for presentation purposes (Table 1). Alternatively, each unique size-grade combination can be related to the equivalent block in a safe environment (Table 2), although caution must be applied as the estimation confidence in each reference block is not equal.

Once a relational risk model is established, the NPV of any project in a high-risk country derived by using a time adjusted discount rate and a risk discount factor derived from the model (i.e. apply a factor of 77% to the time adjusted NPV of a large low grade asset in a high-risk country). This approach to discounting the NPV by a given country risk factor is a valid alternative to the use of a higher and generally arbitrarily set risk-adjusted discount rate to generate the NPV of a financial model. This has significant benefit as when using the CAPM it is often difficult to find a directly analogous asset in medium to high-risk environments. By segregating the financial discount rate used within the DCF from the country risk-discount, the valuer is able to easily communicate to the relevant parties the expected cash flow of a project and its market value in a simple and concise manner. In addition, the country risk discount factors implied within the block-model are based purely on actual asset transactions and are not directly influenced by stock market volatility, and consequently can be used to validate the assumptions used in a conventional CAPM-adjusted NPV. However, this risk-factor must be treated with caution in medium-risk environments as Tables 1 and 2 suggest that a time adjusted NPV would have an inflating factor applied to it. This result may be a function of the marketing value associated with the optimisation of risk in a similar fashion to the optimisation of financial gearing. However, if we assume that high-risk countries have minimal marketing value, then the main differential between safe and risky countries is the sovereign risk. On this basis, the use of the high-risk discount factor may be justified and can be used as a reality check for aggressive risk adjusted CAPM discount rates. For example, the risk adjusted CAPM NPV in a medium-risk country should be greater than the NPV determined by a time discounted and risk factorised NPV, else the CAPM discount rate may be excessively high [eg for a large, low- grade medium-risk project a hypothetical $NPV_{20\%}$ should be greater than ($NPV_{12\%}$ x 77%)].

Perhaps of greater interest is the potential use of the block-model derived risk discounts in sectors outside of the minerals industry as this technique is based on a commodity that in its refined form is valued equally across all geopolitical domains. On this basis, there is potential for the use of risk block-modelling to be used within the oil and gas, banking/finance, stock broking and insurance industries when assessing capital intensive projects with similar investment characteristics to those of the minerals industry.

Caution

The authors have undertaken an informal valuation on African project X using a broad suite of valuation approaches and methods to validate the use of the block-model method, however the method remains to be validated by a large number a real world valuations and consequently the methodology proposed in this paper remains at an early stage of evolution. To increase the acceptance and minimise errors associated with the use of the block-model method the authors have made the following notes:

- **The block-model method and the resultant risk discounts proposed in this paper are based upon the market approach and therefore the valuer must treat the results of this method with the same level of caution applied to more subjective analyses'.** Furthermore, the authors caution that the implied risk discounts derived in this paper are purely retrospective in context and pertain to a period of fiscal stability (ie prior to the American sub-prime crisis in late 2007). Since 31 May 2007 the global aversion to risk has increased, in part due to turbulence in the finance sector, but also due to the rise of sovereign risk in numerous countries in a manner that is reminiscent of the Resource Curse [Davis (1995)] (eg the rise of resource nationalism in Latin America and Africa). Consequently, the risk tolerance of the market may have changed significantly since 31 May 2007 and the market may now demand different premia/discounts in exchange for risk.

- **The quality of the block-model results, like all geostatistical estimation techniques, is contingent upon the quality of the input data.** A valuer who uses the block-model method needs to have at their disposal an extensive transactions database from which to draw upon so that the results have a high degree of integrity (eg the hypothetical equivalent of a Measured Resource), although it must be cautioned that the illiquidity of high-risk environments may not permit high levels of integrity even within an extensive database (ie the high-risk portions of the block-model may not even reach a hypothetical equivalent of an Inferred Resource). Furthermore, due to the extensive use of less tangible consideration (such as royalties) in North America, 'unofficial' payments in corrupt jurisdictions and the exclusion of financial derivatives, the implied values may not be entirely reflective of the true acquisition cost.

- **The use of powerful interpolation software in the block-model method does not negate the need for the valuer's experience or opinion**. The implied discounts in Table suggest that large high-grade assets in all environments are relatively cheap compared to smaller or lower grade assets. The unrealistic pricing of large high-grade assets in favourable geopolitical environments may be explained by excessive extrapolation of the dataset and/or a lack of market liquidity in this size-grade combination, and must therefore be viewed with suspicion that it is unrealistic. The illiquidity of large high-grade assets may be a result of many of these assets already residing in the portfolio of large and diversified companies unlikely of disposing of them by way of individual project sales and of the difficulty to attribute a risk discount to individual projects in a portfolio if acquired through a company take-over/merger.

- **The size-grade domains used to determine the blocks within a model can significant alter the outcome.** If a valuer elected to define the grade-size block boundaries according to the population distribution (ie thirds), the resultant block-model suggests that an increase in grade attracts a discount. Such a result is intuitively incorrect and can be attributed to the statistical block definitions being at odds with what would normally be described as being low to high-grade assets, or small to large assets.

- **The risk domains used to determine the block boundaries do not significantly distort the underlying trends.** To stress test the risk sensitivity, the block boundaries are adjusted such that high-risk as a CFO of less than 0.5; medium-risk a CFO of 0.5 to 0.75; and low-risk a CFO of greater than 0.75. As expected, the block values generally increases and the gap between low and high-risk block values decreases such that the implied discounts are less. Nonetheless, the resilience of high-grade assets and that large low-grade assets in high-risk blocks incur heavy discounts is not disrupted.

Based on the above points it is evident that, like all valuation approaches and methods, the block-model method may be incorrectly used or worse still, be subject to 'financial engineering'. However, given relatively large pool of professionals skilled in the use of geostatistical estimation, the industry is well positioned to accept, use and self-regulate the block-model method without the need to for additional training (a problem still faced by techniques such as Real Options Valuations). Furthermore, as it is based on established geostatistical techniques, the block-model method has an advantage in gaining general acceptance amongst market participants.

Conclusion

The block-model method allows for a rapid assessment of macro-investment trends and preferences for in-situ gold acquisitions in various geopolitical environments. It has the potential for broad industry use as a valid valuation tool to supplement more traditional valuation approaches based on income, cost and market transactions. This methodology can either provide an estimate of the likely in-situ value of gold resources given their size, grade and the country risk of the host nation or of the country risk given the price applied in an actual transaction. It is not envisaged that a 3D statistical method will or should replace the income, cost, market and geoscientific-based approaches (as every mineral asset is unique) but it could be used as a valuable guide to macro-investment trends. Furthermore, the rigorous maintenance of a market block-model could be used by mining analysts to target market inefficiencies (eg identify arbitrage opportunities) that may otherwise not be readily identified.

Images and Tables

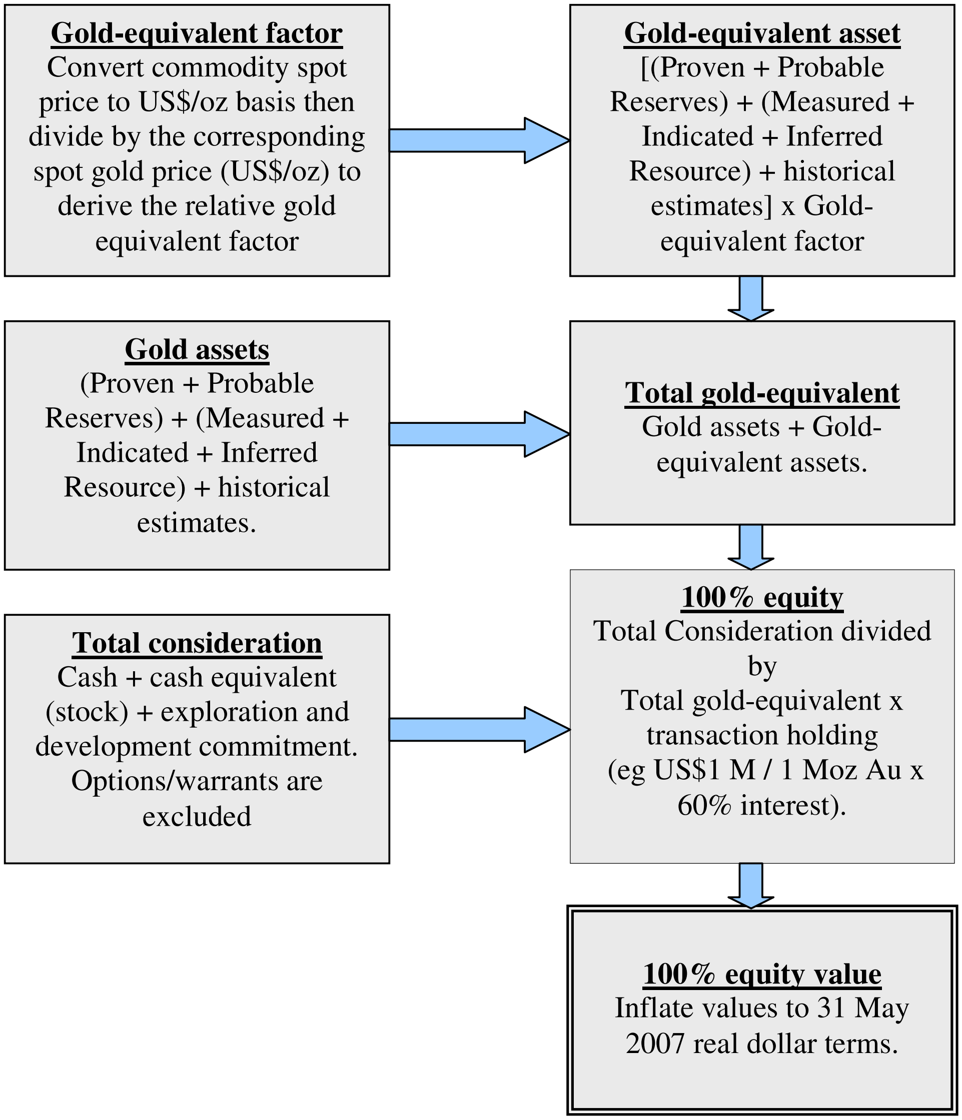
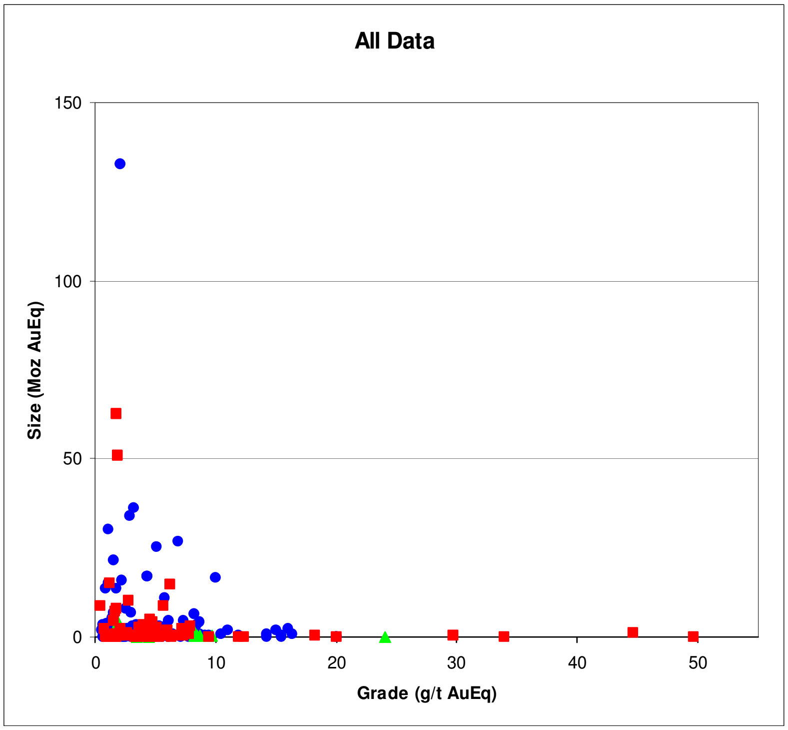
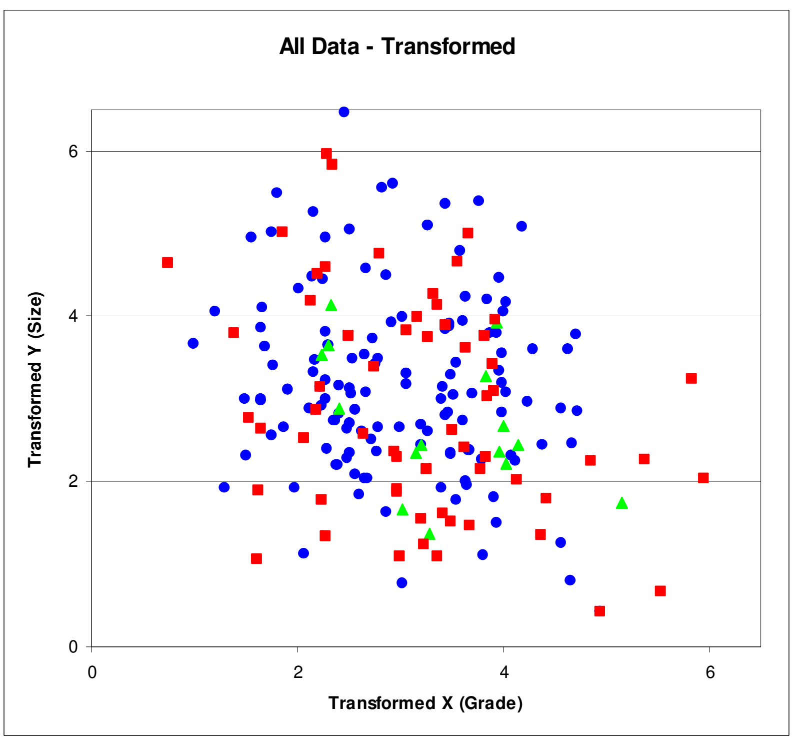


Figure 1 Methodology of the market-based valuation approach



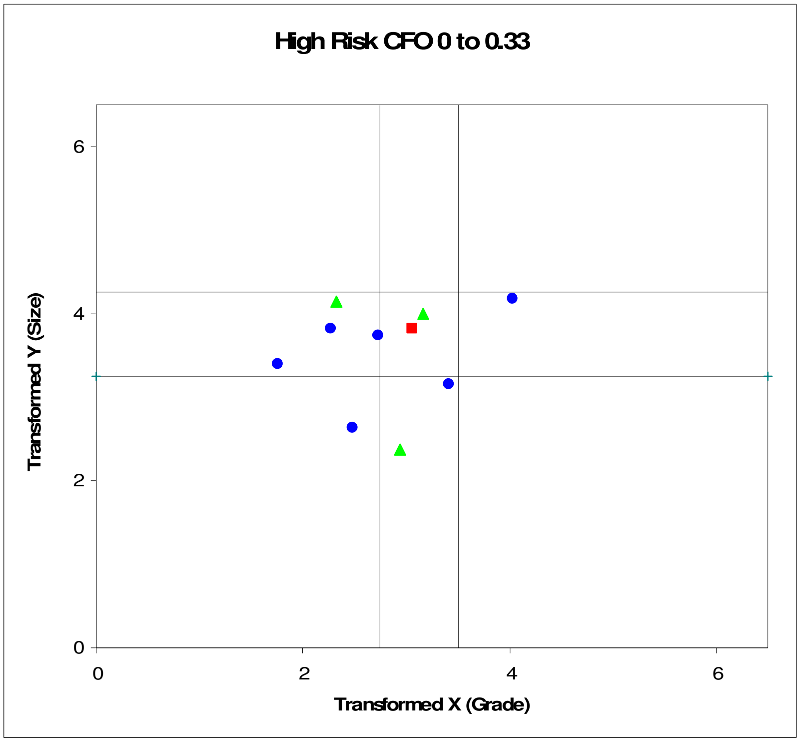
(blue dots=<$25/oz AuEq, green triangles= $25-$35/oz AuEq, red squares=>$35/oz AuEq)

Figure 2 The distribution of the underlying transactions dataset



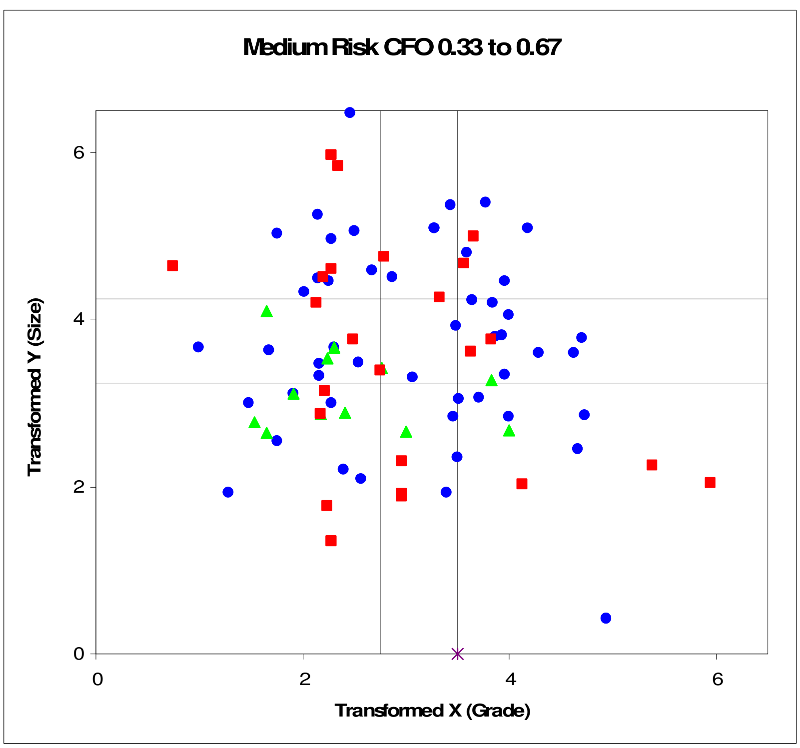
(blue dots=<$25/oz AuEq, green triangles= $25-$35/oz AuEq, red squares=>$35/oz AuEq)

Figure 3 The distribution of the transformed dataset



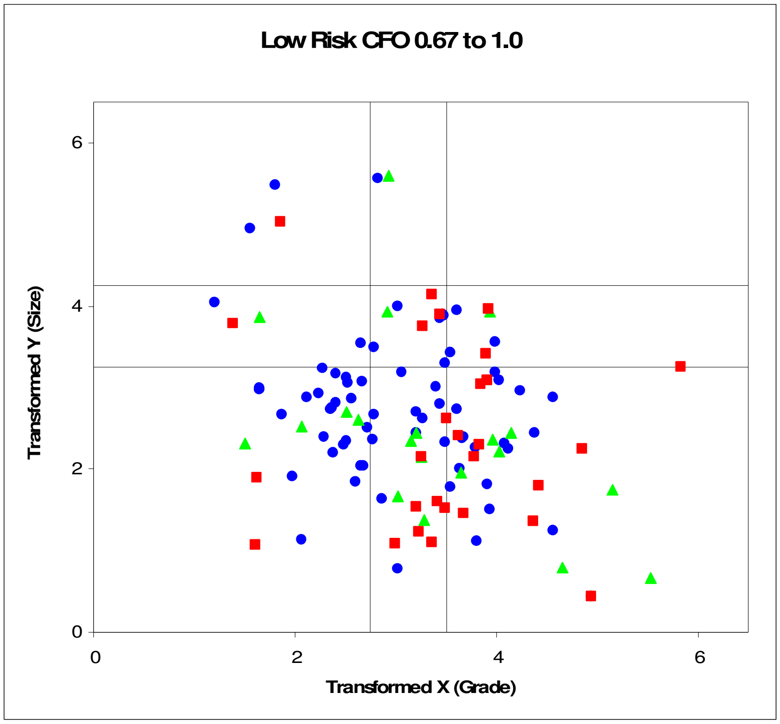
(blue dots=<$25/oz AuEq, green triangles= $25-$35/oz AuEq, red squares=>$35/oz AuEq)

Figure 4 The distribution of the high-risk data subset



(blue dots=<$25/oz AuEq, green triangles= $25-$35/oz AuEq, red squares=>$35/oz AuEq)

Figure 5 The distribution of the medium-risk data subset



(blue dots=<$25/oz AuEq, green triangles= $25-$35/oz AuEq, red squares=>$35/oz AuEq)

Figure 6 The distribution of the low-risk data subset

>4.75 Moz AuEq	$19	$23	$20
1 – 4.75 Moz AuEq	$17	$30	$24
<1 Moz AuEq	$24	$29	$34
	<3.0 g/t AuEq	3.0-6.0 g/t AuEq	>6.0 g/t AuEq

US$/oz AuEq
>35
25-35
<25

Figure 7 The high-risk block-model values

>4.75 Moz AuEq	$38	$33	$23
1 – 4.75 Moz AuEq	$39	$43	$17
<1 Moz AuEq	$35	$56	$38
	<3.0 g/t AuEq	3.0-6.0 g/t AuEq	>6.0 g/t AuEq

US$/oz AuEq
>35
25-35
<25

Figure 8 The medium-risk block-model values

>4.75 Moz AuEq	$25	$42	$58
1 – 4.75 Moz AuEq	$21	$43	$61
<1 Moz AuEq	$35	$32	$34
	<3.0 g/t AuEq	3.0-6.0 g/t AuEq	>6.0 g/t AuEq

US$/oz AuEq
>35
25-35
<25

Figure 9 The low-risk block-model values

		Grade		
		Low <3.0 g/t AuEq	Medium 3.0 – 6.0 g/t AuEq	High >6.0 g/t AuEq
HIGH-RISK	Large >4.75 Moz AuEq	55%	66%	58%
	Medium 1.00-4.75 Moz AuEq	48%	87%	70%
	Small <1.00 Moz AuEq	68%	84%	97%
MEDIUM-RISK	Large >4.75 Moz AuEq	109%	96%	66%
	Medium 1.00-4.75 Moz AuEq	114%	123%	49%
	Small <1.00 Moz AuEq	101%	161%	111%
LOW-RISK	Large >4.75 Moz AuEq	71%	122%	167%
	Medium 1.00-4.75 Moz AuEq	61%	125%	176%
	Small <1.00 Moz AuEq	**100%**	94%	99%

Table 1 Implied risk discounts relative to a small, low-grade asset in a favourable geo-political environment

		Grade		
		Low <3.0 g/t AuEq	Medium 3.0 – 6.0 g/t AuEq	High >6.0 g/t AuEq
HIGH-RISK	Large >4.75 Moz AuEq	77%	54%	35%
	Medium 1.00-4.75 Moz AuEq	79%	70%	40%
	Small <1.00 Moz AuEq	68%	90%	98%
MEDIUM-RISK	Large >4.75 Moz AuEq	154%	78%	40%
	Medium 1.00-4.75 Moz AuEq	186%	98%	28%
	Small <1.00 Moz AuEq	101%	172%	112%
LOW-RISK	Large >4.75 Moz AuEq	100%	100%	100%
	Medium 1.00-4.75 Moz AuEq	100%	100%	100%
	Small <1.00 Moz AuEq	100%	100%	100%

Table 2 Implied risk discounts relative to the equivalent size-grade combinations in a favourable geo-political environment

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