Western Australian School of Mines

Risk Adjusted Evaluation of Mineral Assets Using Transaction Based Statistical Models

Jonathan Alexander Bell

This thesis is presented for the Degree of
Doctor of Philosophy
of
Curtin University

JUNE 2019

Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material that has been accepted for the award of any other degree or diploma in any university.

Signed:

(Jonathan Alexander Bell)

Date: 19 June 2019

Doctor of Philosophy Candidate: Jonathan Alexander Bell[1]

University: Curtin University

Faculty: Science and Engineering

Enrolling area: Western Australian School of Mines

Student Identification Number: 09822847

Course Code: 301924 (v2)

FOR Code: 091405 – Mining Engineering

Study rate: Part time

Chairperson: H Znad[2]

Supervisor: B Maybee[3]

Associate supervisor: P Guj[4],

Keywords: gold, price, pricing, country risk, ownership risk, confidence risk, commodity price risk

1 MAIG, GAICD, Western Australian School of Mines (Curtin University), Locked bag 30, Kalgoorlie, WA, 6433; Managing Director , Alexander Research Pty Ltd; PO Box 6644, Broadway-Nedlands, Crawley, WA, 6009, e: jonathan.a.bell@gmail.com (corresponding author)

2 Senior Lecturer, Department of Minerals, Energy and Chemical Engineering, Western Australian School of Mines, Faculty of Science and Engineering (Curtin University), Locked bag 30, Kalgoorlie, WA, 6433 e: H.Znad@curtin.edu.au

3 MAusIMM, Associate Professor, Department of Mineral and Energy Economics (Curtin University), GPO Box U1987, Perth WA, 6845 e: b.maybee@curtin.edu.au

4 MAusIMM, MAIG, Research Professor, Centre for Exploration Targeting, Curtin Graduate School of Business, c/o School of Earth and Geographical Sciences M006, The University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, e:pietro.guj@uwa.edu.au

Abstract

The objective of this thesis is to answer the question, “how do the characteristics of gold deposit transactions affect their price”? Four hypotheses are posed which address fundamental variables that affect the price of gold deposits. Despite the obvious and significant nature of these variables, their influence on gold deposit prices is poorly described. As well as advancing the scientific knowledge base, this research has direct commercial relevance as it uses public domain data and methodologies that can be readily adopted by mining industry professionals. Even small improvements in the understanding of gold deposit transactions have a significant monetary value, given that during the five-year period between 2008 and 2012 the global gold deposit transactions tallied to (US)$75 billion (Wright 2014).

This thesis demonstrates that there is no single ‘going rate’ for an ounce of in-situ gold in a deposit. The data investigated shows that the size and grade of a gold deposit strongly affects both its price, as well as its price behaviour. It is shown that level of ownership acquired in a gold deposit affects the $/oz Au unit price, and that less than 100% ownership can lead to substantially higher $/oz Au prices being paid during risk-averse market conditions. However, it is shown that in risk-tolerant markets that less than 100% ownership can lead to relatively modest discounts. A reversal in the market behaviour is also observed in the research in country risk, with heavy discounts being applied for less favourable country exposures during risk-averse market conditions. It is also shown that the rate at which a deposit’s price changes is disproportionate to the prevailing gold metal price, and that increasing the confidence of a mineral estimate usually leads to an increase in the deposit’s price. However, it is observed that the market is strongly stratified with small deposits either expressing different rates of price change relative to larger deposits, or different markedly different behaviour. For example, small deposits tend to achieve lower prices when their mineral estimates become highly certain. These behaviours are not shown in the literature nor are they correctly accounted for in industry practice, which means that the research outcomes have direct commercial relevance as well as academic value.

Through a review of the academic literature, it was identified that the field of mineral asset pricing is a poorly researched field, which falls between a number of well-documented fields such as gold deposit valuation, real estate pricing and security pricing. Often, the term price (what you pay) is used interchangeably

with value (what you get). Price is heavily influenced by exogenous aspects (e.g. negotiating with a willing buyer), whereas value is oriented more toward endogenous characteristics (e.g. quantity, quality, depth, morphology). Within the pricing field, there is often an assumption that the price of a security is a direct measure of the price of the underlying asset. However, the process of securitising an asset fundamentally changes its ownership structure and market liquidity, and in doing so, will affect the price (Yiu et al. 2006). The confusion between asset value, asset price, and different ownership structures (e.g. securitisation) is because of "a general lack of mineral property valuation [pricing] understanding" (Lilford 2004). In part, this is due to the need for an interdisciplinary understanding of gold deposit price drivers that requires competence in the technical aspects of the mining industry; an understanding of gold deposit valuation; and how, along with other project-specific and macroeconomic variables, the interaction leads to the determination of the price for a gold deposit.

The Lilford (2004) thesis is a key document in describing the price behaviour of a gold deposit given its size, grade, depth, location and mineral estimate confidence. Building on that research, this thesis hypothesises that:

Ownership risk – the price of a gold deposit on a $/oz basis does not necessarily increase with increasing ownership.

Commodity price risk – the price of a gold deposit changes disproportionally to the prevailing market price for gold metal at the time of the transaction.

Certainty risk – the price of a gold deposit increases disproportionally to increases in the certainty of a deposit's quantity and quality estimate.

Country risk – the prevailing risk tolerance of the market influences the impact of a jurisdiction's systematic risk on the price of a gold deposit.

As the knowledge gaps being tested by the hypotheses are not described in the existing literature, they are investigated in isolation of each other. Future research may expand on the finding by undertaking simultaneous methodologies.

This thesis uses price, something that is directly observable in the market. Consequently, to address the hypotheses an empirical dataset was created from public-domain data concerning mineral asset transactions. These transactions are largely based on gold deposits, as gold mining does not rely heavily on support infrastructure, gold projects are frequently traded relative to other commodity types, and they require little downstream/offsite refining before sale into a terminal market. Identified transactions are manually entered into a database before categorisation, extraction and manipulation in each of the models. Information that is external to the transaction but relevant to the research is sourced from the public domain (e.g. risk indexes, commodity prices).

Market data are inherently noisy, and it is often necessary to simultaneously account for a number of variables to identify patterns. Sight is an important sense and plays a role in pattern recognition by being able to account for four variables [spatial location X-Y-Z, and magnitude (e.g. colour)]. By plotting the price of a mineral asset in an artificial space defined by its quantity (X), quality (Y), risk (Z) and magnitude ($), it can be visually interrogated and described using spatial statistics (geostatistics). To analyse a spatial dataset, semi-variograms are used to identify the nature of the relationship between the data when expressed in three-dimensional spaces. The information from the semi-variograms defines the shape and orientation of the search ellipse. The ellipse is used to apply weights of importance to data points that fall within its space, by considering the direction from which it comes as well as its distance from the centroid. The resulting value for the centroid is then assigned a volume for the cuboid (block). Unlike a simple matrix, (e.g. polygional modelling) ordinary kriging uses soft boundaries where information that falls outside a discrete block influences the estimation of the value contained within the block. The ordinary kriging process acknowledges that the relationships between data points are continuous . A block model is produced when numerous search ellipses are run to define contiguous or related blocks.

The quantity (tonnes, X-axis) and quality (grade, Y-axis) dimensions of the dataset distribute log-normally due to the natural underpinnings of the geological inputs. To enhance visual validation, the X and Y points are transformed prior to estimation. The transformation avoids the resulting model having an excessively planar shape (e.g. like a sheet of paper). No back-transformations are performed, alleviating the difficulty and risk associated with such operations. The block model's results are also to the mean and median of the data in each block. The patterns within the block models are then used to describe the behaviour of the market variables being assessed. It is important to emphasise that the trends within the dataset are important in this research, not the magnitude of the estimated price. These trends are based on coarse 3x3x3 divisions (i.e. low, medium, high) that minimise the impact of noisy data and estimation nuances.

In this thesis, the Z-axis represents the dependent variable that underpins each of the hypotheses (e.g. commodity price, ownership, certainty and country risk). The ability to quantify the Z-axis variable determines its reliability in the block model method. While it is possible to determine a precise and reliable scale for the Z-axis in some applications, others are difficult to quantify and express. Consequently, the hypotheses are sub-divided into two main groupings that reflect the ability to measure their basis:

- **certain** – the inputs are absolute:
  - proportion of the asset that is acquired (endogenous issue)
  - prevailing gold price at the time a mineral asset transacted (exogenous issue).
- **subjective** – manipulation is needed to express inputs on a Z-axis:
  - estimate confidence – market classification of mineral estimate confidence is qualitative, placing uncertainty on the weight that should be assigned (endogenous expression issue)
  - country risk – where the inputs are subjective, but lend themselves to ranking (exogenous input issue).

While it is possible to create a block model using any four variables, it does not mean that the mathematically correct outcome has a connection with reality. As a result, this research is conducted collaboratively with Specialists in geostatistical estimation. These Specialists were supplied with the relevant datasets, advised on how to distribute and transform the inputs and tasked with undertaking semi-variogram analysis and the population of the block models. Different geostatistical experts were used in each hypothesis for the purpose accessing a breadth of knowledge, exposure to a wide range of geostatistical experience, as well as peer validation. The resulting block models were compared with polygonal estimates.

It is important to emphasise that this thesis is not about geostatistics, but is about observing price behaviour. The geostatistical methodology used is well established and does not add to the literature per se. Instead, the geostatistical method is used as a means of dynamically modelling statistical significance of any relationship between the variable. This geostatistical aspect serves to satisfy the statistical significance requirement of the hedonic pricing method. This leaves the focus of the thesis on

- describing the known influence of each risk
- determining a means of plotting the risk on the Z axis
- identifying, quantifying and describing any relationships identified in the resulting block models

- drawing conclusions on the relevance of any identified relationships
- establishing the implication of this research within the current body of knowledge
- concluding the answer to the hypotheses.

This research describes previously unidentified market behaviours, notably that small deposit transactions appear to have a different market behaviour to their larger equivalents; and that deep deposits are more expensive than their near surface equivalents which may be due to a perception of upside optionality. Furthermore, the empirical research yields observations that are not consistent with theories obtained from other fields of knowledge and applied to mineral assets (e.g. securities) or falsifies practices described in the informal literature. As there is little existing literature on mineral asset pricing, the maiden descriptions in this thesis are intended only to demonstrate what relationships exist. Specifically, the underlying data are inherently noisy and erratically populated and as such not suited to specific point-estimation. However, having established the nature of the relationships, this interdisciplinary research provides a building block for further expansion and refinement in the field of mineral asset pricing, which is surprisingly poorly described and has significant and direct commercial importance.

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1 Introduction

1.1 Purpose

The objective of this thesis is to answer the question, "**how do the characteristics of a gold deposit transaction affect its price**"? Between 2005 and 2014, the cumulative monetary value of gold deposit transactions was worth $144,700 M (Wright 2015). Despite the substantial commercial interest in gold deposit transactions, Lilford (2004) notes that there is "a general lack of mineral property valuation [and pricing] understanding".

Gold deposit pricing includes aspects of some well-documented fields such as gold deposit valuation, real estate pricing and security pricing. However, there is limited literature that directly addresses the price behaviour of gold deposits at an individual asset level. In part, this is due to price (what you pay) and value (what you get), as defined by IVSC (2012), being erroneously used interchangeably, as highlighted by Özdilek (2010). Price, as defined by IVSC (2012) is heavily influenced by exogenous aspects (e.g. currency exchange rates (Adolfson 2009), whereas value is oriented more toward endogenous characteristics (Li and Yang 2012; Deneckere and Peck 2012) such as quantity and quality. Within the pricing field, there is often an assumption that the price of a security is a direct measure of the price of the underlying asset as identified by Faltin-Traeger et al. (2010). However, Gaur et al. (2011), Cheng et al. (2011) and Yiu et al. (2006) state that the process of securitising an asset changes its ownership structure and market liquidity, and in doing so, will have an impact on the price. Xiao and Tan (2007) identify that non-securitised markets, such as real estate, display inefficient qualities including high transaction costs and the inability to short-sell. Humphreys (2010) also notes that these markets have a supply lag in response to changes in demand. Mooya (2009) considers that in such markets, the rate of intellectual progress is slow, and the science of price estimating is treated with scepticism. Therefore, the purpose of this thesis is to advance the knowledge of price behaviour relating to gold deposits using an empirical/positive (what it is) rather than normative (what it should be) perspective. Furthermore, as the hypothesis are testing fundamental aspects and the data is limited and inconsistent in its availability, the *a posteriori* methodology is designed to focus on the essence, rather than prematurely delve into precision.

As the price determination of a gold deposit's price, termed "mineral asset pricing" in this thesis, is poorly described in the literature, a variation on the hedonic pricing model advocated by Lancaster (1966) and Kakhki et al. (2010)

will be used to test the four hypotheses listed below. In so doing, this thesis builds upon the work of Lilford (2004), which represents a rare example of using empirical evidence to model mineral asset prices.

The hypotheses investigated are:

- **Ownership risk** – on a dollar per ounce basis ($/oz), the price of a gold deposit does not always increase with the increased level of ownership by one of the parties.
- **Commodity price risk** – the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction but through disproportionate movements.
- **Certainty risk** – the price of a gold deposit increases disproportionately with increases in the certainty of a deposits quantity and quality estimates.
- **Country risk** – the geopolitical characteristics of a country affect the price of a gold deposit.

1.2 Scope

This research is focussed on the price behaviour of gold deposit at an asset level (Figure 1). The scope is restricted to the four hypotheses concerning ownership, commodity price, certainty, and country risk. The scope does not include the value of individual gold deposits or price of a single deposit (point estimate) and excludes the price of securities that may relate to gold deposits. The methodology is restricted to the hedonic pricing approach because it is based on observable qualities (positive analysis, which measures 'what is' (Siggel, 2006)) rather than being theoretical or reliant on judgement (normative analysis, which measures 'what it should be' (Siggel, 2006)). As there is little pre-existing mineral asset pricing literature on the four hypotheses, the results are limited to being at an order-of-magnitude accuracy upon which future refinement can be made. Similarly, the four investigations are made in isolation of one another to avoid the risk of compounding error.

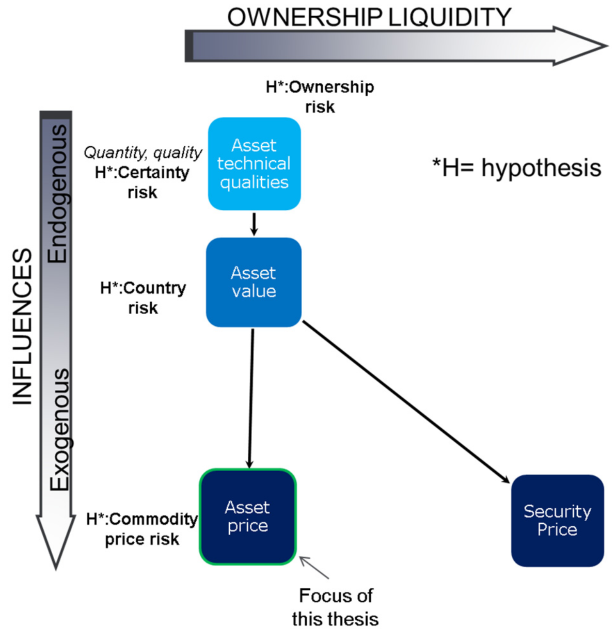


Figure 1. Price behaviour of gold deposit at an asset level of this thesis

1.3 Importance

The research presented in this thesis is both of theoretical and commercial importance. Building on the work of Lilford (2004), this thesis helps to establish mineral asset pricing as a distinct field of research by identifying gaps in the literature and demonstrating that the existing knowledge in other fields cannot be directly applied to fill those gaps. Kahneman and Lovallo (1993) state that most estimates are underestimates and Bertisen and Davis (2008) find that the capital costs of mining project start-ups often fall short of the realised build cost. Based on pre- and post-transaction data, Elnathan and Gavious (2009) identify that ‘expert’ price predictions are typically 29% higher than actual market prices, with the bias being is in favour of the commissioning entity. Mooya (2009) and Lusht (1981) note that pricing is a field that is influenced by art, where equally well-qualified experts are unable to arrive at the same conclusion, as noted by Ratcliff (1975), Smith (1997), Lusht (1981), and Vandell (1982). Within the commercial literature, this is evidenced by Grant (1994) who rejects sophisticated models on the basis that “any conclusion is possible” through their use. Baker and Dodd (1994) state that “in practice, qualitative judgements are made”. Sorentino and Barnett (1994) highlight the common flawed assumption that “subjective evaluation is good enough”. Furthermore, O’Connor and McMahon (1994) state that the “science of the methodology does [should] not dominate the assessment”; and Grant (1994) states: “the real message is that valuation is an art. It is not a science”. This body of literature demonstrates the economic importance of this field of research as it has the potential to improve the accuracy of price prediction in a commercially important area.

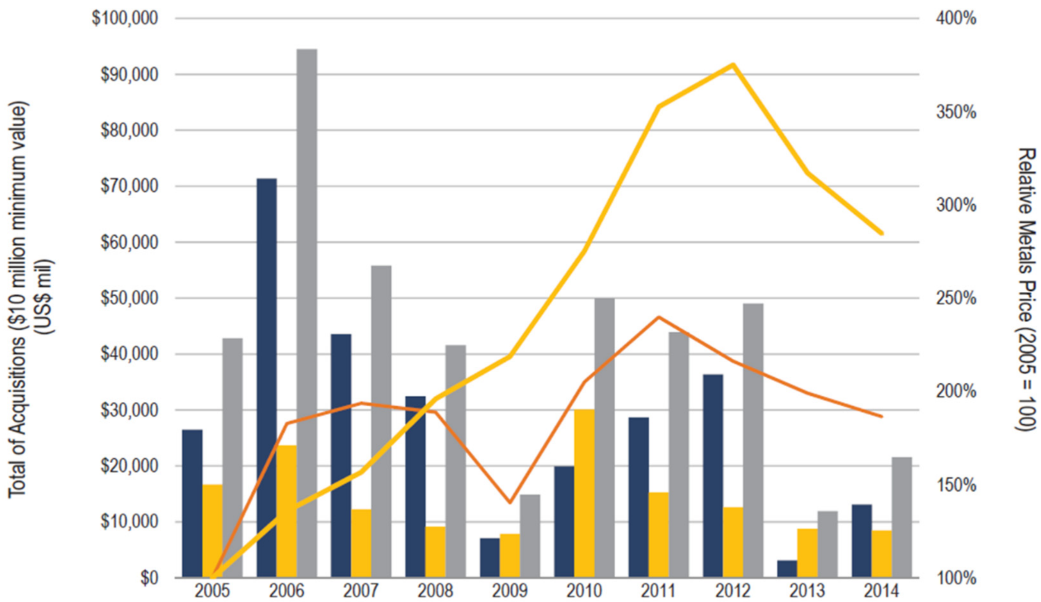
Fuji and Takahashi (2014), Hilton and O'Brien (2009), Boatsman and Baskin (1981), and Lusht (1981) state that price is something that is directly observable in the market through publicly available transaction announcements. In the gold deposit transactions market, Wright (2015) observes that globally the transactions were cumulatively worth more than $9,127 M in 2008 (Figure 2), when the work on this thesis began; and $15,265 M in 2011 (Figure 2), when the data underpinning this thesis ended. Despite the fiscal scale of the transactions, price prediction is inconsistent amongst practitioners, with equally competent and qualified Specialists arriving at different conclusions (Smith 1977; Mooya 2009; Bottazzi et al. 2011; and Yamazaki 2000). Australian mining industry sourced reports appear to assign confidence ranges in the order of ±20% around the preferred price estimate for a gold deposit (Table A-2.1 in Appendix 2).

This is consistent with the 20% price uncertainty range stipulated by the courts in the United Kingdom, and 35% price prediction accuracy bracket recommended by Crosby (2000). Also, Crosby (2000) and Ingenbleek and Van der Lans (2013) identify that there is limited empirical evidence supporting the uncertainty of a price prediction. However, Man and Ng (2007) identify that during periods of high market volatility, price predictions may fall outside of a ±20% confidence band 70% of the time. The inaccurate confidence estimates are consistent with, Aluko (2007) who using controlled experiments in the real estate sector determines that expert judgment inconsistently incorporates critical information.

Mooya (2009) states that valuers are highly influential in the market. As markets are directly observable, it is possible to estimate the impact of improvements in price prediction. For example, if the proposed research results in a 5% increase in the accuracy of price predictions (i.e. well within the current price estimate ranges), then based on the figures published by Wright (2015) the year 2014 economic impact may have been in the order of:

- **$425 M per annum** if only gold deposits are considered
- **$1,080 M per annum** if base-metal acquisitions are included.

Consequently, testing the hypotheses of ownership, commodity price, certainty and country risks is important not only from an academic perspective but has the potential for significant commercial impact.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Base Metals	$26,480	$71,344	$43,566	$32,429	$7,066	$19,902	$28,657	$36,381	$3,108	$13,080
Gold	$16,678	$23,632	$12,241	$9,127	$7,815	$30,078	$15,265	$12,606	$8,776	$8,482
Total	$42,803	$94,485	$55,807	$41,555	$14,882	$49,980	$43,922	$48,987	$11,884	$21,562
Cu Relative Price	100%	183%	194%	189%	140%	205%	240%	216%	199%	186%
Au Relative Price	100%	136%	157%	196%	219%	275%	353%	375%	317%	285%

Figure 2. Aggregated prices of gold and base-metal acquisitions 2005-2014

(Wright, 2015)

1.4 Data sources

To test how ownership, commodity, certainty, and price risk affects the price of a gold deposit, directly observable data were sourced from a commercial mineral asset transactions database. The datasets are wholly owned by Alexander Research Pty Ltd (Alexander Research), an entity that is owned by the author. Alexander Research uses the database for internal commercial purposes. The database accessed in this research is a tool and does not convey economic benefit or conflict the author.The selected data only include transactions where there was sufficient publicly available information on which it is possible to generate unit values. In most cases, the transactions were verified by documents contained on the:

- Australian Stock Exchange (ASX)
- Toronto Stock Exchange (TSX) via www.sedar.com
- Alternative Investment Market (AIM) on the London Stock Exchange
- Johannesburg Stock Exchange (JSE)
- New York Stock Exchange (NYSE).

Exchange rates were obtained from the Reserve Bank of Australia (RBA). Where exchange rates were not quoted by the RBA, rates were obtained from www.x-rates.com. Inflation rates were sourced from:

- US Federal Reserve (www.federalreserve.gov)
- Reserve Bank of Australia (www.rba.gov.au)
- Bank of Canada (www.bankofcanada.ca).

1.5 Thesis layout

This thesis contains six sections such that there are there main sections based on the literature review (Section 2), the methodology used (Section 3) and the results of the investigations in into testing the hypothesis concerning ownership, commodity price, certainty and country risks (Section 4). Along with the introduction section, there is also a section discussing the limitation and future opportunities identified through the thesis (Section 5) and a concluding section (Section 6). Ancillary research that is related to, but are not part of this thesis, are presented in appendices 8 to 13.

The literature review in Section 2 sets out what makes mineral asset pricing a field in its own right. It does this by describing the differences between the concepts of cost, value and price and presents the findings on why security prices cannot be directly applied to tightly held ownership structures. The section goes on to review and present the known influences on the price of a gold deposit, ranging from endogenous (internal) qualities to exogenous (external) influences. Finally, Section 2 reviews the methods used to estimate price and presents the merits and weaknesses of each, allowing the reader to appreciate the importance of the variables that affect the price of a gold deposit and gives context as to the selection of the most appropriate research methodology. The selected methodology is discussed in Section 3.

Section 4 presents the research and results of testing the four hypotheses. The qualities for each dataset used in testing the hypotheses are presented as part of the analysis, which promotes a more concise structure for the reader. The investigation for each hypothesis is then presented. As there is little empirical research on gold deposit price behaviour and many factors may affect the price of a gold deposit, sub-analyses are presented. These sub-analyses demonstrate the veracity of the findings. However, any sub-analyses that are consistent with previous investigations are presented in appendices to reduce repetition.

The sequence of each investigation is based on whether the hypothesis being tested is endogenous or exogenous to the gold deposit, and whether the variable is parametric (distinctly quantifiable) or semi-parametric (can be ranked from high to low but with uncertain quantity).

As such, the structure is:

1. **Parametric and endogenous** – the level of ownership in a gold deposit is explicitly stated in each transaction (e.g. 51% or 100% ownership) and is a quality that is internal to the transaction.

2. **Parametric and exogenous** – the gold price at the date of a transaction can be readily quantified, but its magnitude is not related to the transaction.

3. **Semi-parametric and endogenous** – the confidence in the mineral estimate underpinning a gold deposit is expressed using industry standard classification schemes that are qualitative in their description. This subjectivity means that the mineral estimate confidence may be ranked, but there is uncertainty as to the quantification.

4. **Semi-parametric and exogenous** – country risk is difficult to quantify in absolute terms as it relates to a somewhat intangible uncertainty over future events that are outside of the control of the parties to a gold deposit transaction. However, there are indexes that may be used to differentiate between those countries that are perceived to be low and those that are perceived to be higher risk and ranked accordingly.

Due to the experimental nature of this research, sub- and ancillary investigations were made. These investigations were carried out to test the limitations of the data and methodology, to gain a better understanding of market dynamics. The sub- and ancillary studies are presented in the appendices for contextual purpose and do not form part of the thesis.

1.6 Limitations

The findings of this interdisciplinary research represent an initial understanding of how mineral asset prices behave. The paucity of existing knowledge limits the ability to build upon previous research. Consequently, each of the hypothesis are investigated in isolation despite there being complex interrelations. While the geostatistical methods used serve to implicitly account for statistical significance between four variables, there are more advanced estimation methods that may be adopted in future research. Furthermore, mineral deposits trade infrequently relative to securities and as such, it is difficult to obtain exhaustive datasets under reasonably comparable market conditions. Consequently, the results of this thesis serve to demonstrate the nature of the relationships at a coarse resolution and should not be viewed as being suitable for point-estimation.

While statistical estimation methods are used, it is important to emphasise that the process of transacting a gold deposit involves a significant human involvement (e.g. there is no algorithmic trading). Gold deposits don't often transact at their fundamental value and the significant human element in a gold deposit transaction means that the influence of heuristic bias and emotion cannot be ignored or corrected. This human element also means that while there may be many variables affecting the price of a gold deposit, the way in which they impact the price is likely to be inconsistent, sometimes substantially, and often with many of the variables only having a minor influence. The influence of human decision-making means that the research methodology must reflect the vagaries of the gold deposit market, and as such is not suited to highly precise methods or methods that rely on the consistent application of many variables.

The availability of technical information relating to the gold deposit transactions is also a major limitation. For example, the metallurgical recovery quality of has a major impact the economic viability of a gold deposit. However, through the process of collating the datasets for this thesis, it was evident that many of the deposits had not been subject to metallurgical test-work, had variable metallurgical qualities through the deposit, or simply were not reported. Similarly, other technical characteristics (e.g. underground excavation type) that significantly affect value are difficult to obtain for all but the most economically evaluated deposits, of which there are relatively few. Such limitation on the availability and consistency of information means that research into mineral asset pricing is inherently difficult and imprecise when compared to other fields of study.

Mineral asset pricing is a difficult field of study, due to the small amount of data, the impact of individual and collective human emotion. However, it is for such reasons that it is poorly researched and allows for investigations of fundamental price drivers that, surprisingly, have not been previously described. Given the commercial significance of the field, even small improvements can have a significant real-world impact, making it a field worthy of study despite its difficulties and shortcomings.

1.7 Acknowledgments

This thesis has a multidisciplinary basis and relied upon subject specialist assistance. Specialist assitance was also obtained for work that is relevant to this thesis, but that is presented in the appendices and does not form part of the thesis. The contributions from these persons are shown in Table 1, with more details, including signatures, contained in Section 11 (page 193).

Table 1. Contributor attribution

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Mr Stefan Mujdrica	4.2 Ownership risk				X		
Ms Stephanie Gotley	4.3 Commodity price risk				X		
Ms Susan Havlin	4.4 Certainty risk				X		
Mr Ian Glacken	4.4 Certainty risk				X		
Ms Christine Standing	4.5 Country risk				X		
Mr Mark Murphy	Appendix 12 Cross-commodity price analysis				X		
Dr José Saavedra-Rosas	Appendix 13 Exploration price analysis				X		

2 Literature review

2.1 Mineral asset pricing

This section presents a multidisciplinary literature review of topics relating to price analysis and mineral assets. It frames the key concepts and nomenclature that underpins mineral asset pricing. The literature review covers a broad range of fields including mineral exploration and mining, pricing and decision theory, and psychology. While only formally published literature is relied upon, this section also touches on a limited amount of industry-sourced literature. This informal literature helps provide context to the gaps in the academic knowledge gaps and underscores the commercial importance by covering the full knowledge spectrum. This multifaceted review is in keeping with behavioural economics as described by McDonald (2008), by extending on classical economic theory by drawing on other disciplines.

Accordingly, the key findings of the literature review are that:

- The terms cost, value and price, are fundamentally different concepts but often used interchangeably, leading to a great deal of confusion.
- Much of the price literature relates to securities, with tightly held structures being less researched, resulting in this broad area being identified as a field in where additional research is required.
- Changing ownership structures, such as securitisation, changes price behaviour. Gold deposits are frequently held in partial ownership structures, the price behaviour of which is not well understood.
- Gold has a relationship with macroeconomic uncertainty, with prices expected to rise when there is greater uncertainty and aversion to risk.
- Gold deposits have a trade-off relationship between grade and size that distribute log-normally.
- The uncertainty of a gold deposit is usually reported using qualitative terms.
- Gold deposits occur in a diverse range of geological terranes with differing levels of exposure to country risk.
- There are three pricing approaches, based on cost, income and the market. The market-based approach is best suited to price research as it is positive (as it is) in nature as opposed to normative (as it theoretically should be).

Mergers and acquisitions are notoriously complex (Lee and Prékopa 2015), and consequently, Walsh (1989) identified that despite the prevalence of acquisitions, there is limited understanding regarding strategic fit, organisational fit and the acquisition process itself, as framed by Jemison and Sitkin (1986). Through the study of real estate, Leung et al. (2006) show that the acquisition of durable goods (such as gold deposits), is different from the acquisition of non-durable goods like pharmaceuticals. Much of the existing literature on pricing focuses on corporations whose shares are publicly traded. Dunn et al. (1970) identify that this is problematic as there is an asymmetry of knowledge between the buyer and seller of tightly held assets, a quality that is assumed to be minimal in the pricing of loosely traded securities (Wampler and Ayler 1998). Furthermore, the research focus on security prices and behaviour is problematic for pricing mineral assets as securities do not display price dispersion (Garbade and Silber 1976; Adams 1997; Sorenson 2000), and financial and asset price markets may have non-linear relationships (Zan et al. 2012). Capron and Shen (2007) and Leung et al. (2002) state that there is little academic research on the price behaviour of tightly held, private corporations or assets. Consequently, this section discusses the notion of value versus price; and the differences between tightly held (asset) prices; and securitised prices; and why they must be segregated.

This thesis is concerned with the likely **price** at which an asset (or service) transacts during an exchange (Golbe and White 1988). In contrast, value, as described in much of the literature, often relates to the investment process that results in the perception of a benefit (Mattick 1959; Hardesty et al. 2012). Simply stated, “price is what you pay, value is what you get” (Schlaes 1984). If the notion is that value does not materially differ from price, then human language would not contain relative words like cheap, expensive (Bernhard 1949). While such differences are sometimes viewed as semantics (Lusht 1981), clearly articulating the difference between value and price it is important as:

- the terms value and price are often used interchangeably (Bernhard 1949)
- value is calculated in some instances (e.g. bonds) with an elevated level of certainty (Zabolotnyuk et al. 2010), yet price setting involves a human element that undermines the ability to construct mathematical rules (Mooya 2009)
- value and price do not necessarily equate to one another (Hilton and O’Brien 2009)
- the lack of differentiation results in confusion between normative (should be) and positive (is) conditions (Vandell 1982)
- the hypotheses concern price behaviour.

Fama (1970) defined the efficient market hypothesis, which assumes that all valuable information is instantaneously incorporated and reflected in the market price of an asset (Grossman and Stiglitz 1980). This normative hypothesis is convenient as it promotes a normative mathematical consistency (Wojick et al. 2013), which results in the assumption that value equals price in an efficient market. Vandell (1982), Shiller (1981) and Hasan et al. (2012) state the market contains apparent inefficiencies, with Avlarez-Ramirez et al. (2012), Abounoori et al. (2012), and Kim et al. (2011) finding that the rate of inefficiency itself varies over time. Furthermore, it is known that price dispersion occurs in asset markets, whereby the same good can be sold at a different price despite being ‘near’ and ‘similar’ (Barbade and Silber 1976; Adams 1997; Eden 2001; Sorenson 2000; Leung et al. 2006). Despite contrary evidence in the empirical research (Teodorović 2011) the bulk of the academic literature relies on and uses as a benchmark, the efficient market hypothesis (Wojick et al. 2013; Findlay and Williams 2001). The division between what the market price should be (normative) and what it is (positive), leads to confusion (Mooya 2014) and is reflected in an ideological divide amongst economics schools of thought (Wojick et al. 2013).

The notions of cost, value and price are often used interchangeably (Lusht, 1981), and prices are often used as a substitute for value and cost (Özdilek 2010). In part, this is due to the terms not being differentiated consistently in the literature, but it is also because some of the methods used in estimation are common to the determination of both value and price. For example, Yamazaki (2001) and Quigg (1993) use real options to price real estate, whereas Grovenstein et al. (2011) and Belbase (2012) use it to estimate value, and Moel and Tufano (2002) and Miller and Shapira (2004) use it to model decision-making. Beaver et al. (1980) go as far as to state that price is a determinant of value rather than the conventional view of it being the other way around. Mooya (2009) and Schlaes (1984) consider that this confusion of terminology and concept has led to an array of price/value definitions that point to a lack of clarity. For example, the International Valuation Standards Committee (IVSC 2012a) recognises 18 definitions of value. Outside of that institution, there are also some alternative definitions of price as outlined in Table 2. Vandell (1982) notes this lack of clarity results in many articles beginning with a list of formal institutional definitions to arrive at a consensus definition, usually by developing yet another definition for one of the two terms, or both.

Table 2. Value definitions that actually refer to price

Term	Definition	Source
Fair Market Value	It is the amount of money (or the cash equivalent of some other consideration) determined ... for which the Mineral or Petroleum Asset or Security should change hands on the Valuation Date in an open and unrestricted market between a willing buyer and a willing seller in an "arm's length" transaction, with each party acting knowledgeably, prudently and without compulsion.	VALMIN (2005)
Fair Market Value	The highest price, expressed in terms of money or money's worth, obtainable in an open and unrestricted market between knowledgeable, informed and prudent parties, acting at arm's length, neither party being under any compulsion to transact.	CIMVAL (2003)
Fair Market Value	The price, expressed in terms of cash equivalents, at which property would change hands between a hypothetical willing and able buyer and a hypothetical willing and able seller, acting at arm's length in an open and unrestricted market, when neither is under compulsion to buy or sell and when both have reasonable knowledge of the relevant facts. (Note: In Canada, the term "price" should be replaced with the term "highest price").	ASA (2009)
Market Value	The estimated amount for which an asset or liability should exchange on the date of valuation between a willing buyer and a willing seller in an arm's length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion.	IVSC (2012a)
Market Value	The estimated amount of money (or the cash equivalent of some other consideration) for which the Mineral or Petroleum Asset should exchange on the date of valuation between a willing buyer and a willing seller, in an arm's length transaction after appropriate marketing wherein the parties each acted knowledgeably, prudently and without compulsion.	VALMIN (2015)
Equitable Value	The estimated price for the transfer of an asset or liability between identified knowledgeable and willing parties that reflects the respective interests of those parties.	IVSC (2012a)
Fair Value	The price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date."	IFRS (2012a)
Fair Value	The price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date (an exit price)	IFRS (2012b)

A third term that is often confused with value and price is cost. According to IVSC (2015), a cost is "the amount required to acquire or create an asset or to cancel a liability", a definition that is broadly consistent with that used in education by Casse and Manno (1998), although Özdilek (2010) contends that has a temporal element and as such, price may be considered a cost when viewed in hindsight.

The exact definition of value and price is variable, and often depends on the time, circumstance and purpose for which each is being used (Njowa et al. 2014). For this thesis, the IVSC (2012a) definition of **price** is used. As highlighted by Vandell (1982), the review of the definitions for price has resulted in a new definition. The new definition is important as it removes the normative/idealised requirements such as being a perfectly informed market that acts free of compulsion etc. This is because the hypotheses concerning ownership, commodity price, certainty, and country risk are drawn from the market, in which there is asymmetric information (Dunn et al. 1970; Wampler and Ayler 1998; Hilton and O'Brien 2009), emotion, compulsion (Roser et al. 2012; De and Jindra

2012), non-financial considerations (Man and Ng 2007) and probabilities (e.g. the highest and best use may have a low probability of occurring (Vandell 1982).

For the notion of the benefit obtained by paying a price for a project, this thesis uses the term value to describe “the [future] benefit of an asset to the owner, or a prospective owner, for individual investment or operational objectives”, and is similar to the definition of Investment Value (IVSC 2012). A list of terms with similar meanings to the definition of value used in this thesis is presented in Table 3.

Table 3. International definitions of value similar to those used in this thesis

Term	Definition	Source
Technical Value	An assessment of a Mineral or Petroleum Asset’s future net economic benefit at the Valuation Date under a set of assumptions deemed most appropriate by an Expert or Specialist, excluding any premium or discount to account for such factors as market or strategic considerations.	VALMIN (2005, 2015)
Value in Use	The present value of the future cash flows expected to be derived from an asset or cash-generating unit	IVSC (2012)
Investment Value	The value of an asset to the owner or a prospective owner for individual investment or operational objectives	IVSC (2012)
Intrinsic Value	The value that an investor considers, on the basis of an evaluation or available facts, to be the "true" or "real" value that will become the market value when other investors reach the same conclusion. When the term applies to options, it is the difference between the exercise price or strike price of an option and the market value of the underlying security.	ASA (2009)

Jacobs (1999) and Yiu et al. (2006) state that the price behaviour of securities is subject to extensive amounts of research and is widely published in the academic literature. However, the securitisation of an asset leads to a fundamentally different ownership structure that has its own value and price proposition (Lusht 1981; Haaranen and Nisar 2011). This is because increasing the liquidity of an asset increases its price (Capron and Shen 2007; Leung et al. 2006), allowing a funding re-allocation and reducing the cost of accessing capital (Nadauld and Weisback 2012; Martinez-Solano et al. 2009). As more investors become involved, this helps to stabilise the price (Paul 1993). Even exogenous aspects such as a country’s popularity with US investors can affect security prices (Hwang 2011). For such reasons, empirical evidence shows that asset prices move differently to security markets (Fan et al. 2012; Belke et al. 2010). DeLisle (2008) identifies that this is poignantly demonstrated by the way that real estate asset prices disconnected from their associated securitised debt. The monetary quantum of the ownership differences can be substantial, as demonstrated by Canina et al. (2012) who find that in take-over situations within the gaming industry, the multiples paid for closely/privately held firms are 46% lower than those of public firms. Furthermore, Chan et al. (2011) go even further to state that while linkages exist between security and asset markets, they are not always positively correlated. Such differences between asset and security price behaviour are important as to the hypotheses as the gold deposit transactions have qualities like those of tightly-held assets.

Through a review of the academic literature, it was established that there is a gap in relation to the pricing of gold deposits (Wampler and Ayler 1998). This is due to “a general lack of mineral property valuation [pricing] understanding” (Lilford 2004); philosophical and practical incongruences between value and price (Mooya 2009); and an academic focus on security pricing (Jacobs 1999; Haaranen and Nisar 2011; Yiu et al. 2006).

2.2 Price drivers

The price of an asset is influenced by a myriad of factors (Wincott and Mueller 1995), each of which has a different impact under varying times and circumstances (Gordon and Tilton 2008; Eggert 2008) resulting in gradients of value and price (Wampler and Ayler 1998). This section presents a review of the literature about the factors that may affect the value and price.

The principal price driver is or should be, the potential of a project to yield a positive stream of cash flows from future activities (Cheng and Lyu 2003; Hodos 2004). Through analysis of merger waves, Rhodes-Kropf et al. (2005) and Shleifer and Vishny (2003) show how perceptions of value and acquisition activity are related. Value and price estimates are made based on key price drivers such as location (Wampler and Ayler 1998), quantity and quality (Crowson 2003; Asad and Dimitrakopoulos 2012), macroeconomic conditions (Harford 2005; Paoli and Weeken 2010), market competition (Asquith 1983; Toxvaerd 2008). However, gold deposits are a tradeable asset and, as a result, are also subject to supply and demand forces (Wincott and Mueller 1995; Vandell 1982). This interaction of a buyer and a seller results in non-financial factors that influence the price of an asset (Graebner 2009; Vandell 1982).

Bárdossy and Fodor (2001) highlight that the geological understanding of a deposit is uncertain. Volkov and Sidorov (2013) state that the quantity and quality of a deposit are crucial factors for determining the price, as these reflect the potential revenue. The trade-offs between size (quantity) and grade (quality) of a deposit (Wang et al. 2010) largely impact the economy of scale that can be gained (Crowson 2003; Crowson 2012; Sabour 2004), as the capital intensity and operating costs offset the decline in grade. Fortunately, the size and grade of a deposit are usually presented in standardised reporting formats that are relatively easy to use (Ferguson et al. 2013) and that fit within the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) definitions and standards that provide a common basis to the:

- Australasian Code for the Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code)
- Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Definitions and Standards for Mineral Resource and Mineral Reserves
- South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC Code)
- United States of America's Society for Mining Guide for Reporting Exploration Results, Mineral Resources and Mineral Reserves (SME Guide)
- Chilean Code for the Certification of Exploration Prospects, Mineral Resources and Reserves
- Pan-European Standard for Reporting of Exploration Results, Mineral Resources and Reserves (PERC Standard)
- Russian Code for the Public Reporting of Exploration Results, Mineral Resources, Mineral Reserves (NAEN Code)
- Mongolian Code for the Public Reporting of Exploration Results, Mineral Resources and Mineral Reserves (MRC Code).

Ferguson et al. (2013) also identify that relative to the size and grade, information relating to the metallurgical recovery/performance rates is harder to obtain. Metallurgical performance has a variable component due to the different processing techniques (Filippou and King 2011) and the variety of optimisation parameters and preferences that can be used (e.g. processing material more quickly at lower recovery rates, (Asad and Dimitrakopoulos 2013).

The mineral asset market is stratified (Hodos 2004), with prices varying by an asset's time to production. Njowa et al. (2014) present six strata: dormant; exploration; resource; development; mining; and defunct projects. Within the resource and development categorisations, there are varying levels of geological uncertainty, which are reflected by the following industry-accepted terms (Ferguson et al. 2013):

- ***Scoping study*** – *"a study, other than a Pre-Feasibility or Feasibility study, that includes an economic analysis of the potential viability of Mineral Resources. It is a low level technical and economic study that includes* *appropriate assessments of realistically assumed Modifying Factors together with any other relevant operational factors that are necessary to demonstrate at the time of reporting that progress to a Pre-Feasibility Study can be reasonably justified" (JORC 2012).*

- ***Pre-Feasibility study** – "a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established, and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on the Modifying Factors and the evaluation of any other relevant factors which are sufficient for a Competent Person, acting reasonably, to determine if all or part of the Mineral Resource may be converted to an Ore Reserve at the time of reporting. A Pre-feasibility Study is at a lower confidence level than a Feasibility Study" (JORC 2012; CIM 2012).*

- ***Feasibility study** - "a comprehensive technical and economic study of the selected development option for a mineral project that includes appropriately detailed assessments of applicable Modifying Factors together with any other relevant operational factors and detailed financial analysis that are necessary to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable). The results of the study may reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The confidence level of the study will be higher than that of a Pre-Feasibility Study" (JORC 2012 and CIM 2012).*

Chia-Qu et al. (2010) state that the maturity of a project reflects its certainty and certainty has a significant effect on price. This is important to pricing as noted by Hodos (2004), who states that projects that are at an early stage of discovery scoping and delineation (scoping study and below) attract lower prices than more advanced alternatives. This is in part due to the high opportunity cost associated with exploration occurring in areas where a particular deposit type does not already exist (Hronksy 2004; Penney et al. 2004). Kreuzer et al. (2008) and Bartrop (2010) show that it is possible to calculate a risk-adjusted value for a project. However, the common mineral reporting schemes are qualitative descriptions of uncertainty rather than quantitative descriptions of uncertainty (Amos and Breaden 2001); Meyer and Booker (2001) state that such qualitative descriptions elicit subjective and variable responses. These qualitative variabilities limit the accuracy of any risk-adjusted value estimates. The numerical ranges implied by the wording in the CRIRSCO classification scheme can be gauged using a subjective probability (Sherman-Kent Scale) as shown in Table 4 (Jones and Hillis 2003).

Table 4. Sherman Kent scale

Numerical Weight	Corresponding verbal prediction of near-term economic viability
0.98 - 1.00	Proven; definitely true.
0.90 - 0.98	Virtually certain; convinced.
0.75 - 0.90	Highly probable; strongly believed; highly likely.
0.60 - 0.75	Likely; probably true; about twice as likely as untrue; chances are good.
0.40 - 0.60	Chances are about even or slightly better or slightly less than even.
0.20 – 0.40	Could be true but more probably not; unlikely; chances are fairly poor; two or three times more likely to be untrue than true.
0.02 – 0.20	Possible but very doubtful; only a slight chance; very unlikely indeed; very improbable.
0.00 – 0.02	Proven untrue; impossible.

(after Jones and Hillis, 2003)

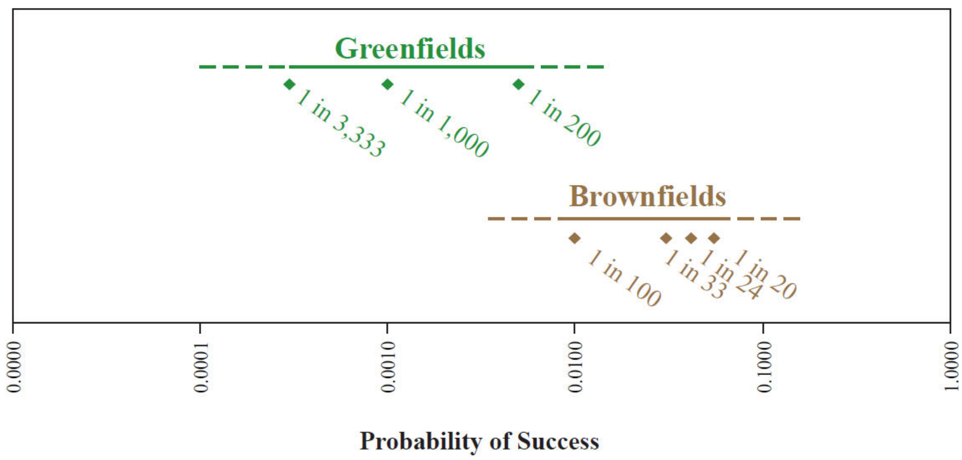
While stating that uncertain projects attract lower prices and highly certain projects, which have immediate or near-term cash flow potential, achieve the highest prices, Hodos (2004) demonstrates that the exploration potential is a motivating factor for the buyer. The exploration potential is a function of the spatial area available and the prediction of the probability of a mineral occurrence based on pre-existing information (Hronsky and Groves 2008). If large tenement areas in the order of 1,000 km^2 or more are held in a single project, then there is an increased likelihood that it will cover a mineral cluster of about 30 km^2 (Jareith and Huston 2010). As a result, large tenement holdings may encourage the use of regional prospectivity assessments and mineral systems techniques (Hronsky and Groves 2008; McCuaig et al. 2010). The value of a project is also driven by whether it is located in a fertile mineral belt, whether it is located in a site of known deposit clusters (Hodos 2004; Mamuse 2010; Mamuse et al. 2010) and the level of maturity of the belt: i.e. does it have the potential to yield significant discoveries (Mamuse and Guj 2011). Guj et al. (2010) provide statistical research into terrane endowment and maturity based on the known endowment. In this paper, the known gold endowment of the Western Australian Yilgarn Craton is analysed over the period between 1973 and 2008. This time-series study suggests that the Yilgarn gold deposits are distributed according to Zipf's Law, which is a discrete reflection of the Pareto distribution (e.g. 1 = size of the largest deposit, 1/2 = second largest deposit, 1/3 = third largest deposit). These distributions are then used to gauge the remnant potential of a mineral belt. In their study, Guj et al. (2011) estimate that the Yilgarn Craton is 95% mature, which suggests that a world-class discovery is unlikely to be made in this area.

Once it has been established how fertile and mature a geological terrane is, the location of the project relative to known mineral occurrences should be considered. This spatial price driver is a reflection of the notion that mineralisation is not equally and uniformly distributed (Laznicka 1999; Goldfarb et al. 2001; Hronsky 2004; Bierlein et al. 2006), with the best endowed mineral belts typically clustering to form mining camps over areas of 100 to 1,000 km^2 (Hodgson 1990; Jaireth 2008; Jareith and Huston 2010). In turn, the camps can comprise clusters of multiple mineralised systems, such as the Kalgoorlie Golden Mile, or one large deposit surrounded by multiple smaller deposits, such as the Boddington, St Ives and Plutonic camps. The dataset underpinning the Guj et al. (2010) study outlined that in the Yilgarn Craton:

- the ten largest deposits account for 55.6 % of the total gold endowment
- two camps occur containing >30 million ounces of gold (Moz Au)
- sixteen camps contain deposits >5 Moz Au.

Unfortunately, accurate statistics describing mineral belts are rare; generally not available in the public domain; uncertain (Knox-Robinson 2000), and sometimes impossible to quantify due to the paucity of reliable information (Rad and Busch 2011). This may result in reliance on a personal perception of prospectivity, which that can vary widely from individual to individual. For example, Wastell et al. (2010) used a standardised dataset and 94 survey participants (all exploration Specialists with at least ten years' experience) to elicit a set of probabilities for finding an economically viable deposit given a similar set of geological conditions. The probabilities range from 0.00 to 0.65, providing a wide range of opinions, which does little to support the validity of judgements based on 'industry experience'.

In classifying the maturity of an exploration project, there is often a reliance on rudimentary terms such as 'mine-site', 'brownfields' and 'greenfields' projects. Guj and Bartrop (2009) estimate that the historical probability of an economic discovery within a greenfields exploration program is around 0.9%, which includes 0.3% for a major discovery and 0.07% for a world-class discovery. A collation of these and other estimates of exploration success are presented in Figure 3 from Kreuzer and Etheridge (2010).



Source: Kreuzer and Etheridge (2010)

Figure 3. Exploration success rates for greenfields and brownfields projects

Iliescu and Dinu (2011) and McAleer et al. (2011) state that when looking at mineral projects, the jurisdictional location (country, state/province, etc.) is an important consideration in investment decision-making. Unfortunately, Davis (1995), Sachs and Warner (2001) and Morris et al. (2012) identify that there is often a correlation between the mineral prospectivity of a jurisdiction and its political/financial risk. Country risk is particularly problematic in the capital-intensive mining industry (Banks 1981; Cuddington and Zellou 2013) as the sector requires specific infrastructure, as well as investment in specialised physical and human capital that cannot be obtained from other aspects in an economy (Davis 1998). Maltritz et al. (2013) state that the over-arching country risk is often difficult to measure in absolute terms as the risk comes from a multitude of factors that may not be readily measurable. For example, country risk may arise out of:

- **Unpredictable fiscal regimes**. Walde (2010) and Otto (1997) discuss how it is common for jurisdictions to use low taxes or tax incentives as a way of attracting companies to explore and develop deposits. However, Matti (2010) notes that as time progresses and administrations change, rent-seeking behaviour often takes over. Such changes to the fiscal regime may undermine the premise on which (often substantial) capital investments were made.
- **Regulatory instability**. Tsani (2013) states that economic development and growth is a result of good governance and strong institutions. However, according to Otto (1997), if the rules which govern how activities on projects are managed change rapidly, it is difficult for the owners to accommodate the changes.

- **Social resistance**. In the context of the Australian mining industry, Parson et al. (2014) discuss how a social licence is required, and identify that the lack of support from local communities that are affected by a project may stop economically viable deposits from being developed.

- **Political instability**. Crowson (1979) states that the stability of a government and its agencies impacts project activities. Busse and Hefeker (2007) discuss how government stability is a significant determinant of foreign investment, and Khattab et al. (2007) identified that the majority of their survey respondents felt vulnerable to political risk.

- **Corruption**. Kolsta and Søreide (2009) state that the level of corruption is one of the main reasons why countries with substantial resource endowments tend to perform poorly in economic terms.

As investments in riskier assets are expected to yield higher returns (Estrada 2001), and as country risk is non-diversifiable (Naumoski 2012), it is an important influence on price. Revoltella et al. (2010) discuss how gauging country risk is often done by analysing sovereign credit ratings, bonds and credit default swaps, even though these measures reflect government rather than corporate risks. Furthermore, Hammer et al. (2006) state that most econometric models used to gauge sovereign risk rely on ratings agency publications such as Standard and Poors, despite their demonstrated failures, such as the ability to predict crises (Reinhart 2002). This difficulty in predicting risk is important in pricing gold deposits, which as Pitcairn (2011) points out, distribute across a wide range of rock types and spatial location. As no academic literature was identified that addresses the effect of country risk on gold deposit prices, this represents a knowledge gap of commercial importance.

Kharitonova and Matsko (2013) state that the inventory of gold deposits is a fixed quantum that is discovered and depleted at slow rates. The inventory of deposits is a result of an exploration process that is influenced by commodity prices and market cycles (Kreuzer et al. 2007). Increases in metal prices may result in renewed exploration activity that leads to the discovery of new deposits (Govett and Govett 1978). For undeveloped deposits, changes in the commodity price may overcome technical hurdles, such as difficult to treat mineralisation (Wharton 2005). In operating mines, supply can be increased by a lowering of the economic cut-off grade during a period of high metal prices (Azimi et al. 2013), thereby allowing the previously sub-economic material to be included in resource and reserve estimates (Monkhouse and Yeates 2005; Evatt et al. 2012). Similarly, Govett and Govett (1978) identify that the ultimate supply of minerals is controlled by geological factors, whereas the actual supply of minerals at any given moment is controlled by economic factors.

Herfindahl (1955) states that the demand for mineral assets is influenced by macroeconomic price drivers, such as commodity and security markets. Such drivers affect the speculative aspect of the market (Sornette 2000; Vandell 1982; Richter-Altschaeffer 1931), with increased enthusiasm surrounding the success of a project increasing the competition for a project (Tor 2002). This speculation is often related to the instantaneously perceived value of a project (Xiao and Tan, 2007), even if a potential discovery and development is years away (Wong et al. 2013; Hodos 2004). Within the mineral exploration sector, Wastell et al. (2010) demonstrate using expert opinion surveys, how there is a consistent negative relationship between rational thinking and the estimation of finding a commercially exploitable deposit. This shows that even exploration experts are sometimes able to correctly apportion probabilities using heuristic processes. Consequently the demand for mineral assets is complex and requires the consideration of many different, and sometimes divergent drivers (Govett and Govett 1978), particularly as Kreuzer et al. (2008) state that most investors are risk averse, and Qadan and Yagil, (2012) state that increasing gold prices may be associated with higher economic uncertainty.

Lee (2011) shows that prices are not only affected by the markets but also liquidity, which acts independently of the markets. The International Valuation Standards Committee (IVSC 2014) defines liquidity as '*a measure of the ease with which an asset may be converted into* cash' which is a significant influence on price (Bernado and Welch 2004; Amihud and Mendelson 1986; Yiu et al. 2006; Schaub and Schmid 2013; Lin et al. 2014)). Changing the ownership structures of an asset allows for the parts to trade in an optimal price range as the reduced capital outlay introduces the market participation from smaller investors (Angel 1997; Maloney and Mulherin 1992). Conversely, through the analysis of reverse stock splits Peterson and Peterson (1992) and Woolridge and Chambers (1983 identify that tightening an ownership structure can negatively affect price. This is important as Guj (2011) states that ownership of a gold deposit is often transacted in tight partial ownership structures such as joint ventures through farm-in/out arrangements. Park and Kim, (1997) identify that such partial ownership structures improve value while Chi (2000) goes further to state that it has a positive impact on price. Kogut (1991) attributes the price improvement to increased optionality; Kent (1991) to potential tax advantages; Reuer and Ragozzino (2012)and Balakrishnan and Koza (1993) to transactional risk and cost reduction while Hennart and Reddy (1997) consider that it is influenced by the ability to reduce information asymmetry between the buying and selling parties in a transaction.

Booth (2001) states that in partial transactions where a block is transacted that gives one party greater influence than the other (control), a premium is payable. This reflects the benefits of being able to set strategy (Le and Jorma 2009), having the ability to learn (Habib and Mella-Barral 2007), being able to peer review and regulate (Madajewicz 2011) and bringing together complementary skill sets (Nakamura et al. 1996). In addition Gupta and Gerchak (2002) consider that control provides better access to markets, Wang and Zhu (2005) and Kumar (2010) identify that control gives the potential to extract disproportionate revenue benefits either to individual parties or to create additional value that benefits all parties (Kale et al. 2002; Merchant and Schendell 2000).

Chu (2012) states that the premia and discounts associated with transactions are poorly understood, in part because their quantification is a complex process. The methodologies used for quantifying control premia are often based on securities market characteristics (Park and Lim 1997; Meschi 2005) and includes the analysis of security price differentials based on pre- and post-announcements information concerning mergers and acquisitions and the price difference between a stock with and without voting rights (Levy 1983). A common rule-of-thumb can be derived from the stock market-based models such as those outlined by Barclay and Holderness (1989) (Figure 4, after Pratt 2009, p5), which shows how premia are a variable that change with the level of ownership. However, such figures are not certain as Massari et al. (2006) and Jordan and Hoppe (2008) contest that that such premiums are overstated, and may be as low as 5% above that of the non-controlling interest. Consequently, Chu (2012) considers that there is no “one size fits all” solution to quantifying control premia.

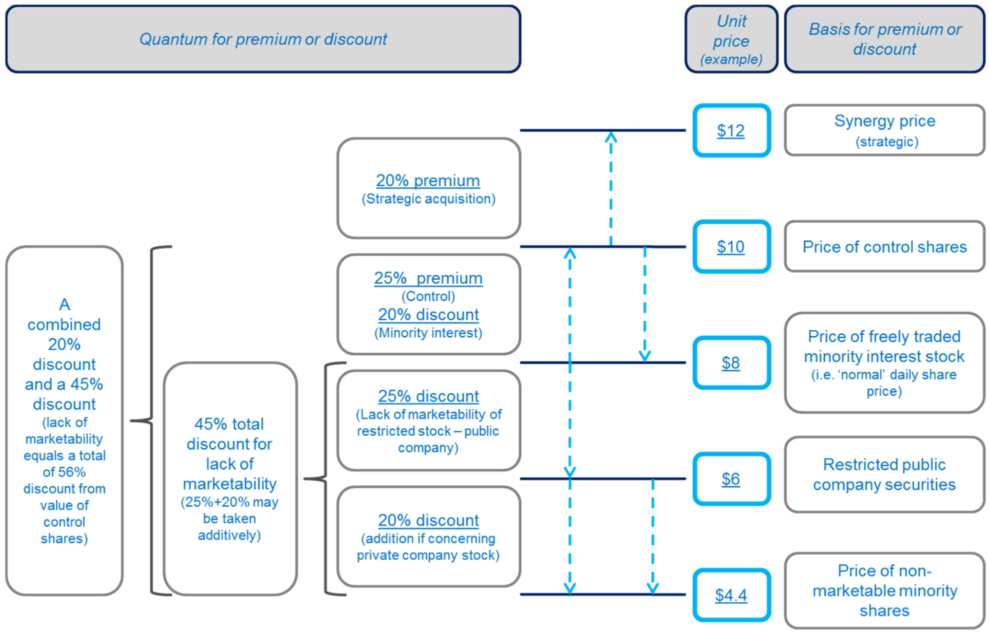


Figure 4. Barclay-Holderness control premia

(after Pratt, 2009, p5)

Within the informal industry-based literature, it is frequent practice to quantify the price of control by using a simple formula (Equation 1, after Mazzoni et al. 2010; Ulrich et al. 2012). This type of equation first appears in Appleyard (1994), which was subsequently corrected by Lawrence (2001). However, Appleyard (1994) cautioned that his method was based on a "limited analysis of existing joint venture deals. It is suggested that further analysis, as well as mathematical input, could lead to the establishment of guidelines which permit a relatively reliable valuation" (p174). No follow up on the recommended research was identified in either the informal or academic literature. This is significant as Equation 1 states that maximum price is achieved through a 100% equity sale, yet this goes against the peer-reviewed academic literature on joint-venture benefits identified in Le and Jorma (2009); Kale et al. (2002); Madajewicz (2011); Merchant and Schendell (2000); Nakamura et al. (1996); Gupta and Gerchak (2002); Wang and Zhu (2005); and Kumar (2010). As the maximum value may involve less than a 100% ownership interest, a knowledge gap was identified as to whether the maximum price is actually achieved at outright ownership.

[Equation 1]

$$V_{100} = \frac{100\%}{D}\left[CP + \left(CE * \frac{1}{(1+I)}\right) + \left(EE * \frac{1}{(1+I)} * P\right)\right]$$

Where:
V_{100} = Value of 100% equity equivalent for a project ($)
CP = Cash equivalent of initial cash and securities ($)
D = Base equity of the incoming party (%)
CE = Cash equivalent of the future consideration (cash, scrip, expenditure)($)
EE = Optional consideration for an additional ownership increment ($)
I = Discount rate (% per annum)
t = term of the stage (years)
P = Probabilty that the stage option will be exercised (%)

(after Mazzoni et al, 2010)

Much of the peer-reviewed research into control premium appears to be based on the price behaviour of securities. As there are fundamental differences between loosely held securities and tightly held asset ownership structures (Section 2.1), there is a knowledge gap concerning how control premiums behave in relation to gold deposits. Given the industry use of Equation 1, which is at odds with the academic literature on value, there is both an academic and commercial need for clarification on the matter.

Every transaction involves at least two parties, the acquiring and divesting parties. Baharad and Eden (2004); Leung et al. (2006); Gupta and Gerchak (2002); and Capron and Shen (2007) identify that these parties have different experiences, strengths and needs. Each transaction that occurs is often the result of an extensive evaluation of multiple opportunities (Tyebjee and Bruno 1984). Chatterjee (2009) identifies that investment bankers are keen to present as many opportunities as possible. An approximation from the petroleum industry literature suggests that for every fifty opportunities, there are:

- two that are evaluated, only one will have a bid placed on it
- of the five bids made, only one will be accepted (Haag 2005).

While the technical price drivers to a transaction outlined in the preceding sections are quantified to some degree, it is not possible to estimate price with certainty because all transactions involve human decision-making processes (Tor 2002; Bottazzi et al. 2011). This is because different people make valuation and pricing decisions differently (Hass and Pryo 2009; Chatterjee 2009), and who are subject to a tension between normative (rationality) and descriptive (beliefs and preferences) dimensions that characterise much of the psychology of judgment, choice, and value (Kahneman and Tversky 1984). This tension comes about through the uncertain interaction between:

- conscious mental processes that require effort, are intentional, and are capable of following rules (Huffman 2012)
- subconscious mental processes that are fast, automatic, effortless and can be influenced by emotion (Huffman 2012).

In the context of real estate pricing, Wyman et al. (2011) state that it is the human aspect that determines the price. For example, conventional economic theory suggests that decision-makers are rational and will only attempt a course of action if it is profit maximising (Levinthal and Wu 2010); however, empirical evidence appears to contradict this assumption (Tor 2002). Brenner et al. (2012) show that even under controlled conditions, the valuation and pricing of assets are largely case-based. Therefore, being aware of human behaviour is not only important because it affects how conclusions are drawn, but also helps explain why there can be such a price variance between seemingly similar value propositions (price dispersion (Sorensen 2000)). It is on this basis that Ratcliff (2001) advocates for price ranges rather than single point price estimates. For discussion in this thesis, the influences of human behaviour on value and price attribution is grouped into three broad categories:

- **individual processes** – due to the influence of asymmetrical risk bias and the use of imperfect mental rules-of-thumb
- **group dynamics** – such as group think where the desire to have harmonious group relations overrides critical thinking and behaviour
- **selected approach** – whether an insider/bottom-up or outsider/top-down perspective is used in the evaluation process.

While the value of a deposit is numerically modelled, it often does not match its price. Huffman (2012) notes that human decision-making processes do not always follow mathematical logic, and Wyman et al. (2011) consider it may be a mistake to search for an all-encompassing pricing theory as price stems from human behaviour and market conditions. Market participants may attempt to weigh the pros and cons of a decision using an '*expected value*', however, such decisions are limited by human cognition and influenced by motivation and emotion (Tor 2002). Kreuzer et al. (2008) show how the expected value of a project should define choices by weighing all potential outcomes by their respective probability of occurrence. However, Kahneman and Tversky (1979) show that rational choices based on maximising expected value are not always followed due to the influence of prior human experience, known as 'Prospect Theory'.

Kahneman and Tversky (1984) describe how Prospect Theory predicts an asymmetrical behaviour whereby increasing losses are disproportionally more painful than the equivalent gain is joyful. Prospect Theory is often cited as being a better replication of real world choices as it takes into account some human behaviour (Zeisberger et al. 2010; Kahneman and Tversky, 1979). The '*certainty effect*' within Prospect Theory suggests that people are more likely to pursue an alternative having absolute certainty than they are to pursue on with a higher expected value, but slightly more risk. For example, given a choice between A and B in Table 5 (after Kahneman and Tversky 1979), there is an overwhelming preference for option B despite it having a slightly lower expected value.

Table 5. An example of the certainty effect

	A		B	
Item	**Outcome**	**Probability**	**Outcome**	**Probability**
Qualities	2,500	33%	2,400	100%
	2,400	66%		
	0	1%		
Expected Value		2,409		2,400
Respondent preference		18%		89%

(after Kahnemand and Tversky, 1979)

Li and Yang (2013) identify that the input costs, such as the purchase price, are also very important in guiding behaviour as there is a tendency to use them as reference points when performance outcomes are assessed. Typically, outcomes are not evaluated according to final wealth levels; rather, it is the relative perception of the gains and losses to the initial purchase price that is used to gauge success (Tversky and Kahneman 1992; Li and Yang 2013). This is known as 'reference dependence'. Nor is the behaviour symmetrical, as 'loss aversion' states that the responses are more dramatic in negative scenarios than in positive ones (Tversky and Kahneman 1991). Furthermore, within either negative or positive outcomes, as the outcomes become more exaggerated, people tend to have '*diminishing sensitivity*' (Tversky and Kahneman 1991, 1992). The effects of loss aversion and diminishing sensitivity are conceptually illustrated in Figure 5 (after Tversky and Kahneman 1991). This diminishing sensitivity behaviour is often cited as a reason why humans tend to sell assets that have risen in value/price (selling too soon) rather than those that have fallen (holding on too long) (Li and Yang 2013), a behaviour known as the 'disposition effect' (Shefrin and Statman 1985). However, the loss aversion behaviour predicts the opposite behaviour to that of the disposition effect (Barberis and Xiong 2009; Hens and Vlceck 2011). What all these behaviours demonstrate is that human preference (for which price is a proxy) is complex and does not follow simple mathematical reasoning, and therefore, it is a crucial element in asset pricing.

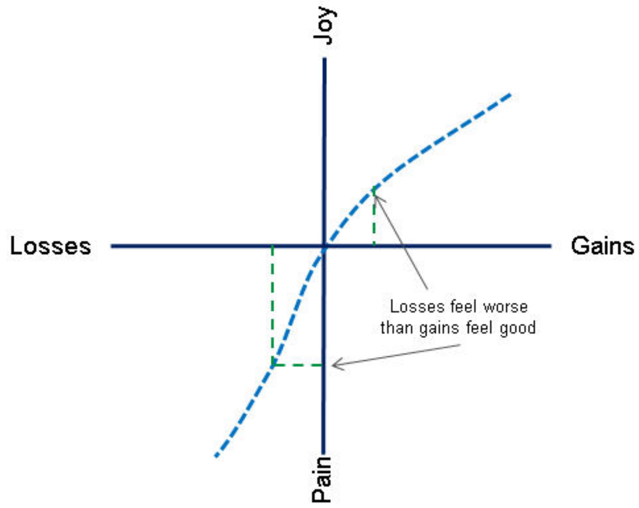


Figure 5. The behavioural value function

(after Tversky and Kahneman, 1991)

Wyman, Sedan and Worzala, (2011) state that in the face of uncertainty, it is common practice to rely on heuristic judgements. Mousavi and Gigerenzer (2014) describe heuristics as the use of rules-of-thumb or mental shortcuts, which enable pattern recognition within incomplete datasets, and their use arises out of an attempt to describe complex systems using simple concepts. However, intuitive judgments are governed by different processes than deliberate computations (Kahneman and Fredrick 2005). Kahneman (2003) warns that without careful management, the simplicity and narrow frame of heuristics can introduce bias and systematic error that is, often, assigned unwarranted confidence. This is because the normative guidelines of logic, probability and confirmation theory that underpin rational decision-making are not approximated by heuristic reasoning (Solomon 1992). The most common sources of bias in heuristic judgements are identified by Tversky and Kahneman (1974), and Bonner and Newell (2010) as:

- **Representativity** – based on limited, imperfect datasets there is a tendency to over-generalise based on a few data points. Consequently, data density and quality have big impacts on interpretation.
- **Availability** – the outcomes are based upon personal experience, resulting in the full range of possibilities being truncated.

- **Anchoring** – initial impressions anchor subsequent perceptions and thus influence outcomes. Any adjustments to the initial impression are often insufficient, narrow and biased towards the anchor.
- **Salience** – the most recent and prominent information overly influences judgement, and there is a resistance to change once a model is established.

Despite their well-documented shortcomings, heuristics are quite useful (Kahneman et al. 1982) but may lead to "profound systematic and fundamental errors [such failings are probably] closely related to, or even at the unavoidable cost of [our] successes" (Nisbett and Ross 1980 paraphrased by Solomon 1992). Use of heuristics is virtually inevitable as they provide a starting point for evaluation from which more rigorous investigations can be made (Connolly and Prince 1992). Furthermore, Mousavie and Gigerenzer (2014) consider that the simplicity of heuristics can be effective in handling substantial amounts of uncertainty. This is because there is one or more underlying mental processes or systems to explain empirical observations (Newell et al. 2011). Fava et al. (2011) and Connolly and Prince, (1992) identify that the benefit of heuristics is that they allow an evaluation process to have a starting point from which more rigorous investigation can be made. As Wyman, et al. (2010) identify heuristics as being deeply entrenched in the valuation/price determination processes. Consequently, they must be carefully managed, as they cannot be eliminated and may provide counterbalancing benefits to statistical analysis (Nisbett and Ross 1980; Eastwood and Kenny 2009). Kahneman and Lovallo (1993) and Tor (2001) consider that projects under assessment are isolated from other alternative projects because of their perceived unique attributes; and assessed from an 'inside' perspective that excludes broader, more generic sources of information. Such an inside perspective in isolation creates a great deal of self-delusional risk, as highlighted by the personal experience of the Nobel Laureate, Dr Daniel Kahneman (Kahneman and Lovallo 1993):

a) "In 1976 I was involved in a project designed to develop a curriculum for the study of judgement and decision-making for high schools in Israel. The project was conducted by a small team of academics and teachers. When the team had been in operation for about a year, with some significant achievements already to its credit, the discussion at one of the team meetings turned to the question of how long the project would take. To make the debate more useful I asked everyone to indicate on a slip of paper their best estimate of the number of months that would be needed to bring the project to a well-defined stage of completion: a complete draft ready for submission to the Ministry of Education. The estimates, including my own, ranged from 18 to 30 months" (p24).

In part a) above, the learned group made an insider's assessment of the timeline based on detailed plans, anticipated events and scenarios that may affect the time to complete the project (the "**inside perspective**"). Dr Kahneman then goes on:

b) "At this point I had the idea of turning to one of the members, a distinguished expert in curriculum development, asking him a question phrased about as follows: "We are surely not the only team to have tried to develop a curriculum where none existed before. Please try to recall as many such cases as you can. Think of them as they were in a stage comparable to ours at present. How long did it take them, from that point, to complete their projects?" After a long silence, something much like the following answer was given, with obvious signs of discomfort: "First, I should say that not all teams that I can think of in a comparable stage ever did complete their task. About 40% of them eventually gave up. Of the remaining, I cannot think of any that was completed in less than seven years, nor of any that took more than ten". In response to a further question, he answered: "No, I cannot think of any relevant factor that distinguishes us favourable from the teams I have been thinking about. Indeed, my impression is that we are slightly below average in terms of our resources and potential" (p24-25).

In contrast to the inside perspective, account b) provided a potential outsider's estimate of the time to completion in that it took little account of the particulars of the project, made no attempt at detailed forecasting and used crude statistics of rough analogies (the "**outside perspective**"). An interesting observation is that until prompted, the distinguished expert did not use his inherent experiential knowledge. It appears that because of the inside perspective, which is anchored in preconceived notions - considered unique - and is isolated from the outside world, the expert was distracted from making a big-picture assessment (Kahneman and Lovallo 1993). However, outside perspectives are often rejected for relying on crude analogies based on superficial similarities. Finally, Kahneman and Lovallo (1993) recount:

c) "The participants in the meeting had professional expertise in the logic of forecasting, and none ventured to question the relevance of the forecast by the expert's statistics: an even chance of failure, and a completion time of seven to ten years in a case of success. Neither of these outcomes was an acceptable basis for continuing the project, but no one was willing to draw the embarrassing

> conclusion that it should be scrapped. So, the forecast was quietly dropped from active debate, along with any pretence of long-term planning, and the project went on along its predictable unforeseeable path to eventual completion some eight years later" (p26).

The strength of the outside view is that it is free from anchors, does not become bogged down in detail, avoids groupthink and is more likely to yield realistic estimates (Kahneman and Lovallo 1993). Unfortunately, people are strongly biased in favour of an inside view and overconfident in their estimates (e.g. correct 80% of the time when they are 99% sure, (Kahneman and Lovallo 1993)).

According to Chatterjee (2009), merger and acquisition activity is not done by an isolated group but instead, by rank-and-file members in an organisation. Kahneman and Lovallo (1993) posit that groups of capable individuals are prone to what Janis (1982) terms '*groupthink*', whereby choices are made influenced by a desire to maintain harmony within the group. Groupthink is partly due to the necessity to make decisions based in uncertain environments using fragments of high-quality information. This leads to a herd mentality that provides psychological comfort due to the notion that if everyone else is doing it, then the chance of being wrong are reduced (Wyman et al. 2011). After considering ill-conceived military disasters such as the Bay of Pigs, Pearl Harbour, the invasion of North Korea and escalation of the Vietnam War, Janis (1982) concluded that groups tend to:

- seek consensus by avoiding controversial issues
- avoid questioning weak arguments
- accept 'soft-headed' thinking
- are likely to be extremely hard-hearted to other groups
- are only interested in facts that support their preferred scenario
- rarely attempt to obtain external perspectives
- fail to develop appropriate contingency plans.

Kahneman and Lovallo (1993) consider that groupthink behaviour leads to the relevance of the outside view being explicitly denied, or the refusal to use or retrieve known statistical knowledge. According to Straus et al. (2011), this can lead to sub-optimal decision making. Smith (2008) and Straus et al. (2011) consider that such collaborative groups with potentially suboptimal decision-making qualities are formed in response to complex situations that may lead to information overload. Laughlin (1999) puts it that such groups may offer benefits such as more efficient or higher quality decision making and solution finding due to the diversity of the member's experiences. Straus et al. (2011) consider it may lead to higher commitment to goals or better error detection and Straus and Olivera (2000) point to knowledge building through group interaction. However, Read et al. (2004) note that the quality of the group output can be quite variable. Hill (1982) points to a substantial proportion of groups are outperformed by their most capable members. On the other hand, Michaelson et al. (1989), through comparing test results of individual before and after joining a group, provide an opposite view in that groups largely outperform their most capable members. Through experiments involving five-person groups, Fay et al. (2000) consider that group size is a key factor in determining group performance. A review of the literature by Kerr and Tindale (2004) shows that much of the gains and losses of group consensus over individual efforts is often attributable to situational and procedural contexts. While there are many influences on the success of group decision-making, the groupthink component concerns how the desire for social cohesion amongst groups interferes with due process (Mojzisch and Schulz-Hardt 2010), and consequently group forecast accuracy is contingent on many factors (Kerr and Tindale 2011).

Bertisen and Davis (2008) find that capital cost estimates for mining projects are typically understated, with cost overruns of 100% occurring in 1 out of 13 projects, despite stated confidence intervals of ±15%. Elnathan et al. (2009) in discussing price estimates of corporations find that they are typically 29% more optimistic than actual market prices. Kahneman and Lovallo (1993) contend that such inaccuracies are common and are a function of personal biases as implied by Kahneman and Tversky's (1984), insider and outsider perspectives (Kahneman and Lovallo (1993), Prospect Theory and Janis' (1982) groupthink. Consequently, the psychological aspects of decision-making and estimation play a key role in explaining the price dispersion described by Barbade and Silber (1976); Adams (1997); Eden (2001); Sorenson (2000); and Leung et al. (2006). In testing the hypotheses concerning ownership, commodity price, certainty and country risk, it is important that the approach used takes into account human behaviour through observation as opposed to one based on theoretical underpinnings.

2.3 Pricing approaches and methods

The methods used to consider the various drivers and estimate the value and price of a mineral asset are grouped into one of three pricing approaches comprising the income, cost and market approaches (Wirtz 2012; Lilford 2004; AASB13 2011). The selection of these approaches is typically contingent on the maturity of the project. The CIMVAL (2003) and SAMVAL (2008) codes and the exposure draft of the 2014 VALMIN Code (VALMIN 2015) provide some guidance in this regard (Table 6 after Njowa et al. 2014). Contained within each approach are methods that draw upon varying degrees of market information and project specific technical information (Lilford 2004).

Table 6. General guidance on which approach to use

Approach	Project development stage			
	Exploration	**Resource delineation**	**Development**	**Operating**
Market	Yes	Yes	Yes	Yes
Income	No	Rarely	Yes	Yes
Cost	Yes	Rarely	No	No

(after Njowa et al., 2014)

The IFRS standard number 13 (IFRS13 2011) recognises that each of the three approaches have different merits and differentiates them using a three-tiered hierarchy (Figure 6). This hierarchy places preferential emphasis on market methods that require no further adjustment, and lowest emphasis on those where the inputs are unobservable in the wider market (IFRS 2011).

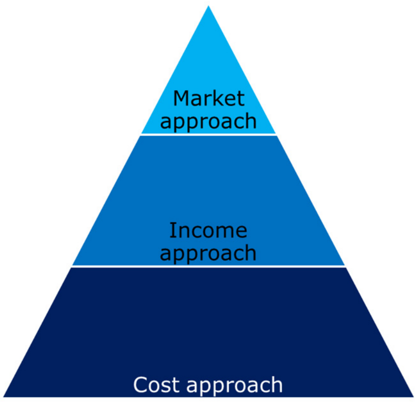


Figure 6. The IFRS13 hierarchy

2.3.1 Income approach

Casey (2001) and Lawrence (2001) state that the income approach assumes that future economic returns can be modelled to a present equivalent. At its core, this approach involves the construction of a discounted cash flow (DCF) model where time and risk-based discounts are applied to the revenue and expenditure streams (Salahor 1998). Despite its potential sophistication, the Income approach has limitations in that it relies on some input assumptions such as discount rates, metal prices, exchange rates, etc. (Doña et al. 2009; Lorek and Willinger 1996; Goldie and Tredger 1991); may not include all the available mineralisation (Lilford 2004); and does not capture all inherent value (Park et al. 2013; Mauboussin and Johnson 1997). Consequently, Lee and Prekopa (2014) state that cash flow prediction is difficult.

The DCF method estimates the value of a project as if it were developed under set assumed economic conditions (Hall and Nichols 2007), cumulating the unobservable (Chen and Zhao 2013) future residual cash flows after meeting all cost obligations and making time and risk discount adjustments to derive a net present value (NPV), which is shown schematically in Figure 7.

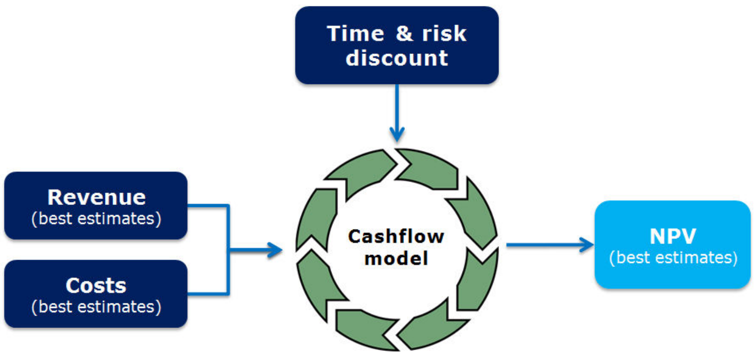


Figure 7. A simple schematic of the DCF method

The resulting ‘classical’ NPV found using a DCF technique is suboptimal (Auger and Guzmán 2010) for reasons that include:

- The ease at which outcomes can be manipulated and sensitivity to specific assumptions (Lind and Nordlund 2014)
- An unclear relation to market activity (Lind and Nordlund 2014)
- The unlikely assumption in the method that once commissioned, the course of action is irreversible, and that the prevailing economic conditions will eventuate as predicted (Jacoby and Laughton 1992)
- The use of excessively high discount rates, in the name of conservatism, may promote the selection of riskier alternatives in a project selection program (Salahor 1998).

Compounding this error, the discount rates that underpin the DCF are often challenged as to their validity. The Sharpe-Linter-Black Capital Asset Pricing Model (CAPM) (Sharpe 1964; Lintner 1965; Black 1972) is commonly used to determine the time/risk discount rate. However, through a comparison of analysis of conditional and unconditional CAPM models and empirical evidence, Lewellen and Nagel (2006) determined that CAPM performs poorly in both explaining value:price ratios and the momentum within market prices. Estrada (2007) and Andrade (2009) also identify a lack of empirical support for adjustments that are made to reflect higher exposure to country risk. The classical DCF also suffers from the assumption that the discount rate is constant through time (Fama and French 1989; Ferson and Harvey 1991; Hoesli et al. 2005; Chen et al. 2013); yet through their discussion on the evolution of behaviour based discounting, Gowdy et al. 2013 show how discounting changes through time. Another drawback of the DCF method is that it epitomises the inside perspective, which is problematic as:

- People are overconfident in their input assumptions to which DCF models are very sensitive (Nicholas et al. 2006).
- If projects are screened according to their DCF model outcomes, it is the best (highest returns) that are the most likely to be associated with optimistic errors (Harrison and March 1984). Conversely, when subsequently making worst-case scenarios, they are often also too optimistic (Arnold 1986).
- When selecting a project on which to create a DCF model, there is a ‘winners curse’, where the price paid for the project is so high that it hampers the economic rationale for which it was selected (Boone and Mulherin 2008).

Despite its shortcomings, the DCF method has legitimacy because of its near universal acceptance (O’Byrne and Young 2009) and therefore, is a key component in the selection and decision-making process. However, in isolation, the discrete DCF method is inferior to other methods or combination of methods for estimating price (Imam et al. 2013).

A Monte Carlo simulation extends the DCF model by modifying key variable assumptions through numerous iterations (Figure 8) (Weaver and Michelson 2008). These assumptions are typically varied within probability distribution (Detemple et al. 2003). The resultant simulation presents a distribution of possible NPV outcomes for the variables selected (De Oliveira and De Medeiros-Neto 2013). A Monte Carlo simulation is a more realistic representation of the potential value of a project as it lessens the error associated with static input assumptions (Nicholas et al. 2006). Given the uncertainties associated with key variables, its accuracy is limited to the validity of the input variables (such as changes in tonnage, grade, commodity prices, capital and operating costs) and the distribution of those variables (Stentoff 2004). This is because projects are subject to step changes and production constraints (Asad and Dimitrakopoulos

2012), and when the input variables change significantly, their effect is not easily incorporated into the continuous function of the Monte Carlo simulation.

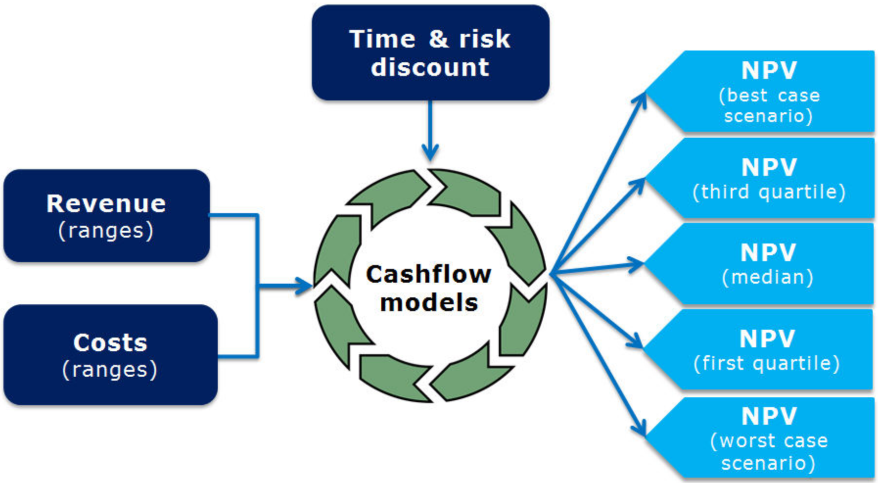


Figure 8. A simple schematic of the Monte Carlo simulation method

Miller and Shappira (2004) and Park et al. (2013) state that the real options value analysis (ROV) methodology captures the value of flexibility/volatility that is associated with a project. Brandão et al. (2005) note that while DCF based analysis typically sets out the expected scenario, it assumes that a project will proceed exactly as planned. However, time and circumstance ensure that even the best-laid plans are rarely carried out as expected (Dimitrakopoulos and Sabour 2007; Hayes and Garvin 1982). This occurs as the management of a project will always maximise opportunity, and minimise losses (Goria 2004). In part, this flexibility accounts for why a price premium may be attributed to a value (Miller and Shapira 2004; Samis et al. 2003) (Figure 9 after Mun 2002). For example, a DCF based estimate is constrained to a narrow range of physical parameters. Lima and Suslick, (2006) provide an example in the form of a mine design that extracts only the 'high-grade' portion of a deposit. However, when the spot price exceeds that used in designing the mine, the 'low-grade' or narrower portion of a deposit becomes economically viable. This 'real option' to expand production to extract the low-grade portions of a deposit can be treated as a financial option (Lima and Suslick 2006). There are many forms of flexibility/optionality, as exemplified by McCarthy and Monkhouse (2002) and Brennan and Schwartz (1985) who discuss scenarios such as include the ability to contract, maintain, abandon or acquire operations.

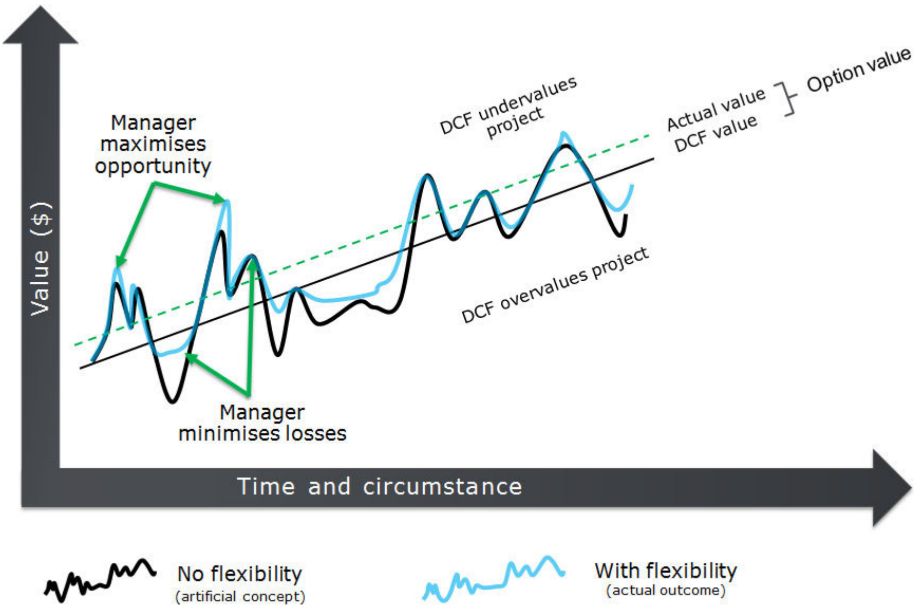


Figure 9. A simple schematic of the ROV concept

Jacoby and Laughton (1992); Salahor (1998); Emhjellen and Alaouze (2003); and Guj and Garzon (2007) present an alternative means of accounting for uncertainty in a DCF analysis using modern asset pricing (MAP) method. Emhjellen and Alaouze (2003) describe how the MAP method involves applying different discount rates to each cash flow component that represent their riskiness. In Guj and Garzon (2007), the MAP method justifies the use of a lower discount rate by using forward sales contracts and matching corporate bond issues with coupons that match various project cost components. The de-risked NPV provides a conservative insight into the value of a project, thereby possibly helping to establish the lower limit of a price range (Figure 10). However, in practice Adam and Fernando (2006) state that such hedging activity erodes valuable optionality.

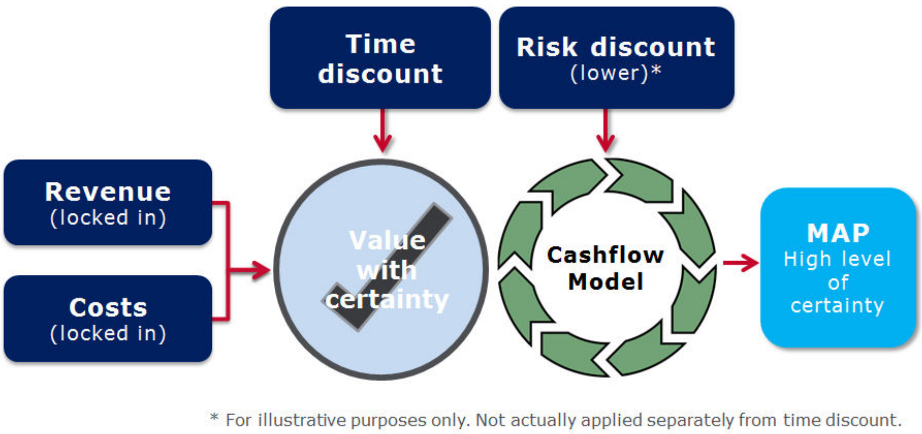


Figure 10. A simple schematic of the MAP method

While the DCF method is universally accepted in practice and is the basis of the Income approach, Sonneman (2009) and Ainslie (2010) identify that the commonly used exponential discounting function does not reflect reality. Behavioural research has shown that both animals and economically sophisticated humans do not discount exponentially (Benzion et al. 1989; Liu et al. 2012; Gowdy et al. 2013). Rather, events that occur in the near term are discounted more heavily than those that are distal (Dasgupta and Maskin 2004), as in Figure 11 (after Gowdy et al. 2012). This resulted in the modification of the DCF method through replacing the exponential discounting curve with a hyperbolic discount (Ainslie 2012). Laibson (1997) notes that this sort of discounting may be observed in the disparity between individuals simultaneously having high-interest credit card debt and low-interest rate retirement accounts, although Gustman and Steinmeier (2012) describe this as quasi-hyperbolic. Gowdy et al. (2013) state that hyperbolic discounting is common in environmental/ecological economics where lengthy periods are often encountered. Hartmann et al. (2013) go further by examining discounting effects exhibited by physical effort, and propose that discounting may best replicate behaviour through the application of parabolic discounting. However, no formal or informal literature on the use of parabolic or hyperbolic discounting in the minerals sector has been identified despite Dube (2012) highlighting how the value of long-life mines is understated.

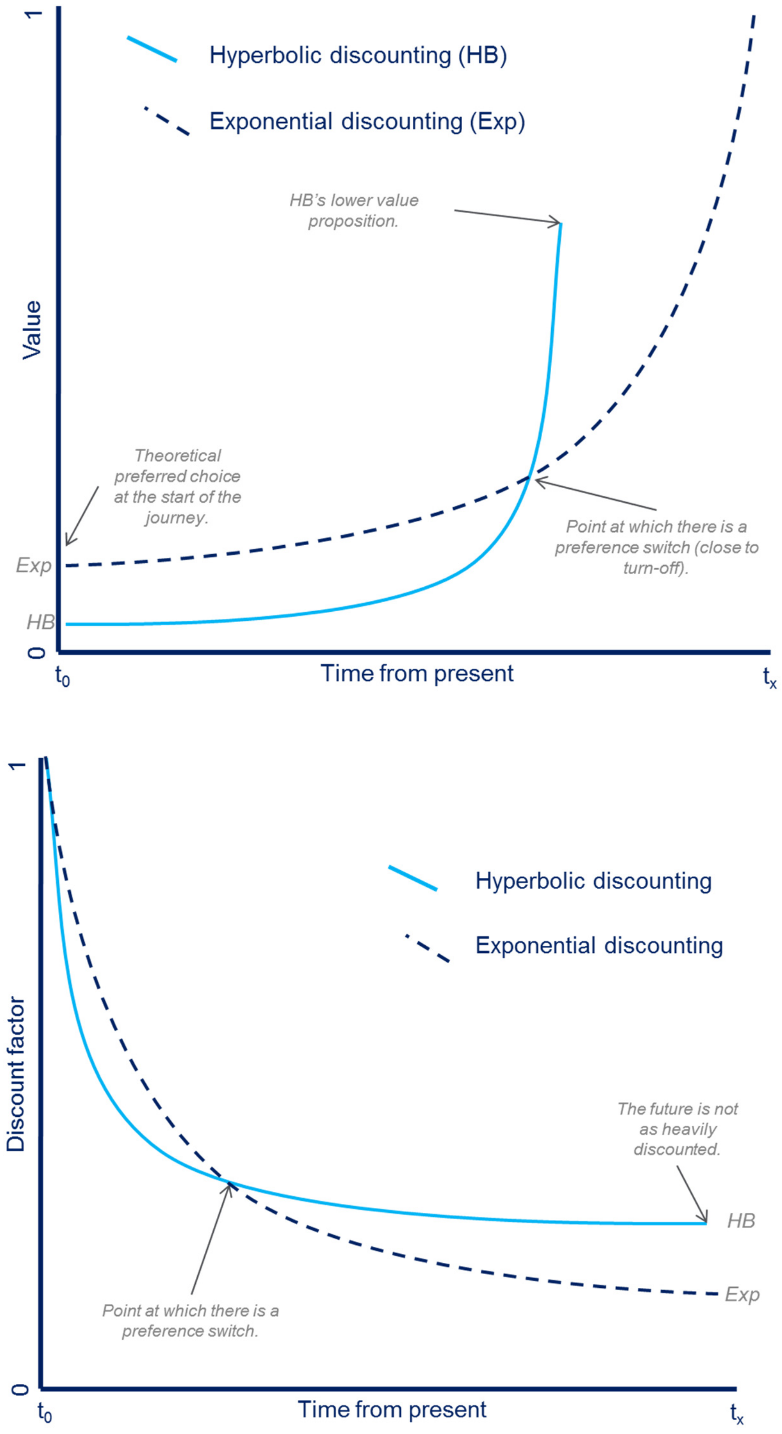


Figure 11. A simple schematic of the Hyperbolic discounting method

(after Gowdy et al., 2012)

Smith and Dimitrakopoulos (1999) identify that gold deposits are inherently uncertain, consequently this uncertainty may be probabilistically modelled using the expected value (EV), method which is also called the decision tree method (Wang and Halal 2014) or in the informal literature, the geological risk method (Lord et al. 2012). This method is based on the use of binomial decision trees to derive a cost and risk-adjusted NPV, which is increasingly converging on the income-based ROV methodology (Brandão et al. 2005; Guj 2011). The EV method uses probability theory (Smith and Nau 1995) to quantify the value of a project by determining the expected 'pay-off' for each step in the investment process (Bonini 1977). The EV is the sum of the probability for each possible outcome, multiplied by the corresponding outcome value (or pay-off), less the implementation costs at each stage (Figure 12) (Kreuzer et al. 2008; Guj 2011; Robinson and Mackenzie 1987). The strength of the EV method lies in its transparency and its ability to replicate a rational decision-making process. The main drawbacks of the EV method is that it is not always possible to confidently gauge the value of a payoff (Robinson and Mackenzie 1987); the high levels of uncertainty associated with probabilities of success (Brandão et al. 2005); and being difficult to apply in complex business situations (Wang and Halal 2014).

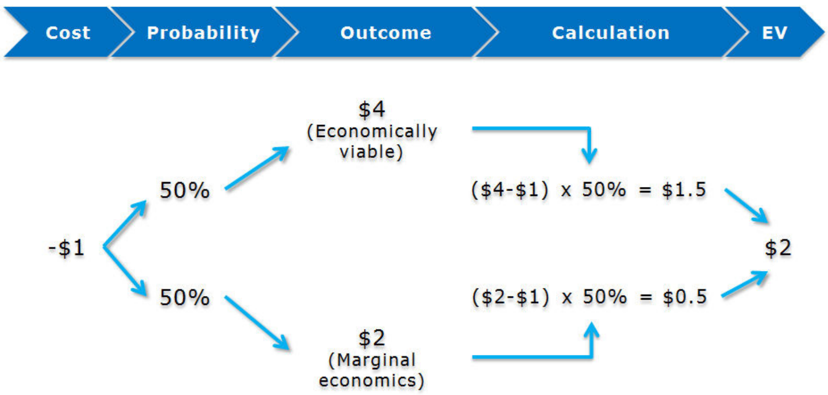


Figure 12. A simple example of the EV method

2.3.2 Cost approach

The cost approach is based on the notion of substitution (Wirtz 2012, AASB 2011), or that a return is expected from sunk costs, fixed costs or future investments (Lilford 2004). Within the formal literature, the cost approach to pricing includes the reproduction and replacement methods (Wirtz 2012), preventative expenditure and opportunity cost methods (Notaro and Paletto 2012). These substitution-based methods attempt to estimate a buyers willingness to pay (Birol et al. 2006). Domingo and Lopez-Dee (2007) state that by taking the position of the vendor who is likely to seek reimbursement of sunk costs with a risk premium, a possible market position is determined.

IVSC (2011) details that the following are considered:

- **Functional obsolescence** – this reflects the loss related to technical advances and efficiencies such as the increased improvement in geophysical exploration techniques.
- **Physical obsolescence** – is the data still usable. For example, reverse circulation drilling samples are likely to have significantly decreased use in a resource estimate if they are a decade old.
- **Economic obsolescence** – adjustments that account for changes in the broader economic environment, new legislation or regulation or marketability as was the case for uranium in Australia during the 1970s (Price 1984; Sorentino 1990).

Reira et al. (2012) note that the draw-back of the replacement cost methods are that they do not consider the risk in attempting to substitute (e.g. exploration), and they lack a direct connection to the market. Despite this shortcoming, Jackson et al. (2014) consider the method useful in its ability to use available information to estimate values and prices of items that may not be observable in the market.

Within the industry literature, CIMVAL (2003) identifies two other cost methods, multiples of exploration expenditure (MEE) (Lawrence 2012; Lilford and Minnitt 2004; Onley,1994) and the Kilburn method (Goulevich and Eupene 1994). The MEE method applies a set of factors to sunk costs, and the Kilburn method applies a series of compounding factors to the minimum holding cost of a project. A third method, dubbed the Lilford Techno-economic matrix applies a similar concept as the Kilburn method but indexes the compounding factors to the market approach (refer to the following section). These methods are discussed in more detail in Appendix 3.

2.3.3 Market approach

The market (hedonic pricing) approach uses the transaction prices of assets to gauge the intrinsic impact of price variables or make estimates of price (Lancaster 1996; Kakhki et al. 2010; Brander and Koetse 2011). This method is positive in that it does not rely on fixed assumptions to arrive at ‘should be’ but recognises that each sale can be viewed as a bundle of attributes that lead to ‘as is’. Rosen (1974) states these attributes (x) in a formulaic relationship where price (p) is predicted by a market function (F), such that p = F*x in a process that van Wezel et al. (2005) and Fan et al. (2006) state may include the use of decision trees. However, it avoids normative determinations by recognising that the hedonic equation is seldom fulfilled due to limited data, misallocation (Helbich et al. 2013) and price dispersion (Sorensen 2000). In so doing, hedonic pricing helps narrow the range of possible answers to a question (Heckman et al. 2010). This approach is most commonly used in the real-estate sector (Harrison and Rubinfeld 1978; Bin 2004) but has also been applied to other assets such as ball-point pens (Tomkovick and Dobie 1995) and digital cameras (Miyamoto and Tsubaki 2002). The main advantage of this approach is that it reduces the reliance on underlying technical parameters and allows price prediction without needing to determine an underlying value (Xiao and Tan 2007). This is important, as it inherently accounts for human behaviour, an aspect that was identified as an important quality in the conclusion of the price driver literature review.

Within the market approach, there are general subdivisions along the lines of parametric and non-parametric models (Bin 2004). Parametric models use known distributions and relationships. Non-parametric models do not make an assumption about data distributions and make limited assumptions about relationships. For parametric models, it is necessary to have observable inputs (Koster et al. 2014); whereas, non-parametric models recognise that distributions may not be known or readily modelled due to unobserved heterogeneity (Heckman et al. 2010). Semi-parametric models recognise that hierarchies can be established but their weights are uncertain (Anglin and Gençay 1996; Parmeter et al. 2007).

Everitt and Hothorn (2011, vii) state that a feature of many datasets is that each data point may have multiple variables describing it, and Birks (1987) describes how this quality also holds true for datasets with geological underpinnings. According to Abzalov (2016, 259), it is common in mineral resource estimation to have to account for grade, by-products, deleterious and non-grade variables of economic significance. According to Birks (1987), geological variables may be independently parametric, semi-parametric, or non-parametric. While some of the variables associated with data may be analysed in isolation, Everitt and Hothorn (2011, vii) consider that it is often necessary to examine them simultaneously. To account for multiple variables, Everitt and Hothorn (2011) state that multivariate analysis can be used. Olkin and Sampson (2001) discuss how multivariate analysis techniques statistically estimate relationships between variables and correlate how important a variable is to the final outcome. Lefèvre et al. (2016) state that multivariate analysis becomes increasingly advantageous over classical statistics as datasets become larger and have more variables.

Chi (2012) describes how the multiple multivariate analysis techniques can be grouped into two main categories, exploratory and confirmatory data analysis. Chi (2012) also states that "*For exploratory data analysis, empirical information from the data is extracted, summarized, and visualized for an ultimate goal of formulating research hypotheses*", and "*For confirmatory data analysis, specific research questions and hypotheses are posed at the outset, and multivariate models are utilized for estimation and hypothesis testing*". Chi (2012) identifies that exploratory multivariate analysis methods include cluster analysis, discriminant analysis, principal component analysis, and canonical correlation, and exploratory factor analysis. Similarly, Chi (2012) identifies the common confirmatory multivariate analysis techniques as structural equations, general linear, and mixed models.

Pripp (2012, pp63) states that multivariate statistical techniques have several strengths when it comes to analyzing highly correlated data - prediction, data exploration, and their ability to analyze data sets with many variables compared to samples. Shiker 2012 also considers multivariate analysis to advantageous as it can *"look at relationships between variables in an overarching way and to quantify the relationship between variables. They can control association between variables by using cross tabulation, partial correlation and multiple regressions, and introduce other variables to determine the links between the independent and dependent variables or to specify the conditions under which the association takes place. This gives a much richer and realistic picture than looking at a single variable and provides a powerful test of significance compared to univariate techniques*". Bruce, Moull and Fischer (2016) also state that multivariate analysis techniques, such as principal component analysis, do not require an *a priori* knowledge about the data.

In addition to identifying the strengths of multivariate analysis, Pripp (2012, pp63) points out that it also has weaknesses. For example, small datasets do not permit the investigation of variable interaction induced heterogeneity by more than a few common variables, a point also espoused by Elwert and Winship (2010, p328). Jones et al. (2016) highlight "*that even with large and complex data sets, is that their decomposition can rapidly reach the point where some of the table's cells have only small counts*". Furthermore, the individual price drivers may be parametric, semi-parametric, or non-parametric (Birks, 1987), which has estimation implications. While Olkin and Sampson (2001) state that multivariate distributions can account for non-normal multivariate distributions, Allegrini et al. (2016) considers that semi- and non-parametric distributions as problematic. Allegrini et al. (2016) point out that multivariate analysis method assumes that there are independent and identically distributed with a normal distribution ('iid'). Allegrini et al. (2018) go on to state that for real datasets, the iid assumption is an exception rather than the rule. Alexopoulos (2018) highlights that random error is not avoidable in the estimation process. Shiker (2012) states to overcome the problems associated with standard error, it is important to have large datasets else the results are meaningless. Similarly, Pripp (2012, pp63) cautions that multivariate analysis often requires substantial pre-processing of data, which may in turn make it difficult to relate the results of the analysis to the original measures. Wuensch (2017) argues that the interpretation of multivariate analysis results may be difficult and result in highly variable conclusions. Wuensch (2017) and Pripp (2012, pp53) argue that it is possible to arrive at materially different conclusions simply by applying different techniques within a given multivariate method, and that the interpretation of the results is the method's main weakness. As the statistical-mathematical foundation multivariate analysis is extremely complicated, Pripp (2012, pp63) considers that it should not be the first line of data analysis of a new data set. Pripp's (2012, pp63) point is particularly important given the fundamental nature of the hypotheses tested in this thesis, and the limitations of the investigated datasets.While there is substantial research into hedonic pricing within the real estate sector, no research on hedonic pricing for mineral assets or more specifically, gold deposits, was identified. This is important as Rosen (1974) emphasised that it is "*inappropriate to place too many restrictions on* [the hedonic price] *at the outset*". In the absence of information relating to the hedonic pricing of mineral assets, a review of the informal literature was undertaken. It was identified that there is a reasonable amount of industry literature on pricing mineral assets; however, the sophistication and transparency of this literature is of markedly lower quality than that on real estate pricing. Nonetheless, the industry literature provides a useful starting point for gaining industry-specific insights, of which there are three sub-divisions: comparable transactions, joint venture terms, and Yardstick methods.

The comparable transactions method is an adaptation of the common real estate method to estimating price (Lawrence 2001). That is, transactions concerning assets with similar qualities to the asset at hand are used as a gauge of the market sentiment and price ranges. To price a mineral asset, Specialists compile and analyse 100% equity acquisitions of projects of a similar nature, time, and circumstance (Thompson 2000; Lawrence 2012a; IFRS 2011). The transactions deemed analogous to the mineral asset at hand are used either in absolute terms (Torries 1998) or to determine a unit price (e.g. $/km^2 or $/oz gold) (Roscoe 2012). The Specialist then uses this to establish a likely price range that the market is willing to pay, and in some instances a preferred number within that range. The strength of the comparable transactions method lays in that it:

- uses empirical data (Lord et al. 2012) that reflect intrinsic qualities (Torries 1998)
- promotes the use of price ranges rather than point estimates in a transparent and meaningful manner (Lord et al. 2012).

Roscoe (2012) states that while this method is widely used, it contains weaknesses that may undermine the accuracy. In part, this is because of an intricate value dynamic between the quantity (size), quality (grade or prospectivity) and confidence in the mineral estimate (Lawrence 2007), which may result in the exclusion of many transactions because of a lack of comparability.

The joint-venture method, a variation of the comparable market value method, differs in that it considers the partial sale of mineral assets that include exploration expenditure commitments (Lawrence 1989). To account for premia or discounts, it is industry practice to use a simple formula (refer to Equation 1) combined with adjustments that reflect the probability of various terms of an agreement being met in a farm-in process (Appleyard 1994; Lawrence 2001). No empirical evidence supporting the relationship implied in Equation 1 was identified, despite there being industry sources recommending an empirical basis (Appleyard 1994). Importantly, Equation 1 implies that the market does not apply an adjustment to a partial acquisition. This is contrary to the academic evidence that presents the notion that partial ownerships structures share and optimise risk (Reuer and Ragozzino 2012; Balakrishnan and Koza 1993), improve information analysis and decision making (Habib and Mella-Barral 2007; Madajewicz 2011), increase liquidity (Bernado and Welch 2004) and price (Park and Kim 1997; Peterson and Peterson 1992; Woolridge and Chambers 1983). Despite this, Chu (2012) identifies partial ownership premia and discounts as being poorly understood in the academic literature.

An alternative form of presenting unit prices is the Yardstick method. This method differs from the more common \$/oz or \$/km^2 method in that it incorporates the prevailing commodity price (Roscoe 2012). For example, a gold deposit that sells for \$10/oz under a \$1,000 spot price is quoted as 1% (\$10/\$1,000). As such, the Yardstick method effectively represents a heuristic interpretation of the parametric hedonic pricing method. This Yardstick method is poorly addressed in the formal literature, with the only references coming from industry sources such as Lawrence (1994) and Ven Der Merwe and Erasmus (2006). Furthermore, no academic literature describes the relationship between the commodity price and gold deposit price. As the prevailing commodity price affects the perceived instantaneous value proposition of a project (Xiao and Tan 2007), it has a direct impact on the speculative aspects of the market (Sornette 2000; Vandell 1982; Richter-Altschaeffer 1931), which influence demand (Tor 2002) and hence price (Wincott and Mueller 1995; Merdan and Alisen 2011). As transaction prices and prevailing commodity prices are readily observable, this knowledge gap can be addressed and has commercial relevance.A variant of the market-based approached was introduced by Bell et al. (2008). This variation uses geostatistical analysis and interpolation to produce models that simultaneously consider three price drivers. Initially, the research envisaged the creation of a three-dimensional surface that would represent gold deposit transactions across countries with varying levels of risk. However, it became apparent that the size and grade of a deposit have an overwhelming impact on how the market attributes price (that is, it is incorrect to analyse by total metal content alone). Consequently, the investigation evolved into the use of geostatistics to interpolate information into a three-dimensional space (as opposed to a surface) based on the deposit size, grade and country risk. Importantly, the method implicitly takes statistical significance into account by describing its direction, distance and importance (weight). In the original mineral system incarnation, the use of geostatistics and block models arose out of the following issues:

- the need to analyse “distressingly complex” (Isaaks and Srivastava 1989) real data rather than being derived from purist ideals
- evolution out of what appears to be an initially inconsistent/ad-hoc application of well-established models (Isaaks and Srivastava 1989)
- applications that are an art as they are neither objective nor can they be automated completely (Isaaks and Srivastava 1989)
- subject to dismissive arguments along the lines of “too complicated and incomprehensible”, “it doesn’t work on my deposit” and “too expensive” (Clark 1978).

The term geostatistics refers to spatial statistics rather than ‘geological’ statistics and traces its roots to the first quarter of the 1900s. Watermeyer (1919) and Truscott (1929) noted that unlike other situations in classical statistics where there are normal distributions, the grade of gold deposits are often log-normally distributed (Singer 2013) and highly skewed with a very long tail into the higher grades (Parker 1991). Discrepancies between the quantity and quality estimates and the mined metal were considered problems relating to production that would be considered later (Krige 1999). In the late 1940s, Sichel (1947; 1966) identified that the distribution of gold grades within the South African gold industry could be handled using log-normal distribution adjustments. Sichel’s models were limited to distributions that perfectly fit a log-normal distribution. Krige (1951; 1952), introduced the concept that there are spatial variables and structures that need to be taken into account when estimating grade, which helped overcome Sichel’s limitation (Krige 1960; 1999). Building on this, and the work of De Wijs (1951), Matheron (1962) evolved the methodology so that (three-parameter) information about the position of a sample, the distance between the sample points and the continuity of the information between the samples, are all considered in the estimation process. This geostatistical information is used to interpolate the grade of a block within a mineralised body that is spatially represented by numerous individual blocks (Hekmat et al. 2011). Interpolation differs from classical modelling approaches as it incorporates information on the geographic position of the data points (Journel and Huijbrogts 1978; Bascetin, Tuylu and Nieto 2011). The most common technique used for this purpose in the mining industry is ordinary kriging, a method developed by Georges Matheron (1962) and named in honour of Danie Krige (Champigny and Armstrong 1993). All kriging methods are essentially variants of basic linear regression (de Oliveira et al. 2013), which in the case of ordinary kriging apportions weight not only to the distance from the point of interest, but also to the related orientation within the ellipse with reference to three orthogonal dimensions (Yasrebi et al. 2009). In mining, the ordinary kriging process involves combing two principal components:

- The physical features of a mineralised body such as structures, source and type of mineralisation and all the parameters associated with the levels and patterns of mineralisation (Krige 1999)
- Mathematics, statistical and geostatistical models for the analytical sampling of data to produce reliable estimates (Krige 1999).

The benefits of using ordinary kriging over non-spatial interpolation techniques, such as inverse distance weighting, include: using weightings that are based on the dataset, rather than being arbitrary (Bohling 2005); correctly accounting for directional differences in spatial dependence (anisotropy) and spatial grade distribution (Boisvert et al. 2009); and minimising the variance of the estimation error, also known as the residuals (Bohling 2005).

Champigny and Armstrong (1993) state that while the initial development and application of geostatistics was driven out of South Africa, it was not until the late 1970s that it became more commonly applied to gold deposits outside of that country. The evolution and application of geostatistics has expanded significantly, and its principles are now commonly applied outside of the mining industry in areas such as environmental science; climate; health science; the performance of computer chips; and motor vehicles (Sacks et al. 1989; Köhl and Gertner 1997; Goovaerts 2000; Pearce et al. 2012; Palialexis et al. 2011; Mililio et al. 2012; Robinson et al. 2013). Geostatistics has also been used within real-estate price prediction (Maria et al. 2012), although this appears to be largely constrained to two-dimensional analysis, and often weighted towards neighbourhood analysis rather than property specific attributes (Bruenauer et al. 2013). The use of geostatistics in pricing systems is relevant because like mineral systems:

- financial returns and asset prices demonstrate highly-skewed distributions (Chen 2001; Leung et al. 2006), a distribution that Parker (1991) notes to occur in gold mineralisation
- Barbade and Silber (1976); Adams (1997); Eden, (2001); Sorenson (2000); and Leung et al. (2006) state that assets display price dispersion, that is, similar assets may trade for different prices which results in a sampling heterogeneity. Like price dispersion heterogeneity, Yunsel and Ersoy (2011) and Cornah et al. (2013) state that drillhole testing of a gold deposit also results in heterogeneous samples (nugget effect), whereby resampling two pieces of drill sample may yield substantially different assay result.

The highly skewed distribution of qualities in the market, as well as the heterogeneous sampling qualities, are aspects that can be considered in the geostatistical estimation process. On this basis, Bell et al. (2008) suggested that it was possible to expand the concept to account for the variability of an input in a virtual space with its three dimensions defined by its main components so that the magnitude of the variable at other locations within this space can be estimated (Palialexis et al. 2011).

2.4 Literature review summary

A review of the available literature resulted in some knowledge gaps being identified. The procession of the presented literature starts at a high level, such as the very concept of cost, value and price; proceeds to identify that asset price knowledge is less than security price knowledge; before working through various price drivers that affect a mineral asset. In so doing, it was identified that human behaviour has a significant effect on price, which led to the recognition that it is most suited to observational (positive) research methodologies which reflect the '*a posteriori*' nuances associated with empirical data.

Özdilek (2010) explains how the fundamental concepts of cost, value, and price are often poorly defined used interchangeably or treated as being synonymous. As Schlaes (1984) puts it "price is what you pay, value is what you get", and according to the IVS Framework (IVS 2013) cost is an input to creation of either value or price. Yet Özdilek (2010) states that price is often used as a substitute for value and cost, which if true would not make it possible to have words like cheap, expensive or over-priced (Bernhard 1949). This lack of clarity creates a confusion and imprecision, making **price analysis** a field of research deserving of attention.

Leung et al. 2006 tell us that durable goods and real assets that can be re-sold like real estate have qualities that set them apart from other asset classes. For example, Xiao and Tan (2007) state that real estate can display inefficient market qualities such as high transaction costs. In analysing price behaviour, it is also important to segregate ownership structures, such as securitisation, which can result in a price rerating (Sing et al. 2003; DeLisle 2008) and behavioural differences (Fan et al. 2012; Belke et al. 2010). As Capron and Shen (2007) and Leung et al. (2004) identify that there is relatively little academic research on the price behaviour of tightly-held private corporations or assets, this is a field that warrants additional research. On this basis, research at an **asset level** is warranted within the field of pricing.

As changing ownership structures has a price impact and Park and Kim (1997) identify that partial ownership structures may improve value, while Chi (2000) demonstrates that this translates into higher prices. However, Chu (2012) points out that quantifying the price change behaviour is a complex process that is often confused with other types of premia or discounts, leading to a poor level of understanding. Consequently, there is an asset price knowledge gap concerning partial ownership structures that are prevalent in mineral asset transactions. This knowledge gap is dubbed '**ownership risk**' within the field of asset pricing.

Cheng and Lyu (2003) and Hodos (2004) state that the principal driver of an asset's price is or should be, the potential of a project to yield a positive stream of cash flows from future activities. Harford (2005) and Paoli and Weeken (2010) note that value is impacted by the prevailing economic conditions. Strang (2012) identifies that in the mining sector the revenue function is different to other goods and services, as it focusses more on logistics than product differentiation. The prevailing commodity price, such as gold, and its importance to deposit price make it a topic that warrants additional research. In effect, this knowledge gap concerns '**commodity price'** risk.

Wampler and Ayler (1998) state that the certainty of the quantity and quality of a mineral asset is an important price driver. Zabolotnyuk et al. (2010) show that elevated levels of value certainty allow for more accurate price prediction and Chia-Wu et al. (2010) highlight that price asymmetry associated with certainty. Fortunately, many mineral deposits have their uncertainty reported according to a standardised reporting formats that are relatively easy to use (Ferguson et al. 2013), although they are qualitative rather than quantitative descriptions (Amos and Breaden 2001). Consequently, there is a knowledge gap concerning how the asset market behaves in relation to subjective risk measures, or put more simply, there is '**certainty risk**'.

Hodos (2004), Wampler and Ayler (1998), Blose and Shieh (1995) and Khoury (1984) identify that the country a gold deposit is in affects the price of a related security. Revoltella et al. (2010) discuss how methods for quantifying the equivalent premiums for heterogeneous assets may lead to mispricing. Even for homogenous goods for which there are limited trade barriers (such as electronics on eBay), it is possible to observe a country of origin premium (Hu and Wang 2010). No literature was identified as describing the influence of heterogeneous durable goods like gold deposits despite their diverse geographical distributions, which includes locations in high-risk jurisdictions (Morris et al. 2012). Consequently, **country risk** is a topic that warrants additional research.

Having identified knowledge gaps in the literature review, potential pricing approaches and methods were detailed. Wirtz (2012), IFRS13 (2011) and IVSC (2014) show that there are three approaches defined as market-based, income-based and cost-based. Of these, only the market (hedonic) approach intrinsically captures all price variables at any given time (Lancaster 1996; Kakhki et al. 2010; Brander and Koetse 2011) including both technical parameters and human influences (Kask and Maani 1992). The trade off with using the market-based approach is that the impact of individual price drivers is less easy to quantify when compared to the income-based approach, which works from first-principles. Given the paucity of literature relating to the specific behaviour of gold deposit price, the lower reliability on assumptions and the need for adjustments is important as a reality check and as a sound reason to use it as the approach to address the knowledge gaps. Within hedonic pricing, the block model method developed by Bell et al. (2008) was identified as a suitable means of being able to observe the statistically significant interaction of three variables to produce an outcome that exhibits price dispersion. The advantage of the Bell et al. (2008) methodology over multivariate analysis is that it does not require substantial pre-processing of data, and the results can be easily related back to the original measures – which are two weaknesses identified by Pripp (2012, pp63). As Leung et al., (2004) identifies that here is little guidance in the academic literature for asset level price behaviour, it is important that the results of an analysis can be easily related back to the original measures.

Consequently, the opportunity to add to the scientific knowledge base is demonstrated using a top-down approach, in that price is poorly demarcated from value and price is mostly described at a security level. Having determined that mineral asset pricing is an area in need of research, four areas for improvement within a mineral asset context were identified, resulting in the hypotheses concerning:

1. **Ownership risk** – on a dollar per ounce basis ($/oz), the price of a gold deposit does not always increase with increased level of ownership by one of the parties.

2. **Commodity price risk** – the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction but through disproportionate movements.

3. **Certainty risk** – the price of a gold deposit increases disproportionately with increases in the certainty of a deposits quantity and quality estimates.

4. **Country risk** – the geopolitical characteristics of a country affect the price of a gold deposit.

While the investigation of mineral asset prices in response to changes in both size, grade and the four risks address knowledge gaps, the investigations are also of significant commercial merit. Ownership, commodity price, certainty and country risk are considered in a gold deposit transaction and of interest to market participants. Furthermore, gold deposit transactions involve large monetary sums. Wright (2015) shows that in any given year between 2008 and 2014, they accounted for 21% to 60% of the cumulative global deposit transactions. This monetary importance, combined with the industrial origins of the proposed methodology make the four knowledge gaps worthy of academic research.

3 Methodology

The objective of this thesis is to determine how the characteristics of a gold deposit transaction affect its price. A review of the academic literature shows that the field of mineral asset pricing is poorly described and falls between some well-documented fields such as gold deposit valuation, real estate pricing and security pricing. Often the term price (what you pay) is used interchangeably with value (what you get); for the purpose of this thesis, it is important to make the distinction between these two terms, as price is heavily influenced by exogenous aspects (e.g. negotiating with a willing buyer) whereas value is oriented more toward endogenous characteristics (e.g. quantity, quality, depth, morphology). An assumption is often made that the price of a security is a direct measure of the price of the underlying assets. However, the process of securitising an asset fundamentally changes its ownership structure and market liquidity, and in doing so, affects its price. The general lack of understanding about mineral property pricing (Lilford, 2004) is in part, due to the need for an interdisciplinary understanding that requires competence in the technical aspects of the mining industry; an understanding of gold deposit valuation; and how, along with other project specific and macroeconomic variables, the interaction between these factors leads to the determination of the price for a gold deposit. While there are numerous research opportunities in the field of mineral asset pricing, the hypotheses of this thesis concern:

- **Ownership risk** – on a dollar per ounce basis ($/oz), the price of a gold deposit does not always increase with increased level of ownership by one of the parties.
- **Commodity price risk** – the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction but through disproportionate movements.
- **Certainty risk** – the price of a gold deposit increases disproportionately with increases in the certainty of a deposits quantity and quality estimates.
- **Country risk** – the geopolitical characteristics of a country affect the price of a gold deposit.

This thesis uses transaction prices that are directly observable in the market to test the hypotheses and as such, is suited to the hedonic (market-based) pricing approach (Hellbich et al. 2013). Hedonic pricing methods are used as they are observational, with minimal 'rule' requirements, where the inputs express heterogeneity, dispersion and heteroskedasticity, as well as semi- or even non-parametric qualities (Brunauer et al. 2010). The strength of market-based approaches is that they allow an understanding of the system (Heidegger 1927, 1962) that includes human preferences and behaviour (Graddy 2009), while considering the direction and strength of a statistically meaningful relationship. To address the hypotheses, a dataset was created from public-domain data concerning mineral asset transactions on gold deposits around the world. Gold deposits were selected as they do not rely heavily on transport infrastructure, as for example a coal or iron ore deposit, they are frequently traded relative to other commodity types, and they require little downstream/offsite refining before sale into a terminal market. The transactions were entered into a database before categorisation, extraction, and manipulation in each of the models used to test the individual hypotheses. Information that is external to the transactions but relevant to the research was also sourced from the public domain (e.g. risk indexes, commodity prices).

Market data are inherently noisy, and it is often necessary to consider some variables to identify patterns. Sight is an important sense and plays a role in pattern recognition as it allows four variables to be taken into account (spatial location X-Y-Z, and magnitude (e.g. colour or size)). By plotting the price of a mineral asset in an artificial space defined by its quantity (X), quality (Y), risk (Z) and magnitude ($), it can be visually interrogated and described using spatial statistical techniques (geostatistics).

Three-dimensional semi-variograms are used to analyse spatial datasets and to identify the nature of the relationships between the data when expressed in space. The information from the semi-variogram defines the shape and orientation of a search ellipse. This information is used to apply weights of importance to data points that fall within its space, by considering their direction and distance from the centroid. The resulting value for the centroid is then assigned to the entire volume of a surrounding block. This is akin to establishing a matrix (like polygonal modelling), which has hard boundaries that result in a rigid averaging of the values of the points that fall within the block. Ordinary kriging, on the other hand, uses soft boundaries, where information that falls outside a discrete block influences the estimation of the value contained within the block. The ordinary kriging process assumes that the relationships between data points are continuous across block boundaries. A block model is produced when numerous search ellipses are run to define contiguous or related blocks. The block model method was selected as it is commonly used within the earth sciences (De Kemp et al. 2011) and the mining industry (Dutta et al. 2010). Using an established methods allow for commercial adoption without the need for reskilling employees or incurring significant capital investments.

The unit prices within the dataset distribute log-normally due to the natural underpinnings of the geological (Singer 2013) and financial inputs (price magnitude) (Black and Scholes 1979). To allow for easier visualisation and validation of the resulting block models, transforms to the X and Y co-ordinates are performed to ensure that the resulting block model does not have a planar shape (e.g. like a sheet of paper). Yamamoto (2007) states that the transformation of gold deposit tonnes and grades serves to reduce data variance and improve calculation statistics. However, Yamamoto (2007) and Dambolena et al. (2009) caution that while such transformations are advantageous in kriging estimates, there is risk of bias when back transformations are performed. As the three-dimensional spaces used in this research is artificial, there is no need to perform back transformation, as would be the case for a mineral estimate. The elimination of the need to perform back transformation avoids the difficulty and error associated with such operations. The magnitude of each estimated block is then compared the mean, and median of the data points to ensure that the patterns between each block are honoured. The patterns contained within the transformed block model, which is subdivided on a very broad scale (a division of 3x3x3), are used to observe behavioural patterns contained within in the dataset.

In this thesis, the Z-axis represents the dependent variable that underpins each of the hypotheses (e.g. commodity price, ownership, the degree of confidence in the resource/reserve estimate, and country risk). The ability to quantify the Z-axis variable determines its reliability in the block model method. While it is possible to determine a precise and reliable scale for the Z-axis in some applications, others may be difficult to quantify and express. Consequently, the hypotheses can be sub-divided into two main groupings that reflect the ability to measure their basis, which is either endogenous or exogenous in nature:

- **certain (parametric)** – the inputs are absolute and can be used to validate the methodology as well as test the hypothesis:
  - prevailing gold price at the time a mineral asset transacted (exogenous issue)
  - proportion of the asset that is acquired (endogenous issue).
- **subjective (semi-parametric)** – manipulation is needed to express the inputs on a Z-axis:

- estimate confidence – market classification of mineral estimate confidence is qualitative, placing uncertainty on the weight that should be assigned (endogenous expression issue)
- sovereign risk – where the inputs are subjective, but lend themselves to ranking (exogenous input issue).

While it is possible to create a block model using any four variables, it does not mean that what appears to be a mathematically correct outcome necessarily has a meaningful connection with reality. As a result, this research was conducted with the help of geostatistical experts (detailed in Section 11: Acknowledgments) in geostatistical estimation. These experts were supplied with the relevant datasets and tasked with undertaking semi-variogram analysis and populating the block models. Guidance was provided on how to handle the data sets to ensure consistency between investigations. Different experts were used in each hypothesis for accessing a breadth of knowledge, exposure to a wide range of geostatistical experience and peer validation. As a result, the focus of this thesis is on:

- describing the known influence of each source of risk
- determining a means of plotting the risk on the Z-axis
- collating the appropriate datasets, assuming 100% metallurgical recovery and deposits where gold accounts for more than 75% of the in-situ value at the time of the transaction.
- analysing the spatial relationships within the variables using 3-D variogram models. A search ellipse based on these relationships is then used to inform the model. The search ellipse has its axis defined by the separating distance between size, grade and risk, such that the variogram function (γ) is defined by the separating distance between size ($\eta 1$), the distance between grade ($\eta 2$) and the distance between the risk ($\eta 3$).
- validating the results of the block model by comparing estimates to the raw data which underpins each of the domains.
- identifying, quantifying and describing any relationships identified in the resulting block models
- drawing conclusions on the relevance of any identified relationships
- establishing the implication of this research within the current body of knowledge

- concluding with answers to the hypotheses.

A flowsheet outlining the adopted methodology is presented in Figure 13. The following sections (3.1, 3.1.1 and 3.2) detail the hedonic pricing and geostatistical methods, as well as how they are used to test the hypotheses.

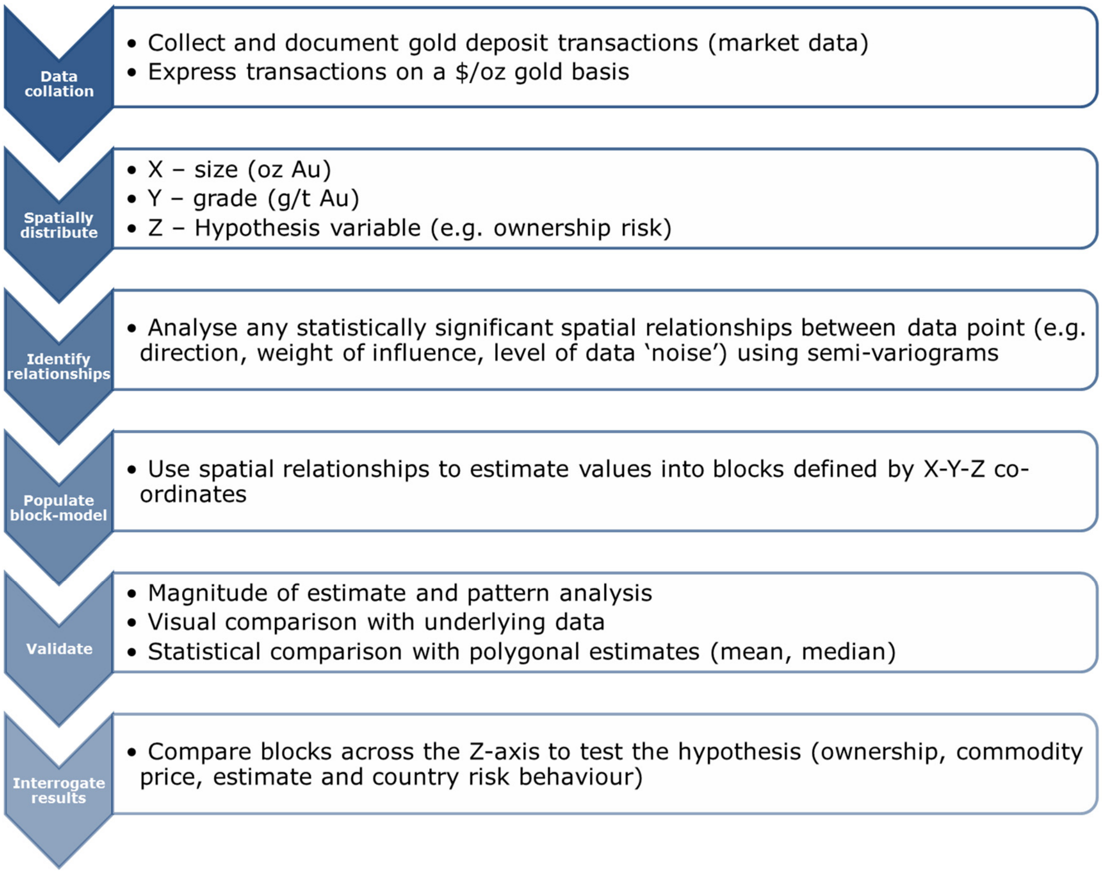


Figure 13. Flowsheet of the research methodology

3.1 Market based

Based on the literature reviewed in Section 2, the market approach to valuation is the most suited method for testing the impact of the various drivers that affect mineral asset prices. Above all else, the approach was selected as it requires the fewest number of assumptions and provides some protection against forecasts that may not be within the range of reasonable possibilities (Kahneman and Lovallo 1993). As a result, the market-based methods provide a top-down perspective on price analysis (Powe and Bateman 2003), which focuses on 'what is', rather than a theoretical 'what should be'. In this instance, outright gold deposit sales prices (comparable transaction method) are complemented with partial gold deposit sales (joint venture method) to create larger datasets in a field of study where, when compared to securities, there are few data points.

Gold deposits are used as a study medium because geologically, metallurgically, and macroeconomically they have research qualities that make them superior to other mineral commodities. Gold is an appropriate commodity for research as:

- the deposits and associated exploration projects are found in many countries (Burton 2005; Kabete et al. 2012), mineralisation styles (Nikoklaeva et al. 2013), and quantity-quality combinations (Zhou et al. 2000)
- gold does not have a minimum economy of scale and infrastructure requirement like bulk-commodities (Ronen 1985)
- it generally leaves the "*mine-gate*" as a product in a highly refined form (doré) (Wampler and Ayler 1998) and therefore it achieves a price close to that of the spot refined gold price for doré, which in most situations, may return between 99.8% and 99.95% of the metal value (Cotton 1993). Alternatively, base-metal mines may produce concentrates with payable returns in the range of 40% to 80% of the value of the contained metal due to additional costs and penalties (Wilson and Chanroux 1993a, 1993b, 1993c; Cunningham 1993; Lewis et al. 1993) – note that payability figures are often subject to confidentiality agreements and are rarely published in the public domain
- it has limited industrial use and is largely used as a store of wealth (Baur 2010). It has little differentiation and is sold into a sophisticated market that has linkages with currency markets (Wang 2013)
- it has a high rate of recycling (Nicholls and Corti 2010), which helps reduce supply-demand imbalances (Burton 2005; Govett and Govett 1982)
- the price of gold has been modelled using a random walk (Brownian motion) path (Shafiee and Topal 2009), with a more stable price growth trend compared to the mean-reverting price processes exhibited by many base metals (Stobart 1991)
- it has a deeply stratified deposit transaction structure (Hodos 2004) that provides access to many market participants. It is the most commonly traded deposit type as evidenced by it accounting for about 49% of all deposit transactions identified in the Alexander Research database.

Figure 14 shows the technique used to calculate the unit prices of transactions. It includes the conversion of all by-product metals to gold-equivalents based on their spot prices at the date of each transaction. The price is then divided by the gold-equivalent metal, converted to a common USD basis and inflated to a real term using using the US CPI (BLS 2013).

No price adjustments were made to reflect the prevailing spot gold price at the time of the transaction. The spot gold price is a discrete price driver and is investigated further in Section 4.3.2.

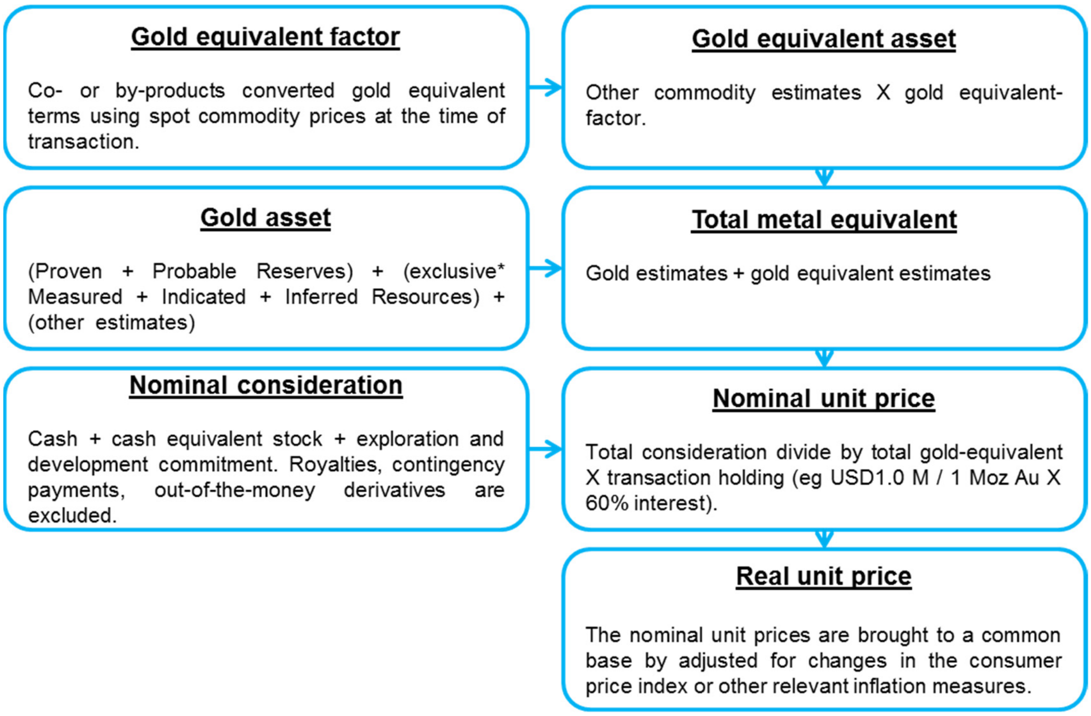


Figure 14. The price calculation used in this research

Given the empirical nature of the research and variability within the natural dataset, it was necessary to use as many transactions as possible to address the knowledge gaps surrounding the behaviour of the market for gold deposits in a statistically valid manner (Vandell 1982). By using a large dataset, there will inevitably be a high degree of variability (Wolfe 2013), but this also creates an opportunity for improving mineral asset price predictions if enhancements can be made (Knapp 2013). This thesis draws information from the commercial database owned by Alexander Research. While other commercially available databases exist, these do not contain a level of information adequate for this research as:

- The majority are not specific to mineral assets and consequently, omit important technical details. For example, abnormally high transaction prices for a deposit due to initial exploration successes that have not been formalised into a mineral estimate.
- Multi-sector databases only focus on large deals, often more than $5.00 M, resulting in the omission of many small but important transactions, particularly those involving projects that whose full spatial extent have not been fully defined.

- At the time this study commenced, no commercial database was identified that catered for exploration projects having no estimated mineral resources.
- The mineral asset specific transaction databases that are available present simplified information with limited qualitative descriptions of the projects. Being able to interrogate the datasets in detail is fundamental to this thesis as:
  - the consideration terms of transactions are variable, be it the proportion of cash, securities, expenditure commitments, earn-in options, contingency payments, or equity exchanged
  - there are numerous value drivers that impact price interdependently (Brunauer et al. 2010). Consequently, it is important to be able to differentiate between deep deposits, near surface deposits, project maturity, the contributions of each mineral estimate class (e.g. Measured, Indicated, Inferred), state/province jurisdictions, prevailing metal prices, metal ratios, and mineralisation types.

The process of compiling the database gave considerable experience to the author in reviewing the terms and conditions of individual project transactions and their technical insights, as well as other relevant market dynamics. While laborious, the insight gained from this process provided *a posteriori* knowledge and understanding for inductive interpretation of the results of the research presented in this thesis. This tacit knowledge would not be gained from an ‘off the shelf’ solution if it were available. In total, this thesis used up to ~1,500 unique transactions. This number is a filtered result of the screening of many more transactions that were not included in the analysis on the basis that they did not contain the requisite technical details. For example, the last dataset used in this thesis contained 6,066 unique transactions, which expands to 9,377 when deal variations are included.

This methodology is consistent with other hedonic pricing models in that it does not consider any transaction in isolation; rather it uses objective, empirical analysis of a large volume of transactions to observe overall market behaviours. This fits with Hodos (2004), who states that market data is key to identifying the investment behaviour, evaluating the competitive market conditions and providing confidence in the consistency of an appraisal. Furthermore, it takes into account the warning of Ratcliff (2001) who states that conventional market-based valuation methods are reliant on the subjective analysis of individual reference points. Consequently, Ratcliff (2001), advocates the use of statistically determined prices rather than absolute estimates to overcome this problem, and

Lusht (1981) supports this suggestion by probability adjusted models that are consistent with the methodology used in this thesis in the context of a block model.

3.1.1 Block model method

This thesis expands and refines the initial methodology identified by Bell et al. (2008), which was limited to country risk between September 2001 and June 2007, by using alternative price drivers in the Z-dimension covering this period as well as that up until mid-2012. In the context of this thesis, the proposed X and Y axes of a block model are used to represent the magnitude of the size and grade variables respectively, while the Z-axis is changed in each application to represent one of:

- equity interest – a percentage figure that represents the ownership level acquired
- transaction gold metal price index – where the unit sales price ($/oz Au) is divided by the prevailing gold metal price at the time of the transaction
- mineral estimate confidence – an index weighted according to the CRIRSCO family of mineral estimate confidence categories
- country risk – where a combination of opinion-based and financial risk indicators are used.

Each of the block models were cross-checked using the means and medians of each domain (akin to polygonal modelling, where values within a pre-defined area is estimated without considering information across boundaries). Visual inspection of the underlying data points relative to the block model outputs was also undertaken to help ensure that the model outputs broadly reflect the underlying datasets.

In analysing mineral deposits, the geostatistical information that is typically derived from drillhole information, the X, Y, Z spatial locations of each sample, as well as the magnitude at each point (such as the gold grade) was compiled into a dataset. Once a dataset was collated, geostatistical analysis was undertaken in two stages:

1. Determining the spatial (direction and distance) relationship between data points, and the variation in the magnitude of the attribute studied (typically grade) between the points. This is typically done in a graphical format known as a '**semi-variogram**' (stylised in Figure 15, after Clark 1979),

which can be combined for a range of orientations to produce a two-dimensional map of variability in the horizontal (X:Y) plane, the vertical plane, and the plane interpreted from the strike and dip (Figure 16). The weight of influence assigned to each data point decreases with distance from the estimation point (Bohling 2005). The observed relationships are used to establish an ellipse that represents the lateral extent and associated weight of the relationships. The widely used Snowden Supervisor software package is used to analyse the spatial relationships.

2. Estimating values into the unsampled space (Gooevaerts 2000) using the search ellipse established by the semi-variogram analysis. This estimation is done through interpolation (although there is limited scope for extrapolation) to create the three-dimensional block model (Bascetin et al. 2011; Zhao et al. 2011) (Figure 17). Sample spacing, and hence the size of each block, should be set so that the value at the contained sampling point can determine the value for the block within an acceptable degree of confidence (Vann and Guibal 1998).

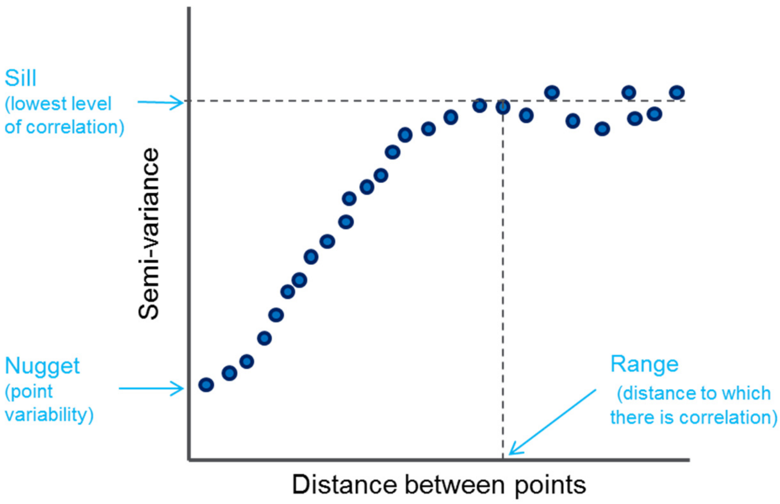


Figure 15. A schematic of a semi-variogram

(after Clark, 1979)

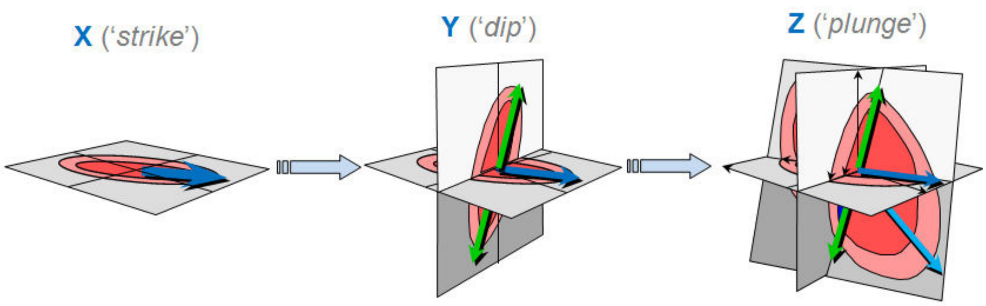


Figure 16. A schematic of a geostatistical search ellipse

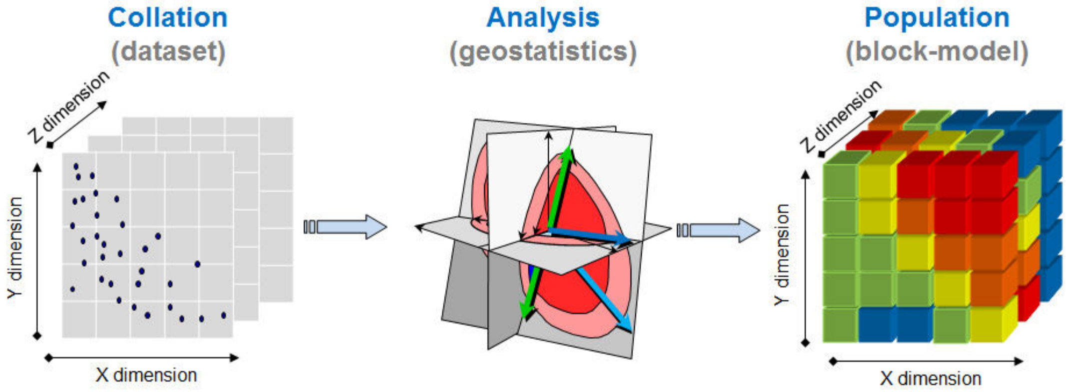


Figure 17. The block model process

Where the underlying datasets are heavily skewed, such as with mineral deposits (Singer 2013; Parker 1991), financial returns (Chen 2001; Leung et al. 2006), and market prices (Black and Scholes 1973), the raw data tends to cluster heavily in the southwest quadrant of the X, Y and Z dimensions (Figure 18). By applying log-normal transforms to the size (X) and grade (Y) dimensions, the dataset is presented in a manner that is easier for visual validation and interpretation, without affecting the underlying distributions.

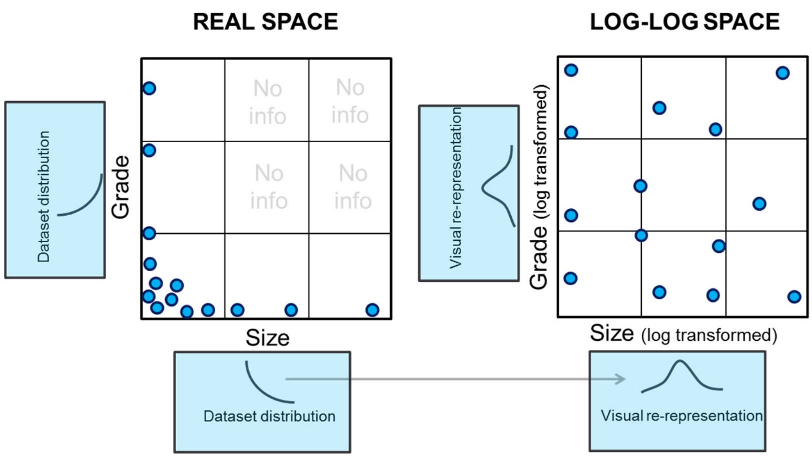


Figure 18. Effect of log-log transformation

An analysis of market behaviour in relation to specific price drivers is made possible by casting a price driver against the technical measures of a deposit (size and grade; represented by X and Y respectively), any differences across the Z dimension become attributable to that price driver, assuming that all those parameters that affect price are held constant for the various transactions. For example, if two gold deposits with the same size-grade combination are considered (being similar in all other respects), where one is in a safe country and the other in a risky country, then, all else being held equal, the price differential must be attributed to this risk, which can in turn, be measured by relative means. In this manner, it is possible to identify relative factors, from which market behaviour can be observed and described (Figure 19). Bell et al. (2008) is the only application of the block model method to gold deposit transactions that the author could locate in the literature. Consequently, different geostatistical experts were engaged to contribute to the models, so that a wide range of knowledge was accessed, promoting a focus on understanding the systems, and providing peer validation as well as acceptance. As there is no literature filling the knowledge gaps relating to ownership, commodity, certainty and country risk relating to gold deposits, each of the hypothesis variables is considered in isolation from each other. The compartmentalisation of the hypothesis results minimises the impact of assumption-based adjustments and provides a basis for future research which includes more complex interdependence analyses.

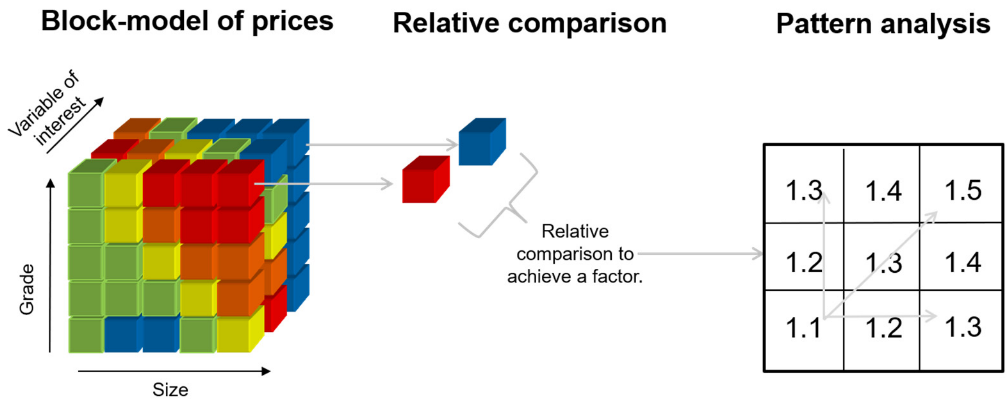


Figure 19. Market pattern analysis

3.2 Assumptions

While the market approach that underpins this research accounts for a wide range of parametric and semi-parametric value drivers and is easy to communicate, it relies on some assumptions. These assumptions may lead to inaccurate price predictions on an individual scale. As the purpose of this research is to gauge overall market behaviour rather than the price of an individual, it is assumed that any inaccuracies in calculating prices are similarly distributed throughout the models and do not significantly distort the 'big-picture' trends in the data. In collating and analysing the datasets used in this thesis, the following assumptions were made:

- **Time frame** – this study uses mineral asset transactions involving the sale of gold deposits that range from 1 September 2001 to 31 July 2012. Due to the relatively illiquid nature of mineral asset transactions compared to frequently traded financial securities, it was not possible to collate a significant database of transactions without using a relatively broad timeframe. This timeframe covers a period during which the financial markets went through positive and negative cycles. It also represents a timeframe over which the market price of gold made significant advances without a major correction. These factors affected the prices paid for various deposits and the degree of influence of various price drivers (Leung et al. 2002). Consequently, each application of the block model attempts to analyse the results on a pre- and post-June 2007 basis, when the global economic imbalances associated with the Global Financial Crisis (GFC) started to become evident and increases in the price of gold metal began to accelerate.

- **Public domain information –** it was assumed that all transactions recorded were based on gold as their primary commodity; were principally valued as *in situ* resources; the estimates were representative of the resources irrespective of whether they meet the reporting criteria of the CRIRSCO group of codes (Njowa et al. 2014); and the full value of the consideration involved in the transaction was disclosed.

- **Efficient market** – as mineral assets are infrequently traded, it is assumed that the market has efficiently differentiated between the varying resources, reserves and ‘other’ estimates. This is not true in the literal sense, as asset markets are well known to demonstrate price dispersion (Barbade and Silber 1976; Adams 1997; Leung et al. 2006) and price drivers can exhibit heteroskedasticity (Yiu et al. 2006). Consequently, there is no ‘correct price’, only a range of prices (Vandel 1981). It is for such reasons that the block modelling method is used as it accounts for the heterogeneous (‘nuggetty’) nature of the information in estimating the magnitude of any given point.

- **Foreign exchange** – currencies are expressed in United States of America dollar equivalents at the time of the transaction, so it is assumed that changes in exchange rates over time do not significantly distort the price paid for a deposit. This assumption is preferable to the of applying a standardised currency exchange rate which leads to inaccuracy in all the data, and undermines the data informing on the circumstance under which the transaction occurred.

- **Consideration type** – there is often a mixture of types of consideration used in a mineral asset transaction. Deal terms may include securities, expenditure commitments in incrementally staged transactions that may also include overlying performance-based payments, and royalties on future production. This thesis attempts to study the effect of the consideration type, but it is done as part of sub-themes to the main investigations (country risk, ownership structure, etc.).

- **Estimating price** – although most of the terms of a transaction are publicly disclosed, it is not always possible to accurately ascribe a monetary amount to each component of the consideration involved. It is assumed that pricing errors are homogenously distributed throughout the datasets and thus do not significantly affect the overall market relationships.
    - **Securities** – where securities are issued without a stated value, they are deemed to have a price equivalent to the share price at the opening of trading at the date of the transaction.
    - **Derivatives** – due to a pre-existing artefact of the database, no price is ascribed to derivatives unless they are in-the-money. This is a pre-existing artefact of how calculations are made in the source database. After June 2007, less than 5% of gold deposit transactions included derivatives; however, some of these did not include enough information on which to calculate the price. It is assumed that any pricing error associated with derivatives is similarly distributed throughout the datasets, thereby having minimal impact on the observable patterns which are the focus of this thesis.
    - **Royalties and performance payments** – to calculate the likelihood of a royalty or performance payment being triggered, detailed project-specific knowledge is required from which somewhat subjective probabilities of realisation can be calculated. As this research considers thousands of transactions in many regulatory jurisdictions, it is not possible to make reasonable probability estimates for every transaction. Consequently, to ensure consistency, royalties and performance payments were not included in determining the unit price. Disclosure may improve, with recent changes to IFRS13 (IFRS 2011), which introduced the requirement of valuing contingent consideration at "fair value" irrespective of how low its probability of realisation may be from 1 July 2013. However, the changes to the IFRS13 accounting standards post-date the dataset used in this thesis.
- **Plant and infrastructure** – in some instances, particularly with very advanced projects or former mines, the transaction may include fixed plant and infrastructure. These items may have involved significant cost when first

established; however, as they are difficult to relocate, they may have limited sale value. Consequently, it is assumed that projects are acquired primarily on the merit of their mineral potential, with the plant and infrastructure being ascribed little value.

- **Tenement area** – deposit transactions invariably include at least some further exploration potential. However, the independent expert reports listed in the tables of Appendix 2 show that the price contribution of early-stage exploration tenements associated with a deposit transaction is relatively immaterial.
- **Joint-venture, estimate certainty and by-products** – outside of topic-specific studies, it is not possible to collate data sets of significant size without including joint-ventures and deposits of various maturity and type. As the CRIRSCO Template is not prescriptive, there is subjective variance in what defines each of the estimate categories. It is assumed that these imperfections do not significantly distort the relationships that are drawn out along the Z-axis of the block models.
- **Dollar terms** – the official US inflation rate (BLS, 2013) is used to inflate prices into USD terms relevant to the point at which each model is generated.

On balance, these assumptions have the potential to reduce the accuracy of the total price paid for the deposits. This potential distortion is not considered significant in the context of the current analysis given that overall market trends are sought rather than precise price prediction, and could be overcome if better information becomes available. Similar shortcomings can be levelled at all market-based methodologies and the reader should consider that the proposed methodology helps reduce some of the difficulties associated with real-world processes. No matter how much computer power is used, the block models are subject to fundamental uncertainty and therefore must be used with a mindset of being “better to be vaguely right rather than precisely wrong” (Bratvold and Begg 2008).

3.3 Structure

The hypothesised price drivers of ownership, commodity price, certainty, and country risks are present in all gold deposit transactions. Due to the low turn over rate associated with gold deposit transactions, it is not possible to address any of the hypotheses in isolation without distorting effects from other price drivers. To account for this inherent weakness within the hedonic pricing method, namely model specification, multicollinearity, independent variable interactions, heteroskedasticity, non-linearity and outlier data point interference

(Limsombunchai et al. 2004; Ebru and Eban 2011), multiple models are generated within each hypothesis test. This allows for not only the main hypothesis under investigation to be answered but acts as a means of stress testing the models to ensure that other forces are not unduly influencing the outcome; and where they are, being able to take them into account. This structure provides an additional benefit in that the consistency of the sub-analyses across the investigation of the hypotheses helps increase the confidence in the observational conclusions that are drawn. The main drawback of generating multiple models is that once all the various permutations are analysed and discussed, the reader is at risk of being overwhelmed by information. To reduce the risk of information overload, the hypotheses investigations are presented such that:

- the largest available dataset is used first, which represents the base-case where the least number of assumptions are made, and the data have the least amount of manipulation and editing
- sub-analyses are undertaken where the base-case datasets are cleansed of potential distorting influences such as partial ownership, different payment structures, economic cycles and deposit qualities
- where the sub-analyses observations are consistent across the investigations of various hypotheses, these sections are relocated to appendices, with the relevant comments left in the main body of the text.

3.4 Contribution

The methodology used in this research draws upon established techniques and applies them to publicly available data in a manner that has not been previously described elsewhere. By plotting size and grade of a gold deposit on the X and Y axes of a spatial model, and the hypothesis variable on the Z-axis, the relationship between the data points can be determined. The hypotheses plotted as the Z variables are ownership, commodity price, certainty, and country risk. The information for the X-Y-Z relationships is then used to interpolate into models from which each hypothesis can be tested (Figure 20).

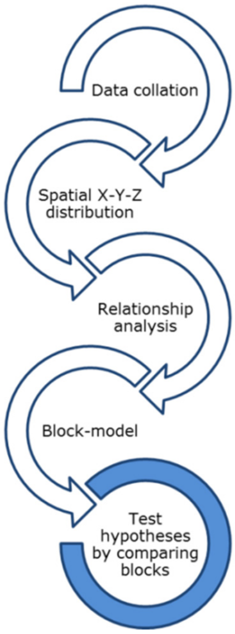


Figure 20. Methodology stages

This methodology builds on the Bell et al. (2008) study by expanding the price drivers beyond country risk, as well as varying the market conditions. The combination of the real-world oriented hedonic pricing method with powerful geostatistical estimation allows for improvements in gold deposit price prediction. Furthermore, it leverages established, and industry accepted techniques as well as wisdom from geostatistical experts experienced in handling heterogeneous, noisy and log-normally distributed datasets; and pricing Specialists who understand price, the multitude of price drivers and their possible influences and behaviour.

This interdisciplinary collaboration allows for research in a field that is poorly described in the academic literature, in a manner that is relatively free of rules, on topics that are commercially relevant and can be adopted by industry practitioners, in some cases with little need for re-skilling. Furthermore, block model outputs are amenable to interrogation with little specialised knowledge, thereby making it ‘end user’ friendly. As identified by Haldane (2012, quoted in Mousavi and Gigerenzer 2014), this is elegantly powerful as it addresses complexity with relative simplicity, thereby avoiding the risk compounding complexity and uncertainty.

4 Investigations

Using the methodology identified in Section 3, this section tests whether the price behaviour of a gold asset fits the following four hypotheses (the 'investigations'):

- **Ownership risk** – on a dollar per ounce basis ($/oz), the price of a gold deposit does not always increase with increased level of ownership by one of the parties.
- **Commodity price risk** – the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction but through disproportionate movements.
- **Certainty risk** – the price of a gold deposit increases disproportionately with increases in the certainty of a deposit's quantity and quality estimates.
- **Country risk** – the geopolitical characteristics of a country affect the price of a gold deposit.

The investigation of each of these hypotheses involves sub-analyses (Table 7) to test the impact of other price drivers that may alter the interpretation. This results in a lot of overlaps or subtleties in the difference between the various investigations. Sub-analyses where no significantly new observations were made, are located in the appendices.

Table 7. Investigation models

Risk	Number of analyses presented	Number of models generated and considered	Comment
Ownership	12	12	Sub-analysis includes Yardstick adjustments and staged transactions. The pre- and post-2007 and near surface vs. deep differences analysis in turn had three variations that investigated the influence of cash consideration and staged optionality on the price behaviour.
Commodity price	8	8	To make direct comparison with the Yardstick method, both two- and three-dimensional analysis were undertaken.
Mineral Estimate Certainty	6	6	Sub-analysis includes Yardstick adjustments, pre- and post-2007 analysis, near surface vs deep differences, shifting the confidence domain and using alternative means for quantifying confidence.
Country	1	3	Sub-analysis previously investigated in Bell et al. (2008), with minor difference noted in the new investigation.

4.1 Inputs

4.1.1 Gold metal price

Prevailing market conditions have a substantial impact on transaction prices (Wampler and Ayler 1998). The study period of the data used in this thesis spans from 11 September 2001 to the end of June 2012. This period represents a time during which the price of gold increased nearly seven-fold from 260 United States Dollars per ounce ($/oz Au) in September 2001 to a peak of $1,896/oz in September 2011 (Figure 21, Kitco 2012; Yahoo 2012a; 2012b). Over this timeframe the annualised volatilities for a selection of minerals using the standard deviation of the daily logarithmic returns on holding the metal (Mun 2002) are as follows: gold 22%; silver 43%; lead 46%; zinc 38%; copper 35%; and nickel: 43%.

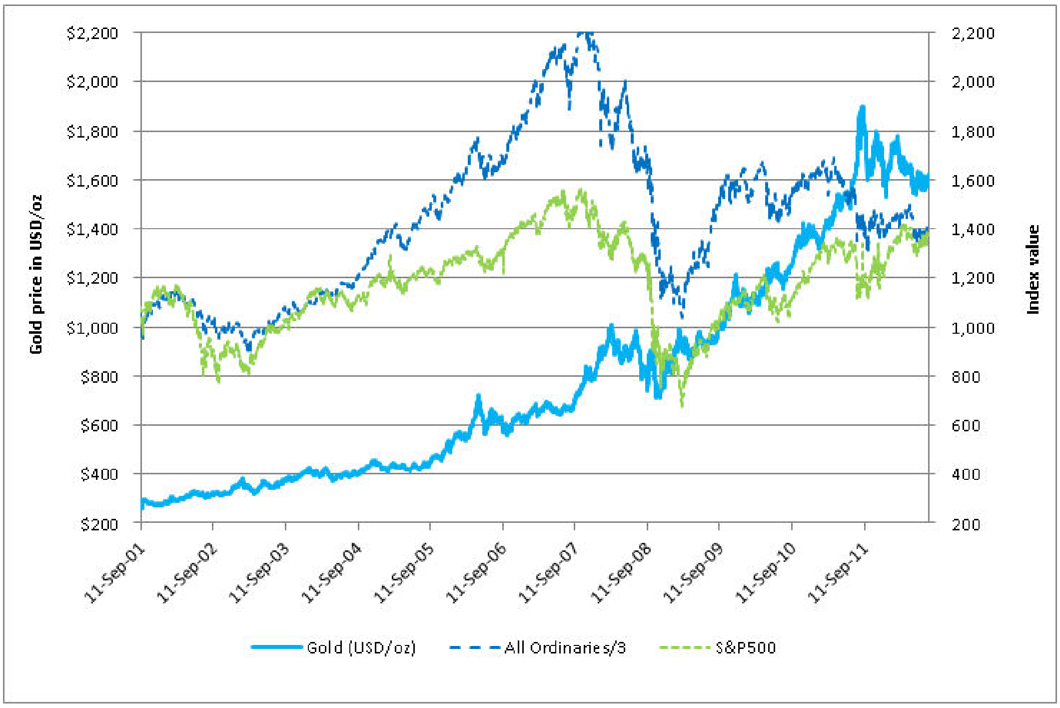


Figure 21. Gold prices, S&P500 Index and ASX All Ordinaries Index between 2001 and 2012

As the gold metal price grew nearly seven-fold during the study period of 11 September 2001 to the end of June 2012, it is necessary to account for both the absolute price of gold metal during this time, and what led to the metal price pattern. The underlying qualitative aspect of 'why' is important because gold is viewed by the markets as both a commodity and currency (Capie et al. 2005), a function that gives the gold price its behavioural characteristics. As market observations are observations of behaviour, understanding what drove the gold price is important in analysing gold deposit price behaviour.

The influences that affected the gold metal price can be attributed to the following factors:

- **Gold being a safe-haven investment** for the US and European markets, which were the focal point for global economic concerns over the period 2007 to 2012 (Baur and McDermott 2010). On this basis, gold demand increased due to the perception of it as a safe(r) investment in difficult economic conditions (Reboredo 2013; Baur 2011).
- **Steady total supply of gold relative to variable demand**. The demand for gold is only partially driven by its industrial and jewel manufacturing consumption, as its demand is also driven by emotion and the perception of it being a storage of wealth and a hedge against political risk and inflation (Govett and Govett 1982; Capie et al. 2005; Starr and Tran 2008). On the supply side, a sizable portion of gold is sourced from the recycling of existing inventories (40%) with 'new' gold sources accounting for only 60% of the total global supply (WGC 2011). Few other metals demonstrate such a prominent level of recycling through time; Govett and Govett (1982) state that the supply-demand relationship is quite different to that of other metals.
- **Coming off a '*low base*'**. The mid-1990s through to early 2000s represented a period when central banks around the world sold their gold reserves (Aizenman and Inoue 2013; Duckenfield 2008) and forward sales emerged as risk management strategy adopted by many gold miners. The effect was to suppress the growth in gold prices below what they would have been in under less hedged market conditions (Kearney and Lombra 2008).
- **The central banks of newly emerging economies**, such as those of China and India, becoming active gold buyers and increasing the amount of gold held in their reserves (Chen, et al. 2014).
- **Economic stimulus programmes initiated since 2009 in response to the GFC** (Hazelkorn and Massaro 2011). These had the effect of reducing the value of the $ (which is the principal unit used to measure the worth of gold) as well as creating a hedge against inflation (Reboredo 2013, Larsen and McQueen 1995, Jaffe 1989, Chau and Woodward 1982).
- **Increased ease of access and liquidity in trading.** Financial instruments such as exchange-traded funds increased the accessibility of gold as an investment asset by making it as liquid as other securities (Shafiee and Topal 2010; Baur and McDermott 2010).

The study period in this thesis covers a period of sustained gold price appreciation that started when gold was an undesirable asset class through to when gold had near record high prices (Figure 21). The positive metal price sentiment throughout this period makes it suitable to study the impact of various price drivers on the prices realised in gold deposit transactions.

4.1.2 Dataset qualities

Each of the gold deposit investigations used slightly different datasets due to different technical selection criteria and data availability at the time of analysis. The relevant qualities of the datasets used in each block model investigation are presented in Table 8. These datasets were gradually collated as transaction information became available. The commodity price risk dataset is the largest, as it is the last hypothesis tested and covered a full gold cycle (2001-2012). The country risk dataset, which includes countries other than Australia, Canada and the USA, has a high total price ($34,908 M). This high cumulative sales price is a function of the deposits located outside of Australia, Canada and the USA having a median size three times that in those three countries. The datasets used in each of the investigations is presented in Appendix 4.

Table 8. Gold deposit investigation dataset qualities

Quality		Ownership risk	Commodity price risk	Certainty risk	Country risk
Time frame	From	Sept' 2011	Sept' 2001	Sept' 2001	June 2007
	To	Dec' 2009	June 2012	Aug' 2009	Oct '2010
Filters	Gold contribution	≥75%	≥75%	≥75%	≥75%
	Equity interest	All	≥50%	≥50%	≥50%
Dataset	Points	316	370	300	337
	Total price ($ M)	3,836	7,736	6,402	34,908
Grade (g/t Au)	≥6 g/t Au	118	128	101	101
	3-6 g/t Au	57	81	62	65
	<3 g/t Au	141	161	137	171
	Median	1.9	3.9	3.3	3.0
	3rd quartile	7.8	7.3	7.6	6.8
Size (Moz Au)	≥4.75	N/A	N/A	N/A	20
	1.00 – 4.75	N/A	N/A	N/A	5
	<1.00	N/A	N/A	N/A	232
	≥1.00	43	58	53	-
	0.25- 1.00	124	126	117	-
	<0.25	149	186	130	-
	Median	0.28	0.25	0.31	0.94 -1.02
	3rd quartile	0.70	0.69	0.75	2.3-2.4
Mineral estimate classification (CRIRSCO)	Proved and Probable Reserves	30	42	40	59
	At least Measured Resources	105	119	94	114
	At least Indicated Resources	72	88	76	203
	At least Inferred Resources	42	52	46	47
	Non-compliant estimates	97	110	84	85
	Historic 'reserves'	4	6	3	4
Status	In production	29	29	31	57
	Scoping to feasibility study	63	62	71	60
	Former producer	70	89	50	73
	Exploration	154	189	148	147

The shape of the block models in real space, in the absence of scaling adjustments, would be a long, thin wafer because of:

- X – gold deposit size is measurable in millions of ounces
- Y – gold deposit grade is measured in grams per tonne, with usually no more than three or four significant figures.
- Z – being a variable but usually within a small range of 0 to 100

This is not an issue in computing geostatistics; however, it does make the models unwieldy and difficult to visually assess and validate. Consequently, each of the block models used in the investigation required a transformation to make them visually manageable. Lognormal transformations are used because the lognormal distribution is considered the best fit for the size of mineral deposits (Singer 2013). The distribution of the data used in this thesis is presented in Appendix 4. The transformations used to visually enhance the various block models are slightly different for each block model to best suit the different datasets used (Table 9).

Table 9. Transformations, search elipses and block dimensions

	Ownership risk	Commodity price risk	Certainty risk	Country risk
X transform	2[ln(size) – 9]/3	ln(size)	ln(size)	2[ln(size) – 9]/3
Y transform	1.1[ln(grade) + 1.65]	ln(grade) + 1.1	ln(grade) + 1.1	1.1[ln(grade) + 1.65]
Z transform	equity x 10	gold price/100	none	Risk index *10
X continuity	2.0	3.0	3.0	3.5
Y continuity	1.5	1.5	1.5	1.6
Z continuity	5.0	1.5	1.5	1.0
X size, subdivision	0.25, 22	0.5, 12	0.1, 17	0.25, 24
Y size, subdivision	0.25, 23	0.5, 17	0.1, 5	0.25, 26
Z size, subdivision	0.25, 11	0.5, 33	0.1, 6	1, 3

4.1.3 Size and grade definitions

For ease of communication and understanding that is consistent with risk matrices (Levine 2012), the datasets are classified by a simple system of low, medium, and high for each of the three dimensions (size, grade and the Z variable). As four datasets are used to test the hypotheses, it is necessary to maintain commonality between each of the investigations. The relevant attributes consistent to all of the dataset are the size and grade of the deposits subject to a transaction. In addition, prior to the adoption of the method described by Bell et al (2008), an attempt was made by that author to perform analysis using graphical methods (e.g. three-dimensional surfaces). However, the graphical method was unsuccessful which led to the adoption of geostatistical analysis and block-modelling, which includes the use of log transforms to handle the skewed datasets. As block-models can be produced with block sizes that are of much higher resolution than required for the purpose of the first-pass nature of the hypotheses, the reblocking to 3x3x3 matrices is appropriate in this instance. Furthermore, Bell et al (2008) performed experiments on the domains, and where new metrics are used in this thesis, similar experiments were performed.

The regrouping of the block-models fulfils the need to identify large-scale market behaviours that make higher resolution descriptions harder to follow, particularly when discussing sub-analyses where the smaller datasets result in noisier outputs on a local scale. This representation is in keeping with Brooks et al. (2014) who advocate the effectiveness of substantive communication. As size and grade are common to all the investigations, a review of industry perceptions was undertaken and compared to the dataset distributions. The review of perceptions in mature mining countries (Australia, Canada, USA) resulted in low-grade being defined as anything below 3 g/t Au and high-grade anything above 6 g/t Au; and small being less than 0.25 Moz Au and large being more than 1.00 Moz Au. In countries with less mature mining industries, it was determined that small is likely to be defined as a deposit with less than 1.00 Moz Au, and large being more than 5.00 Moz Au.

Bell et al. (2008) administered a survey of four members (for a total of seven opinions when the authors were included) of Snowden Industry Mining Consultants Pty Ltd’s corporate service division to establish the grade and size boundaries. This process resulted in grade boundaries of 3 and 6 g/t Au, which match the boundaries used by Cullen and Craw (1990). The derived size boundaries were 1.00 M and 5.00 Moz Au. The 5.00 Moz Au size is consistent with the threshold used in Schodde (2004), and the minimum threshold for Crowson (2003).

In contrast to global scale perceptions, the definitions of small/low-grade to large/high-grade in Australia, Canada and the USA are different. This is due to discoveries becoming less frequent in these countries, and remnant resources tending to be smaller and of lower grade (Schodde 2012a, 2012b). Consequently, the perceptions, expectations, and economic potential of deposit size and grade found in these countries are different (Singer and Menzie 2010). As part of this research, a new survey of industry valuation and pricing pracitioners from a variety of backgrounds is presented in Appendix 6. Obtaining a sense of opinion is important as price is driven by market behaviour, and market behaviour is, in part, a function of individual opinion. The survey confirms that the 3 and 6 g/t Au grade boundaries are valid; with the market perceiving small deposits as being anything under 0.25 Moz Au, and large deposits anything above 1.00 Moz Au. The perceptions of size are consistent with Schodde and Guj (2012) and Schodde (2004) who define ‘major’ as being >1.00 Moz Au. Consequently, there is a sufficient body of opinions to support the notion that anything less than 0.25 Moz Au is ‘small’ in safe and mature mining countries such as Australia, Canada and the USA.

Schodde and Guj (2012) use 0.10 Moz Au as a marker for ‘moderate’; however, as the Australian projects detailed by Ulrich and Twigger (2018) in Appendix 7, have a median production rate of 0.1 Moz Au per annum, a deposit of 0.10 Moz Au is more likely to be considered ‘small’. This is consistent with Crowson (2003), who determines that the lower quartile of annual gold production rate is ~0.1 Moz, the median is ~0.2 Moz, and the upper quartile is just under 0.4 Moz Au.

An analysis of the dataset distributions used in each of the investigations shows that the suggested boundaries broadly match the population medians and third quartiles (Table 10). While Microsoft Excel™ was used in calculating these medians, it should be noted that as the datasets each involve more than 300 transactions, the discrepancy between percentiles at the tails of the distributions as calculated by the exclusive Excel formula, and those calculated by an inclusive method is not material. The variance between the datasets used in each investigation reflects the geological distribution of size and grade differing from that of deposits that have been the subject of sales transactions. For example, large, high-grade deposits may rarely transact due to large multinational corporations having no interest in divesting such high-quality assets. In comparison, small low-grade deposits may frequently transact among many junior companies. A comparison of a Zipf curve based on the largest transaction, plotted against the actual population distribution supports the notion that the geological population, as per Guj et al. (2011), and the transaction population distributions are distinctly different (Figure 22). This is important as it signifies that the market does not sample randomly from the geological endowment, and may be due to either market dynamics or the temporal aspect of the Zipf theory in its application to mineral endowment.

Table 10. Dataset size-grade distributions

Quality		Ownership risk	Commodity price risk	Certainty risk	Country risk
Grade (g/t Au)	Median	3.7	3.9	3.3	3.0
	3rd quartile	7.9	7.3	7.6	6.8
Size (Moz Au)	Median	0.27	0.25	0.31	0.94 -1.02
	3rd quartile	0.70	0.69	0.75	2.3-2.4

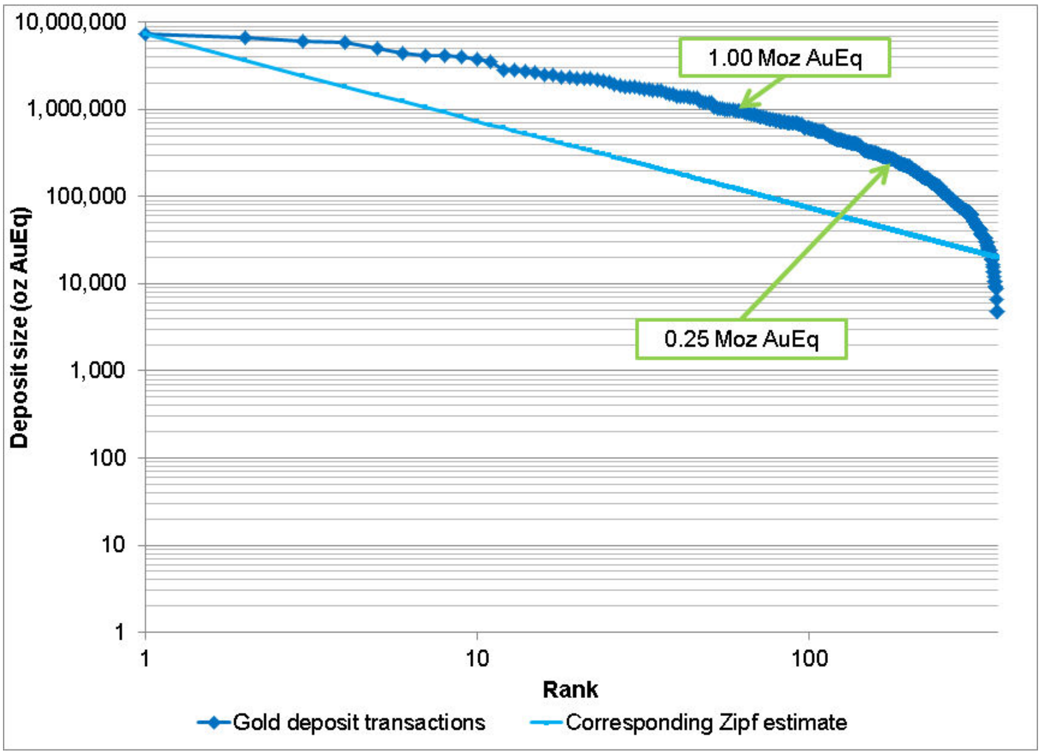


Figure 22. Deposit transaction size vs. hypothetical Zipf distribution

4.2 Ownership risk

4.2.1 Background

This section tests the hypothesis that on a dollar per ounce basis ($/oz), the price of a gold deposit does not always increase with increased ownership by a single party. Ownership premia and discounts are a key factor in mineral asset pricing, as exploration and mining are capital-intensive activities with high risk-reward trade-offs that promote risk diversification through 'joint ventures' (Guj 2011). The literature considers that smaller parcels of ownership attract discounts. Harper and Lindquist (1983) and (Hall 1989) discuss minority share prices in closely held corporations, Webb (1999) characterises minority discounts in the real estate sector and Wampler and Ayler (1998) state that minority discounts are applied to mineral deposit transactions.

The most common industry method for adjusting partial acquisitions, previously shown in [Equation 1] but represented, is the formula shown in [Equation 2] after Lawrence (2012b), Mazzoni et al. (2010) and Ulrich et al. (2012). However, this formula does not convey a premium or discount that may be associated with various levels of ownership, as the key term of D/100% (incorrectly written as 100%/D) simply scales the transaction terms up to a 100% equivalence. For example, using the terms of a 10% equity interest, a full acquisition is scaled to 100% by simply multiplying it by a factor of 10. Given the significant regulatory and taxation differences, as well as the strategic considerations associated with partial acquisition, this commonly used industry formula does not appear to reflect asset value and is a source of error in pricing estimates.

[Equation 2]

$$V_{100} = \frac{100\%}{D}\left[CP + \left(CE * \frac{1}{(1+I)^t}\right) + \left(EE * \frac{1}{(1+I)^t} * P\right)\right]$$

Where:
V_{100} = Value of 100% equity equivalent for a project ($)
CP = Cash equivalent of initial cash and securities ($)
D = Base equity of the incoming party (%)
CE = Cash equivalent of the future consideration (cash, scrip, expenditure)($)
EE = Optional consideration for an additional ownership increment ($)
I = Discount rate (% per annum)
t = term of the stage (years)
P = Probabilty that the stage option will be exercised (%)

(after Mazzoni et al. 2010)

Alternatively, the premia and discounts associated with varying levels of ownership are documented by commercial firms such as MergerStat (Jordan and Hoppe 2008) and may take the form of the Barclay-Holderness scheme (Barclay and Holderness 1989). The Barclay-Holderness method implies that premia increase incrementally with increasing levels of ownership. However, there are significant differences between publicly traded securities and the tightly held ownership structures that may apply to mineral assets (Bernado and Welch 2004; Amihud and Mendelson 1986; Yiu et al. 2006; Schaub and Schmid 2013).

Research shows that partial acquisitions convey significant value (Kogut 1991; Brouthers et al. 2009). This is because a partial acquisition can be viewed as a call option that limits the downside risk while giving managers the benefit of positive developments (Lukas 2013), the ability to learn (Habib and Mella-Barral 2007), and the benefit of peer review and regulation (Madajewicz 2011). This is at odds with both [Equation 2] and the Barclay-Holderness type models but is consistent with Chu (2012), who states that control premia and minority discount determinations are complex processes that are often confused and subject to a poor level of understanding. Consequently, there is uncertainty within the literature both academic and industry, as to how the price of a gold deposit changes with various levels of ownership. Given that close to half of the identified gold transactions used in this study involve less than 100% ownership interest (Section 4.2.2) and only 20% concern 'minority' transactions, there is substantial commercial importance in understanding the price behaviour of partial acquisitions.

4.2.2 Ownership block models

The dataset that underpins the following block model comprises 316 asset transactions sourced from Alexander Research's global mining mergers and acquisitions database. A review of this database determined that the median acquisition was for a 76% interest. The database also shows that 75% of the transactions included staged (incremental options) structures, with the most commonly staged transactions being for 51% ownership, followed by positions of 70% and 75%. Based on the distribution of the entire dataset, the equity domains are:

- **absolute** – 100% equity interest (168 transactions or 53% of the dataset)
- **overwhelming** – 70.0% to 99.9% (53 transactions or 17%)
- **majority** – 50.0% to 69.9% (35 transactions or 11%)
- **minority** – 0% to 49.9% (60 transactions or 19%).

The basis for the size and grade domains is based on a review of the available literature and the datasets that underpin this thesis (for further detail, refer to section 4.1.3 on page 75). The simplicity of a 3 x 3 domains for size and grade helps to reduce variances associated with different estimation techniques, and maintain a focus on overall market behaviour (i.e. point estimates are not relevant to this thesis). While fixed domains are used in this study for discussion purposes, a market block model can be analysed at any point or through any plane in three-dimensional space. This flexibility of the block model allows the user to choose subdivisions that are fit for purpose.

4.2.2.1 Base-case

Based on the discussion outlined in the preceding sections, a CPI-adjusted sales price block model was created where the prices are inflated into USD terms as at 31 December 2009. The 100% equity domain for the resulting block model along with the implied total acquisition costs are shown in Table 11.

Table 11. CPI block model prices using 100% equity transactions

Grade (g/t Au)		100% Equity acquisitions unit prices ($)			Implied magnitude of transactions (millions) ($)		
High	>6	37	23	29	5	14	29
Medium	3-6	25	19	30	3	12	30
Low	<3	15	13	16	2	8	16
Size		<0.25	0.25-1.00	>1.00	0.125	0.68	1.00
(Moz Au)		Small	Medium	Large	Small	Medium	Large

The 168 transactions that underpin Table 11 show that unit prices generally increase with grade (vertically within the table). This is an expected result, as there is a higher probability of economic viability associated with increases in grade (Rockerbie 1999). On a $/oz basis, small deposits are more expensive than their medium-sized equivalents. This may imply that the magnitude of the transaction size affects the number of market participants who can compete to purchase the asset, and a possible expectation that with additional drilling a small deposit may grow (i.e. they have higher option value). From here on in, this is dubbed the “small deposit effect”. This small deposit effect is like the value of open-space increasing with population density (i.e. parks are more valuable where there is high-density housing) (Brander and Koetse, 2011)

To highlight the premia rather than absolute prices determined by the block model, Table 12 uses the block prices of all partial transactions relative to the 100% slice, due to it being the most populous area within the model, and presents a logical sequence of premia as the equity interest decreases. Furthermore, while the absolute prices in Table 11 provide an interesting snapshot in time, their commercial and academic relevance rapidly become dated due to changing market conditions. Therefore, a more resilient way of analysing the data is to look at the proportional relationship between each of the block prices.

Table 12. Ownership premia factors for all partial acquisitions relative to 100% equivalents

Grade (g/t Au)		Partial acquisition factors (<100% - 0%)		
High	>6	1.57	1.64	1.54
Medium	3-6	2.12	1.29	1.00*
Low	<3	1.34	1.44	1.24
Size (Moz Au)		<0.25	0.25-1.00	>1.00
		Small	Medium	Large

*no underlying data points

An analysis of Table 12 suggests there are across-the-board premia payable for partial acquisitions over outright acquisitions (i.e. a small high-grade deposit is likely to achieve a price 1.57 times higher through a partial transaction rather than 100% transaction). This is due to partial acquisitions conveying additional value (Park and Kim 1997; Kogut 1991; Kent 1991; Reuer and Ragozzino 2012; Balakrishnan and Koza 1993; Hennart and Reddy 1997), and therefore, the acquiring party is prepared to pay a premium, which is consistent with Chi (2000). Alternatively, the vendor may place a premium on ceding control as it may place them at the mercy of the incoming party, while the acquirer may view the willingness to maintain an interest in the deposit as a sign of good faith and confidence in the asset. Regardless of the motivation and circumstances in any particular transaction, the consistent and substantial premiums observed confirm that the market attributes option value to joint ventures (Lukas 2013), and that increased liquidity (as represented by the deposit size) positively affects price (Bernado and Welch 2004; Amihud and Mendelson 1986; Yiu et al. 2006; Schaub and Schmid 2013).

While there are consistent and substantial premia paid for partial acquisitions, the patterns within Table 12 appear to be somewhat random. To increase clarity and resolution, partial acquisitions have been segregated into overwhelming, majority and minority intervals as shown in Table 13 and Figure 23.

Table 13. Ownership for partial acquisitions using overwhelming/majority/minority

Grade (g/t Au)		Overwhelming (<100% - 70%)			Majority (<70% - 50%)			Minority (<50%)		
High	>6	1.20	1.26	1.29	1.69	1.72	1.81	1.81	1.93	1.51
Medium	3-6	1.36	1.25	1.08*	2.55	1.35	1.04*	2.45	1.26	0.89
Low	<3	1.11	1.34	1.15	1.42	1.58	1.33*	1.48	1.41	1.24
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

*no underlying data points

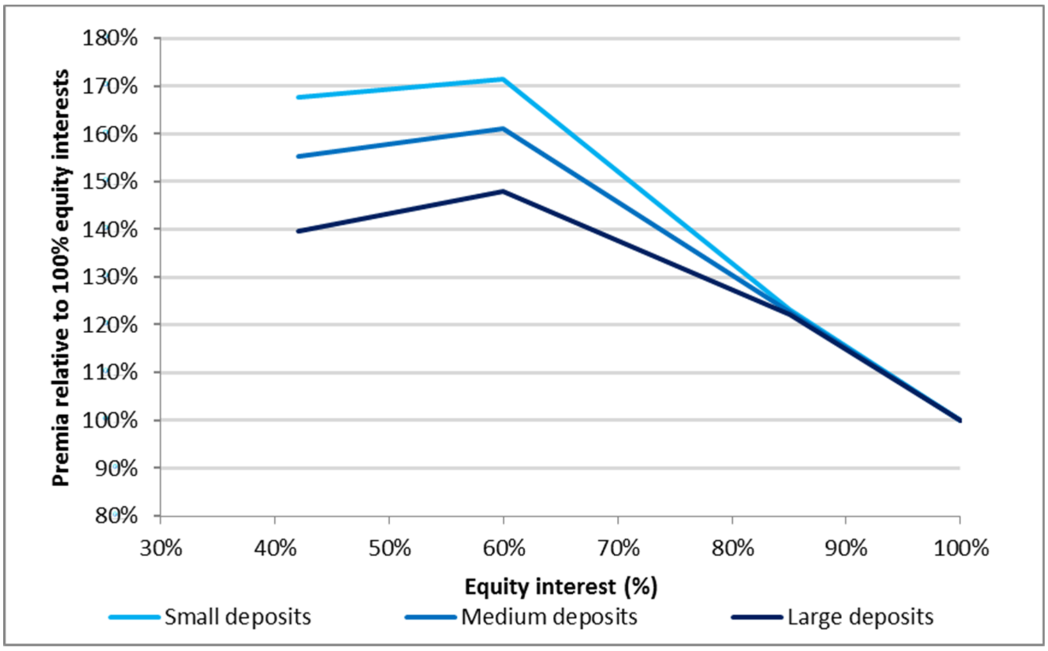


Figure 23. Ownership factors for partial acquisitions

An analysis of Table 13 suggests that there are liquidity issues relating to partial acquisitions, as three blocks have no underlying data points. Extrapolations of the trends in the entire dataset are used to estimate prices for these blocks. As a result, caution must be exercised in interpreting the results. While not ideal, this demonstrates the advantage of using geostatistical estimation techniques over matrices of medians where the three blocks would be excluded from the analysis. Regardless, an attempt to analyse the macro-patterns in Table 13 suggests that:

- Irrespective of the size or grade of the deposit, the cheapest unit prices involve those transactions using 100% equity. Absolute control appears to generate a discount possibly due to reduced liquidity from the larger capital investment required, potentially reducing the number of market participants and thereby being consistent with Angel (1997) and Maloney and Mulherin (1992). An overwhelming interest may attract a ~20% premium over an outright sale (i.e. a factor of 1.2 times more expensive); a majority interest a 60% premium; and a minority interest a premium of 55% compared to an outright acquisition.
- For small deposits, a relative premium of 10% to 40% (factors of 1.1 to 1.4 relative to the 100% equivalent price) is payable for overwhelming control; 40% to 70% for majority control; and 50% to 150% for minority interests. The small deposit blocks suggest there is a general decrease in the premium as equity progresses from minority to overwhelming stakes. This could be a

function of increased market liquidity for transactions with smaller capital requirements.

- For medium size deposits, a relative premium of 20% to 40% is payable for overwhelming control; 30% to 70% for majority control; and 20% to 100% for minority interests. The medium size deposits also suggest that the highest premia are generally associated with minority stakes.
- For large deposits a relative premium of 10% to 30% is payable for overwhelming control; 0% to 80% for majority control; and -10% to 50% for minority interests.

It appears that liquidity and the influence of risk-sharing synergies are key price drivers in determining the appropriate premium for gold deposit acquisitions. Small deposits are relatively liquid because of the small capital outlay (especially for partial acquisitions), and it appears that the acquiring party is willing to pay a premium to share the risk that the deposit may never reach a critical mass to be economically viable. Conversely, the significant capital required for partial acquisitions of large deposits appears to result in a reduction in market competition; and the increased economic potential due to critical mass reflects the reduction of synergies. The presence of a discount for a minority interest in a large deposit may be a function of insufficient data density in this category of transaction (one underlying data point), and it is possible that the smaller deposits and levels of equity acquisition may be over-represented in the database.

4.2.2.2 Non-staged transactions

In contrast with securities, the ownership of a mineral asset can be gained through a staged, contractual acquisition process, referred to as a ‘farm-in’. For example, an acquirer may have the option to sequentially obtain a 25%, 51%, or 75% interest in a project by meeting certain conditions (often minimum expenditure commitments or technical hurdles). It is hypothesised that the option, without an obligation, to sequentially acquire portions of a project may attract a market premium above that paid in static transactions due to risk spreading and cost reduction (Kogut 1991; Guj 2011). To test this hypothesis, a block model using CPI-adjusted unit prices was created from a dataset that excludes staged acquisitions that convey option value (Guj 2011), which represents 20% of the total dataset (Table 14).

Table 14. Non-staged block model price factors relative to the entire database

Grade (g/t Au)		Overwhelming (<100% - 70%)			Majority (<70% - 50%)			Minority (<50%)		
High	>6	0.67	1.00	1.03	0.65	1.07	1.02	0.75	1.07	1.21
Medium	3-6	0.72	1.02	1.03	0.62	1.15	1.23	0.71	1.28	1.21
Low	<3	0.93	0.78	0.88	0.83	0.74	0.90	0.88	0.89	1.00
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

The removal of the staged transactions results in the prices observed within the block model falling by around 5%. However, much of the decrease in price is associated with small and low-grade ('***inferior***') deposits across all ownership brackets. This suggests that the right, but not the obligation, to farm into possibly sub-economic deposits attracts a significant premium given the inherant uncertainty, and the volatility in the market price of gold. This is expected given that, just like financial derivatives, real options have a tangible price that is a function of the value of the underlying asset, which is reflected in the sales price of a gold deposit. Such options convey value and price increases because the acquirer can neutralise risk by limiting losses should future events (technical or financial) be unfavourable while retaining the upside potential. For deposits of at least medium size, with medium-grade ('***superior***'), the analysis shows that non-staged transactions are slightly more expensive, possibly as a reflection of the eagerness of the acquiring party to gain exposure to an asset with good fundamentals providing a reasonable likelihood of economic viability.

The premia of non-staged gold deposit transactions are shown in Table 15 and Figure 24. In this table, a simplified format using inferior (small and low-grade) and superior (at least medium size and grade) classifications are used to illustrate the market behaviour in a more clear and concise manner.

Table 15. Non-staged ownership premia

Ownership brackets		Premia: entire dataset			Premia: non-staged		
Overwhelming	100%-70%	1.23	1.23	1.23	1.06	1.13	1.21
Majority	70%-50%	1.72	1.61	1.48	1.36	1.46	1.59
Minority	<50%	1.68	1.56	1.40	1.51	1.55	1.60
Category		Inferior	All	Superior	Inferior	All	Superior

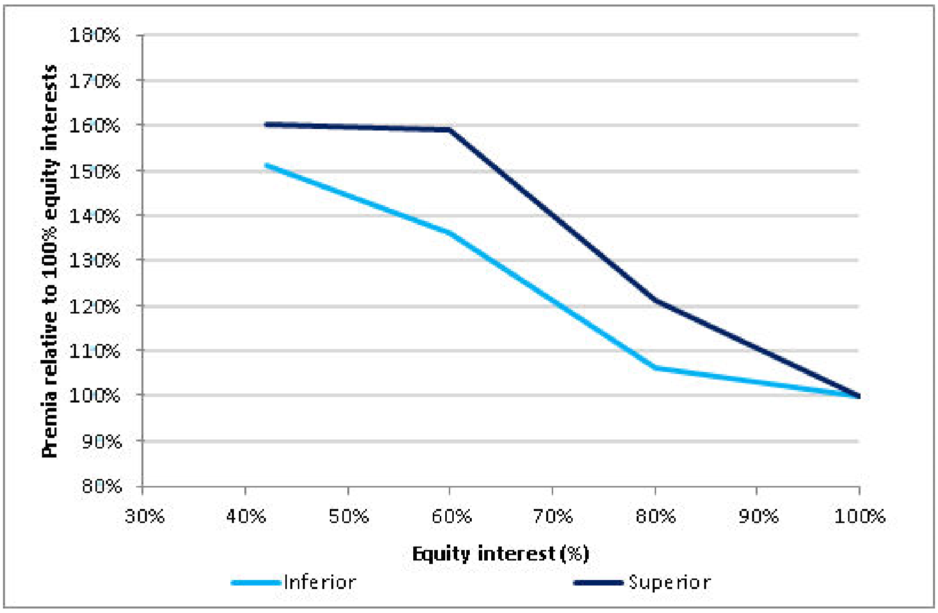


Figure 24. Ownership premia for using non-staged transactions

Compared to the original premia identified in Table 13, this analysis shows that the premia are higher for superior deposits compared to inferior ones, where static deal structures are concerned (the converse is true for the dataset including staged transactions). Non-staged superior deposit transactions are not only more expensive, but the premia for partial interests are also higher.

The removal of the staged transactions decreased the number of data points by 20% but had a significant impact on the model behaviour both regarding sales price and relative premia. There is justification for applying this separation to most commercial applications. On this basis, the following sections provide analyses using both the entire dataset and the non-staged data subset.

4.2.2.3 Cash and scrip

In the preceding sections, all price (cash equivalents) and cost (future burden) financial consideration components are used in the calculation of the implied price. However, while expenditure commitments are a financial burden on the acquiring party, both parties may benefit from them. In this section, the transactions containing real option value associated with exploration expenditure commitments (Guj 2011) are excluded from the models. This resulted in about one-third (107) of the transactions being removed from the dataset. The model, relative to the original prices in Table 13 is shown in Table 16.

Table 16. Cash and scrip block model prices relative to the entire dataset equivalent

Ownership brackets		Relative prices		
Absolute	100%	1.06	1.07	1.09
Overwhelming	100%-70%	1.11	1.01	1.10
Majority	70%-50%	1.02	1.02	1.02
Minority	<50%	1.01	1.05	1.08
Category		Inferior	All	Superior

The effect of removing transactions involving expenditure commitments resulted in generally higher prices. This is surprising, as intuitively, it would be expected that terms such as expenditure commitments would lead to higher prices. This suggests that vendors prefer exposure to future expenditure commitments that may result in capital asset growth compared to an outright cash and scrip sale (i.e. it is better to have a smaller slice of a large pie tomorrow than a large slice of a small pie today). For the acquiring party, the motivation is that they do not have to free-carry the vendor who, in a cash and scrip only transaction, is required to contribute pro-rata to ongoing expenditure commitments. Alternatively, the willingness to use upfront payments instead of deferred expenditure commitments may reflect the acquirer's confidence in the quality of the gold deposit being purchased. This creates an interesting interplay between the influence of staged acquisitions and firm expenditure commitments (although the two are not mutually exclusive). The analysis shows that a staged acquisition will add to the implied price of inferior deposits, possibly due to option value, while the inclusion of expenditure commitments results in a decrease in the implied price as there may be an anticipation of capital growth.

Having analysed the impact on absolute prices, Table 17 and Figure 25 show that the effect of removing exploration expenditure affects the implied ownership premium. The premia generally increase relative to the entire dataset. This suggests that vendors prefer exposure to a possible capital (asset) gain and may accept a cheaper unit price as well as reduced ownership premia to receive it.

Table 17. Cash and scrip ownership premia factors

Ownership brackets		Premia: entire dataset			Premia: cash and scrip		
Overwhelming	100%-70%	1.23	1.23	1.23	1.29	1.27	1.23
Majority	70%-50%	1.72	1.61	1.48	1.65	1.52	1.37
Minority	<50%	1.68	1.56	1.40	1.62	1.51	1.38
Category		Inferior	All	Superior	Inferior	All	Superior

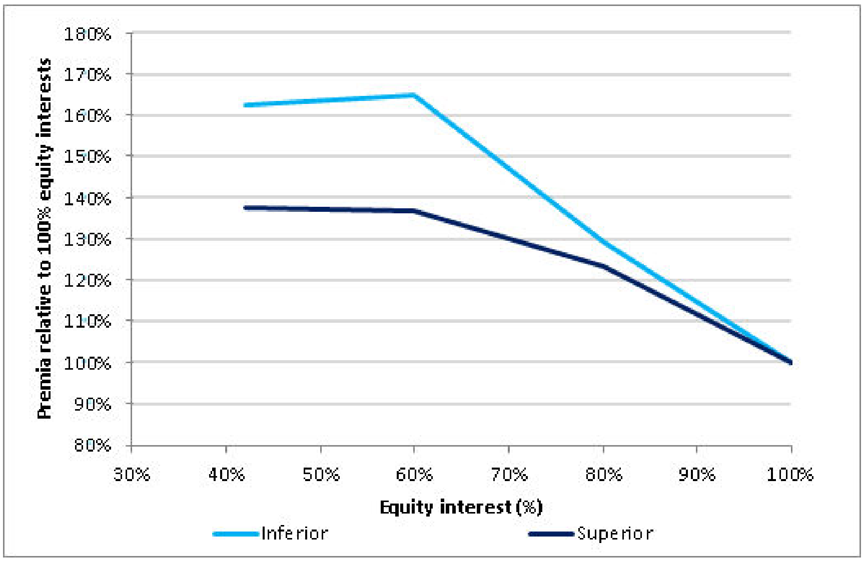


Figure 25. Ownership premia for using cash and script transactions

4.2.2.4 Pre- and post-June 2007

To test the influence of changing market conditions before and after June 2007 (as discussed in Section 4.1.1), two block models were generated. The start of June represents the start of summer in the northern hemisphere where ~87.5% of the global human population resides (Kummu and Varis, 2011). According to Baur (2013), the gold price undergoes a statistically signficant period of volatility in Autumn, consequently having data on either side of this volatilty period was selected for this research. The first block model uses 105 (33% of the dataset) transactions that occurred before 01 June 2007, and the second block model uses 211 (67%) transactions occurring on or after 01 June 2007. In both these time intervals, the proportion of projects amenable to open-pit mining techniques was in the range of 50% to 60%. While there are differences between the two models, the results are comparable given that smaller data subsets are used.

The base-case analyses (Table 18, Table 19, Table 20 and Figure 26) set out the market behaviour using the combined dataset of transactions occurring both before and after 01 June 2007.

Table 18. Post-June 2007, 100% equity price factors relative to pre-June

Ownership brackets		Relative price		
Absolute	100%	0.98	0.89	0.77
Overwhelming	100%-70%	1.25	1.14	1.01
Majority	70%-50%	1.95	1.76	1.5
Minority	<50%	2.08	1.79	1.43
Category		Inferior	All	Superior

Table 19. Ownership premia of pre-June 2007 transactions relative to absolute acquisitions

Ownership brackets		Premia		
Overwhelming	100%-70%	1.03	1.01	0.99
Majority	70%-50%	0.98	0.94	0.89
Minority	<50%	0.92	0.88	0.84
Category		Inferior	All	Superior

Table 20. Ownership premia of post-June 2007 transactions relative to absolute acquisitions

Ownership brackets		Premia		
Overwhelming	100%-70%	1.30	1.30	1.32
Majority	70%-50%	1.98	1.90	1.80
Minority	<50%	1.95	1.79	1.59
Category		Inferior	All	Superior

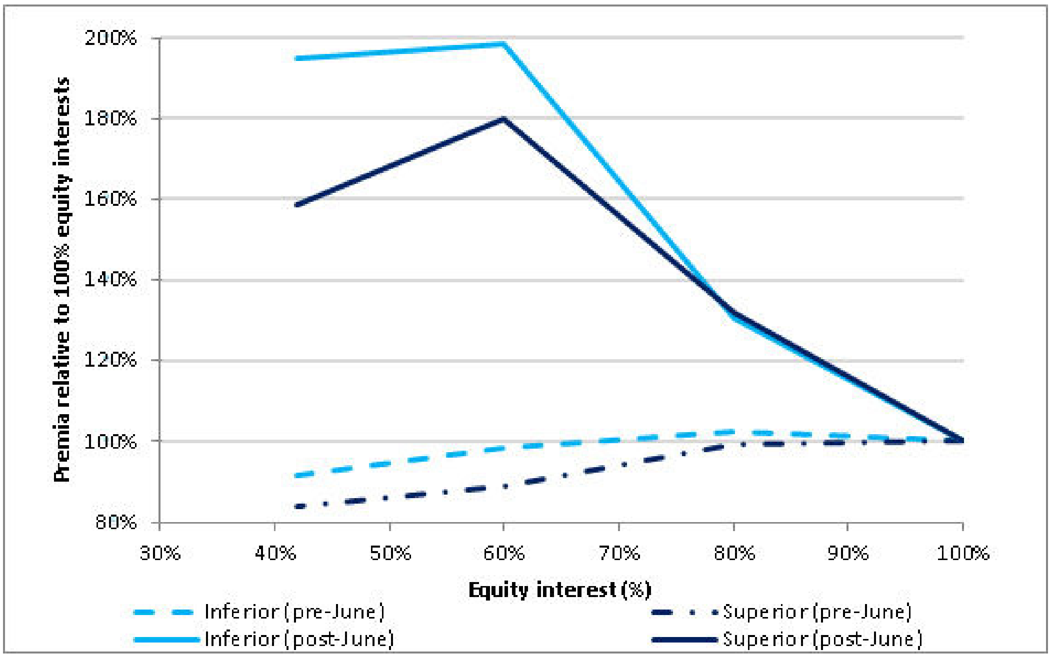


Figure 26. Ownership premia pre and post-June 2007

The following observations are made:

- **Prices of the post-June 2007 subset** – partial acquisitions were increasingly more expensive with decreased equity participation, and absolute acquisitions were cheaper than those in the pre-June 2007 subset.
- **Premia of the pre-June 2007 subset** – discounts were generally applicable to acquisitions. Also, inferior deposits attracted higher discounts than those of superior deposits.

- **Premia of post-June 2007 subset** – all partial acquisitions incurred a significant jump in premia over the 100% equity acquisitions. It appears that many of the acquisitions may have achieved the optimal balance between capital investment requirements and ownership benefits under the prevailing economic conditions.

The switch from predominantly discounts for less than 100% control to premia for partial acquisitions across the two time periods is quite distinct. The dominance of discounting in the pre-June 2007 subset suggests that in a global risk tolerant markets, where the gold price has a comparatively low level of volatility, the market favourably views increased equity interests because of the value benefits of control (Le and Jorma 2009). In contrast, the post-June 2007 subset suggests that the market is risk-averse: the ability to share risk and gain a lower entry price makes such transactions more appealing in a market where capital raising is constrained. This suggests that time and circumstance specific analyses are more appropriate than the 'whole of cycle' study presented in the preceding section, which is consistent with Canina et al. (2013).

4.2.2.5 Near-surface and deep deposits

To account for the cost and risk differences that exist between near-surface and underground deposits, two sub-models were generated. The classification of a near-surface deposit is based on those that are stated to, or are reasonably expected to be mined using open-pit mining methods. The first model uses only near-surface deposits that may be amenable to open-pit operations, while the second sub-model uses transactions involving deeper mineralisation likely to be mined using underground methods. The relationship between the two sub-models is shown in Table 21 and Table 22.

Table 21. Deep deposit factors relative to near-surface equivalents using 100% equity transactions

Grade (g/t Au)		100% equity acquisitions		
High	>6	2.34	1.74	1.65
Medium	3-6	2.07	1.54	1.53
Low	<3	1.20	1.05	1.26
Size		<0.25	0.25-1.00	>1.00
(Moz Au)		Small	Medium	Large

Table 22. Deep deposit factors relative to near-surface equivalents using all transactions

Grade (g/t Au)		Overwhelming (<100% - 70%)			Majority (<70% - 50%)			Minority (<50%)		
High	>6	2.58	1.93	2.02	3.16	2.05	2.37	3.68	2.40	2.39
Medium	3-6	2.25	1.24	1.68	3.36	1.88	2.57	4.53	3.23	2.97
Low	<3	1.38	0.89	1.08	2.03	1.14	0.95	3.17	1.75	1.48
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

The deposits that are likely to be amenable to underground exploitation are more expensive to buy than those near the surface, with the difference becoming more marked with increased grade (vertically within Table 21). It is hypothesised that the strong and consistently higher sales prices for deposits with presumably higher capital and operating costs are due to the expectation of future exploration success; more flexible mine designs; or, the construction cost associated with underground mines is more likely to have an optimistic bias (Bertisen and Davis 2008). As such, it is possible that the value of underground deposits may be overstated.

The ownership premia for the partial acquisition of near-surface and deep deposits relative to their 100% equity equivalents are shown in Table 23, Table 24 and visually in Figure 27. Rather than using the inferior/superior groupings, the most consistent premia are associated with the size of the deposit, perhaps as a reflection of requisite critical mass, or that underground deposits usually have higher grades.

Table 23. Ownership premia factors for near-surface deposits relative to absolute transactions

Ownership brackets		Premia		
Overwhelming	100%-70%	1.11	1.29	1.09
Majority	70%-50%	1.21	1.50	1.15
Minority	<50%	1.08	1.27	1.04
Category		Small	Medium	Large

Table 24. Ownership premia factors for deep deposits relative to absolute transactions

Ownership brackets		Premia		
Overwhelming	100%-70%	1.24	1.17	1.14
Majority	70%-50%	1.89	1.75	1.40
Minority	<50%	2.27	2.13	2.51
Category		Small	Medium	Large

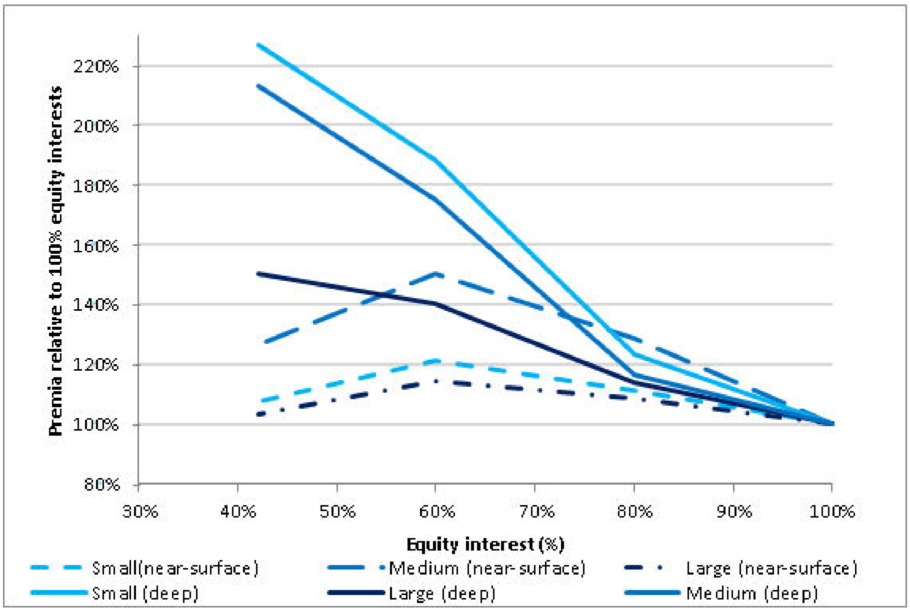


Figure 27. Ownership premia for near surface and deep deposits

The analysis of the sub-models presented in Table 23 and Table 24 show that:

- Premia associated with near-surface deposits are consistently higher for medium-sized deposits, followed by small deposits and then large deposits.
- Deep deposit premia are highest in the small grouping, with the premia decreasing with increasing size. As there is additional risk associated with deep deposits (Bertisen and Davis 2008), the partial sales may have attracted higher premia as a reflection of the risk sharing option value that is consistent with Park and Kim (1997).

In both near-surface and deep deposit transactions, the large deposits attracted the lowest premia. This is a function of both groupings having reached a critical de-risking threshold that diminishes the benefits of shared ownership. The preference for medium-sized near surface deposits suggests that partial sales achieved the optimal balance between exploration potential, the magnitude of the requisite exploration expenditure, and the broad market appeal within the medium-sized group.

4.2.2.6 Other sub-analysis

Additional ownership block models were generated and analysed (Appendix 8). These models used data subsets concerned with:

- making adjustments to the prevailing gold price (yardstick adjustments) at the time of transaction
- comparing staged/non-staged, with pre- and post-June 2007

- modelling the between cash and scrip consideration with pre and post-June 2007comparisions
- segregating deep deposits from their near-surface equivalents.

As commodity price differences for these datasets are examined in Section 4.3, their use for analysing ownership risk is not discussed here. However, the commodity price risk observations from the sub-analyses are consistent with those noted in other investigations. Similarly, the sub-analyses models contained within Appendix 8 show results that are consistent with those outlined in the section above.

4.2.3 Discussion on the ownership premia investigations

The block models analysed in this study show that the ownership premia payable for a gold deposit are dependent on market conditions. In the pre-June 2007 data, it is apparent that the $/oz prices increase with increased equity exposure; however, after this time the market strongly favours partial transactions over 100% exposure to an asset. This observation confirms the hypothesis that the market price does not necessarily increase with increased equity exposure. This is because there are numerous aspects that impact the premium paid in a mineral asset transaction, such as expenditure commitments, which may vary with the prevailing circumstance. These results are consistent with the multitude of influences on real estate price (Bunaeur et al. 2013). In dealing with partial acquisitions, premia appear to be influenced by financial, security, and commodity markets; the size of the required capital outlay; deal structure (particularly for deep deposits); composition of the consideration; and technical risk. As there are multiple price drivers involved in any market method, it is often difficult to disassociate drivers such as ownership premia. This study is no exception.

The block models developed from the 316 recorded gold project transactions suggest that:

- In partial acquisitions, the market is efficient in most cases in attributing higher unit prices with an increasing size-grade combination. The determination of unit sales prices (e.g. $/oz Au terms) appears to work well in each of the models as they increase with size and grade, as would be expected.

- The number of market participants is a major influence on price. Like Brander and Koetse (2011), who observed that parks are more valuable when closer to high-density populations, it appears that small deposits are accessible to many market participants, which may be contributing to their higher unit prices. This is because liquidity is an important positive influence on price (Roll and Subrahmanyam 2010) and liquidity increases when the capital outlay is optimised for smaller investors (Maloney and Mulherin 1992).
- If equity is gained through a staged transaction, a substantial premium is payable, particularly with riskier assets. This is consistent with the findings of Brouthers and Dikova (2010) and Anand and Delios (2002). Staged transactions convey the right but not the obligation to sequentially acquire increasing equity interests in a project. In effect, they are priced as including call options.
- In times of economic uncertainty, the risk-sharing benefits and lower capital requirements for partial acquisitions result in substantial premia. As mining is an inherently uncertain activity, the risk-sharing quality of transactions for partial ownership and those having proportionally lower capital outlay appear to make them the preferred deal structure. As partial acquisitions convey benefits due to the pooling of assets, risk reduction, information sharing (Broll and Marjit 2005), cultural leverage, and adversarial considerations (Kent 1991), they appear to be particularly favoured in constrained capital markets, thereby satisfying a desire for exposure to safe haven investments such as gold (Reboredo 2013), without the related full expense.

This last point confirms the hypothesis that increasing the ownership level in a transaction does not necessarily translate to an increase in the $/oz unit price**.** This finding is important as is it calls into question the use of stock market derived premia in estimating gold deposit prices, such as those published by MergerStat (Jordan and Hoppe 2008), Barclay-Holderness rules of thumb (Barclay and Holderness 1989), and Equation 2. Instead, it shows that the partial acquisition premium identified by Lukas (2013) holds true, depending on the prevailing circumstances. As such, it is not possible to have a whole-of-cycle rule-of-thumb that can be used to take ownership premia into account when pricing a gold deposit. This finding is important given the prevalent industry use of Equation 2 and the magnitude of the transactions to which they relate.

4.3 Commodity price risk

4.3.1 Background

This section investigates the hypothesis that the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction through disproportionate movements. The prevailing gold price in the market is a key revenue driver in the gold mining sector and influences the prices of gold mine securities (Blose and Shieh 1995; Jaffe 1989) and gold deposits (Wellmer et al. 2010). A low market price for gold is the principal cause for mine closure (Moel and Tufano 2002). However, despite being a prominent input in the decision-making process for both the vending and acquiring parties, the relationship between the market price of gold and the deposit price (the "*price-price relationship*") is not well understood. As it is a highly visible and contentious item in the process of determining a transaction price, this section presents empirical evidence into the price-price relationship to test the validity of the commonly used Yardstick method.

It is common industry practice to consider the metal price by expressing transactions as a percentage of the prevailing gold price (the Yardstick method). The underlying assumption is that the market attributes a consistent, linear, proportional price to deposits relative to the commodity price. This method is appealing in its simplicity, as most heuristic methods are (Kruglanski and Aizen 1983), but does not appear to have an empirical basis. For example, in defence of its Yardstick method used in the takeover of Dioro Mining NL, Coffey Mining Pty Ltd quoted five example transactions, one of which was more than six years old (Spicer 2009). Such a limited body of evidence, in what was a vigorous takeover defence does little to suggest that there was an empirical basis to support the validity of the method. Unfortunately, many industry examples of the application of the Yardstick method go unsupported by empirical evidence (e.g. Stephens 2008; Dunham et al. 2012).

Some factors that undermine the Yardstick method include:

- In the absence of expansionary monetary policy (Białkowski et al. 2014), the gold price is often considered to be a measure of fear (Cohen and Qadan 2010; Qadan and Yagil 2012) and a hedge against falls in the US dollar (Reboredo 2013). When the markets are fearful, it is reasonable to expect that investors will avoid higher risk asset classes (Dewally and Shao 2014) such as mining and exploration.

- A high gold price is indicative of limited capital supplies (Martel and Kravchuk 2012), thereby putting downward pressure on demand and limiting the ability to fund acquisitions.
- Established mining projects have high fixed costs (Sabour 2002; Davis 1995). Consequently, as the metal price increases, the profit margin is disproportionately leveraged.
- Higher gold prices may make lower-grade mineralisation economically viable (Craig and Rimstidt 1998), potentially increasing the reserves base and lowering the unit price.
- The gold price is influenced by a multitude of factors (Lili and Chengmei 2013); however, it is not the only variable that may affect the deposit price. The reality is that there are multiple price drivers, each of which may take precedence at various times and under different circumstances.

Given the financial magnitude of deposit transactions and the risk posed by mispricing them, there is a need to question the validity of the linear assumption that the Yardstick method is built upon. In assessing the price relationship of a deposit with the gold price in the market, this section uses the block model analysis described in Section 3. This method spatially distributes gold deposit transactions based on their size, grade, the spot gold price at the time of the transaction, and the transacted unit price ($/oz). Also, Appendix 9 contains a two-dimensional analysis where unit prices are plotted against the prevailing gold price. While this representation does not allow for the differentiation of the important size and grade drivers of a transaction, it does replicate industry practice and provides support for the conclusions of the three-dimensional analysis.

4.3.2 Gold-price adjusted block models

For slicing the block model along the Z-axis, the intervals of $700/oz Au and $1,000/oz Au were used. During the study period, gold prices below $700/oz Au generally occurred before the onset of the US housing crisis in 2007, which culminated in the GFC in 2008. Gold prices above $1,000/oz occurred after late 2009 when the growth trajectory increased significantly.

The result is:

- **low gold environment** - 79 transactions (26% of the dataset)
- **medium gold environment** - 104 transactions (28%)
- **high gold environment** - 168 transactions (46%).

4.3.2.1 Base-case

In an ideal situation, all data points would be a function of similar factors, and there would be minimal distorting effects from variables outside the scope of the analysis. However, deposits transact on a relatively infrequent basis, and there is a high degree of variability in the circumstances surrounding both the deposits and the transactions. These factors result in the datasets also being variable. While the temptation is to cull the datasets so that they contain only similar deposits/circumstances (e.g. only 100% equity, near-surface deposits that have not been subject to detailed economic studies, etc.), such processes may reduce the available information to a fraction of the original dataset and weaken its statistical significance. As a first pass in this study, a block model was generated that used all the available information and relied on the assumption that variability is evenly distributed across the size-grade-price space. This allows the ordinary kriging estimation technique to account for distortions that are difficult to address using simple statistical or heuristic analyses. The average block model price results of this first-pass are shown in Table 25, and the associated unit price appreciation factors presented in Table 26.

Table 25. Gold-price block model unit prices using all available transactions

Grade (g/t Au)		Low gold environment (<$700/oz Au)			Medium gold environment ($700-1,000/oz Au)			High gold environment (>$1,000/oz Au)		
High	>6	41	29	45	51	39	67	92	48	51
Medium	3-6	28	17	36	41	24	49	98	34	48
Low	<3	20	12	17	26	15	28	75	23	43
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

Table 26. Gold price appreciation factors using all available transactions

Grade (g/t Au)		Low-medium gold price comparison (<$700 vs $700-1,000 oz brackets)			Low-high gold price comparison (<$700-1,000 vs >1,000 oz brackets)		
High	>6	1.23	1.37	1.50	2.24	1.69	1.15
Medium	3-6	1.47	1.44	1.38	3.50	2.02	1.33
Low	<3	1.29	1.25	1.63	3.73	1.95	2.49
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large

The unit price patterns in Table 25 are vertically consistent, with general increases for a higher grade. There is a minor aberration in the high gold price environment where there is a strong decrease in the unit price ($75-$98-$92); however, because of the sample size and the marginality of the difference (6%), this is considered to be a reflection of noisy data rather than a market trend/behaviour.

A common feature amongst all gold deposit block models is the small deposit effect, which was discussed in Section 4.2.2. Figure 28 shows its expression in the commodity price risk dataset where, for example, the premium of a small deposit over a medium deposit in the low and medium gold prices is approximately 1.6. The small deposit effect refers to the consistent observation of the block models presented in this thesis that small deposits trade at higher unit prices than the larger equivalents, a feature that may be explained by increased liquidity or enthusiasm for an earlier stage project. In this analysis, the effect is strongest in the high gold price environment, as numerous junior corporations compete for deposits so that they can rebrand themselves and have their shares re-rated.

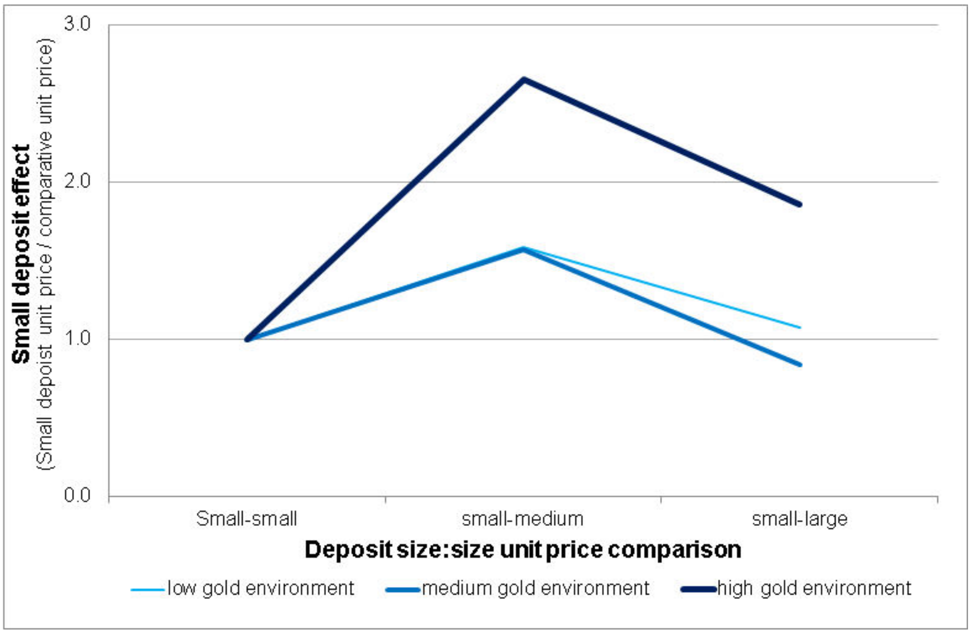


Figure 28. The small deposit unit price multiples over the larger equivalents

While individual unit prices are important for estimating the price of deposit, this section is concerned with behavioural differences in the market rather than discrete individual estimates. On that basis, the unit price appreciation in response to growth in the gold metal price appears to be variable with the gold price rather than fixed (Table 26, Figure 29). Also, the shift between low

(<$700/oz), medium ($700 to 1,000/oz), and high (>$1,000/oz) gold price environments elicits different responses. For example the shift between the low and medium gold price environments, where there is relatively little differentiation between the price appreciation based on either size or grade.

The blocks in Table 26 have an average appreciation factor of around 1.35 to 1.38, compared to the median metal price growth of 1.97 for the underlying data points. This inferior performance of the price-price relationship is due to the medium price environment (September 2007 to September 2009) representing the period when there was significant turbulence in the global financial and securities markets.

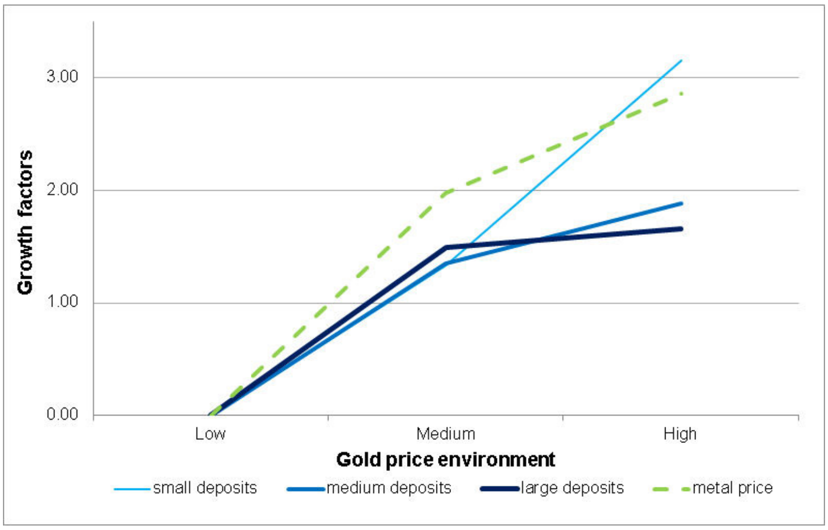


Figure 29. Price appreciation factors using all available transactions based on size

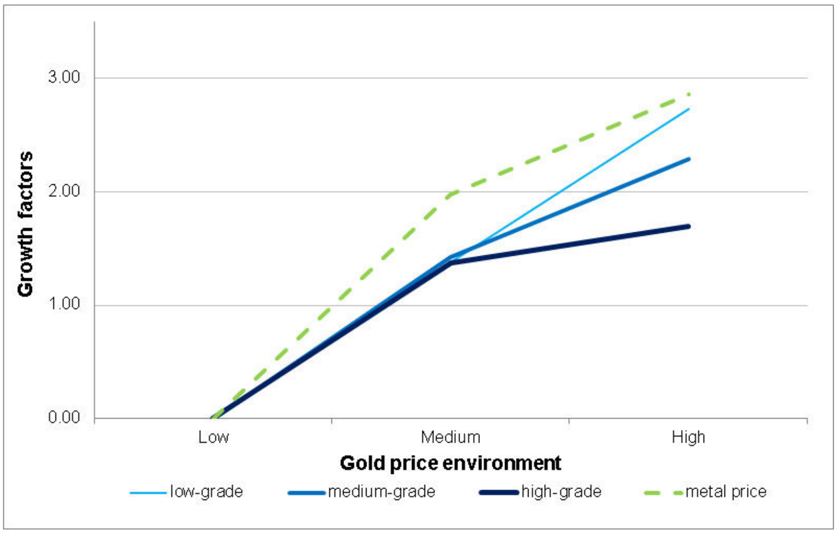


Figure 30. Price appreciation factors using all available transactions based on grade

In comparing the high gold price environments in Figure 29 and Figure 30, the following observations can be made:

- Small deposits outperform their larger equivalents (i.e. 3.13 to 1.89 to 1.66 from small to large). Within the medium gold price environment, all deposit sizes appreciate at similar rates.
- The grade-related price appreciation strongly decreases with increased grade (2.73 to 2.29 to 1.69 from low to high grade). The strengthening of this relationship is due to higher-grade deposits having the potential to be more resilient to fluctuations in the prevailing price of gold in the market, whereas for lower grade deposits, it may mean the difference between an operating loss and profit.
- The average appreciation factor is 1.9 (size) to 2.29 (grade) compared to 2.86 for the gold metal price. This highlights how, despite the robust performance of the small deposits, the medium and large deposits fared poorly in keeping pace with the prevailing metal price. This may be due to larger corporations being conservative in a constrained capital market, whereas small corporations are forced to re-invent themselves into gold deposit owners to remain relevant to market whims.

An important aspect in Figure 29 and Figure 30 is that in a medium gold price environment, the strong market differentiation between small-large and low-high grade deposits is not as pronounced, which may be due to investors being more discerning in high gold price environments. The market differentiation may reflect a fearful market that rewards small projects that may have the ability to be brought into production rapidly at low capital cost. This highlights the importance of considering more than one price driver in analysing market characteristics, and the folly in using overly simplistic methods such as Yardsticks when pricing a deposit.

4.3.2.2 Smoothed dataset

To be consistent with the Yardstick method which assumes deposits transact at a fixed percentage of the prevailing gold price, operating gold mines and transactions priced at over \$100/oz Au were excluded from the dataset. This resulted in a regeneration of the block model using 317 data points. The transactions are not differentiated by their maturity, as this thesis works on the assumption that the effect of any factor not considered in the analysis is evenly distributed throughout the three-dimensional space, and that the ordinary kriging technique considers the natural variability/nugget effect of the data points.

However, for comparison purposes, a block model for the “smoothed” price-price dataset was generated, with the results presented in Table 27.

Table 27. Price appreciation factors using a smoothed dataset

Grade (g/t Au)		Low-medium metal price comparison (<$700 vs $700-1,000 oz brackets)			Low-high metal price comparison (<$700-1,000 vs >1,000 oz brackets)		
High	>6	0.85	1.22	1.25	1.13	1.06	1.39
Medium	3-6	1.13	1.23	1.36	1.66	1.66	2.77
Low	<3	1.32	1.27	1.09	1.71	1.25	2.97
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large

A review of the unit prices that underpin the factors outlined in Table 27 suggests that the unit prices of all the blocks are lower than in the preceding analysis. This is not surprising given that the high prices in the dataset have been truncated. The small deposit effect remains: small deposits have higher unit prices than their medium size equivalents. However, as the highest prices are often associated with small deposits, the effect is less prominent. The prices generally increase horizontally (from medium to large size) and vertically (from low to high grade). However, these changes are not as consistent or logical as those observed in Table 26, which was constructed using all available data points. For example, given a set grade, absolute unit prices are generally lower for large deposits over their medium size equivalents. This observation is likely to reflect the artificial truncation of the dataset given that it is inconsistent with the numerous other block models generated as part of this thesis. Regarding the premia, the block model for the smoothed dataset showed that in going from a low to medium gold price in the market (metal price appreciated by a factor of 2.02):

- small deposits only managed a price growth appreciation factor of 1.10 (previously 1.33 for the unsmoothed block model). Notably, the small, high-grade unit prices appear to have incurred a difficult-to-explain discount (0.85) when comparing the low and medium gold metal price environments. As increased grades are associated with the economic resilience of deposits (Cairns 1990), no logical explanation for a discount was identified. As high-grade deposits generally attract high $/oz unit prices elsewhere in this thesis, the artificial truncation of the dataset may have penalised and distorted the predicted market behaviour associated with these deposits in assorted size categories.

- increasing grade for all size deposits attracted a weak response (i.e. no significant reward for higher grades).

The low to high-price environment comparison, in which the metal price appreciated by a median of 2.85 times, shows that:

- small deposits only managed a price growth appreciation factor of 1.50, where previously they had appreciated by ~3.16 in the untruncated block model
- medium deposits only appreciated by a factor of 1.32 (previously 1.89) and large deposits had a significant appreciation of 2.37 (previously 1.66)

For unknown reasons, the relationship with increasing grade becomes less clear as a result.

The erratic unit price and premia/discounts observed in the smoothed block model suggest that artificially truncating a dataset through the application of a top-cut may significantly distort observations about market behaviour. This supports the preference for using all available data points and allowing the ordinary kriging process to take care of outlying data points.

4.3.2.3 Near-surface and deep deposits

Section 4.2.2.5 showed that near-surface and deep deposits might display significant pricing responses. As a result, two separate price-price block models were generated to test the market differences between near-surface (Table 28) and deep deposits (Table 29), with the premia and discounts shown in Table 30 and Table 31.

Table 28. Block prices of near-surface deposits under different metal price conditions

Grade (g/t Au)		Low gold price environment (<$700 oz)			Medium gold price environment ($700-1,000 oz)			High gold price environment (<$1,000)		
High	>6	$24	$19	$40	$25	$16	$36	$91	$49	$36
Medium	3-6	$23	$10	$37	$21	$13	$36	$78	$30	$39
Low	<3	$19	$12	$20	$23	$15	$26	$60	$24	$44
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

Table 29. Block prices of deep deposits under different price conditions

Grade (g/t Au)		Low gold price environment (<$700 oz)			Medium gold price environment ($700-1,000 oz)			High gold price environment (<$1,000)		
High	>6	$50	$35	$35	$57	$42	$62	$88	$40	$37
Medium	3-6	$40	$21	$24	$57	$34	$45	$98	$35	$35
Low	<3	$29	$12	$16	$43	$17	$24	$103	$32	$26
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

Table 30. Price appreciation factors using only near-surface deposit transactions

Grade (g/t Au)		Low-medium metal price comparison (<$700 vs $700-1,000 oz brackets)			Low-high metal price comparison (<$700-1,000 vs >1,000 oz brackets)		
High	>6	1.05	0.85	0.91	3.85	2.55	0.9
Medium	3-6	0.92	1.29	0.95	3.41	2.92	1.05
Low	<3	1.20	1.22	1.33	3.06	1.94	2.23
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large

Table 31. Price appreciation factors using only deep deposit transactions

Grade (g/t Au)		Low-medium metal price comparison (<USD700 vs $700-1,000 oz brackets)			Low-high metal price comparison (<$700-1,000 vs >1,000 oz brackets)		
High	>6	1.15	1.19	1.80	1.76	1.14	1.06
Medium	3-6	1.43	1.65	1.89	2.45	1.68	1.48
Low	<3	1.49	1.35	1.54	3.53	2.57	1.65
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large

The near-surface transactions of Table 28 suggest that the deeper deposits of Table 29 command higher unit prices than those that are nearer to the surface. This was also identified in Section 4.2.2.5 and is thought to reflect a notion of increased blue-sky potential (i.e. optionality) that is more likely to have been sterilised in near-surface deposits. Where there are discounts, they appear to be most prominent in large deposits and strongest in those with low or medium-grade.

The size-based differences between Table 30 and Table 31 are represented in Figure 31 and Figure 32. It is observed that deep deposits had a price appreciation in the order of 1.50, effectively keeping up with the growth observed in the market price of gold of 1.52. However, the near-surface deposits only appreciated by a factor of 1.08 against a median prevailing gold price growth of 2.16. Relative to deep deposits, near-surface deposits have a higher level of differentiation based on their size. For both near-surface and deep deposits, the smaller deposits appreciated more than their progressively larger counterparts.

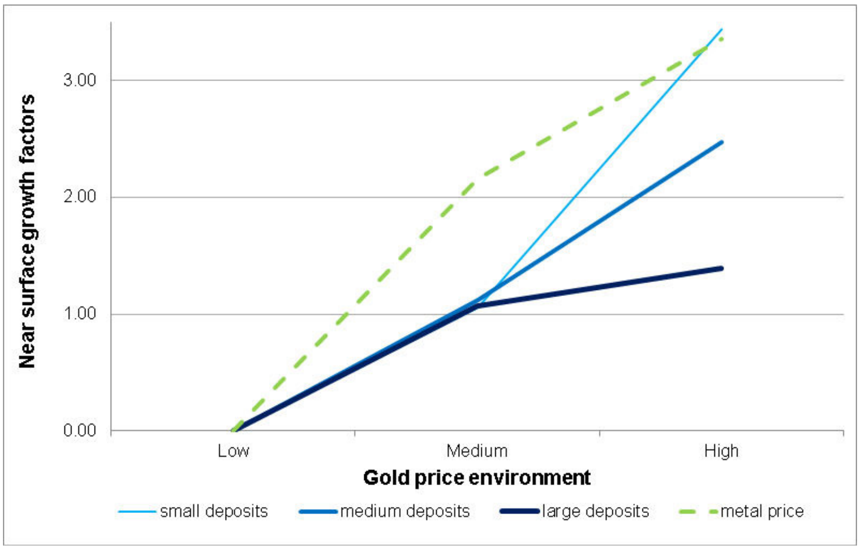


Figure 31. Size based price appreciation factors using only near surface deposit transactions

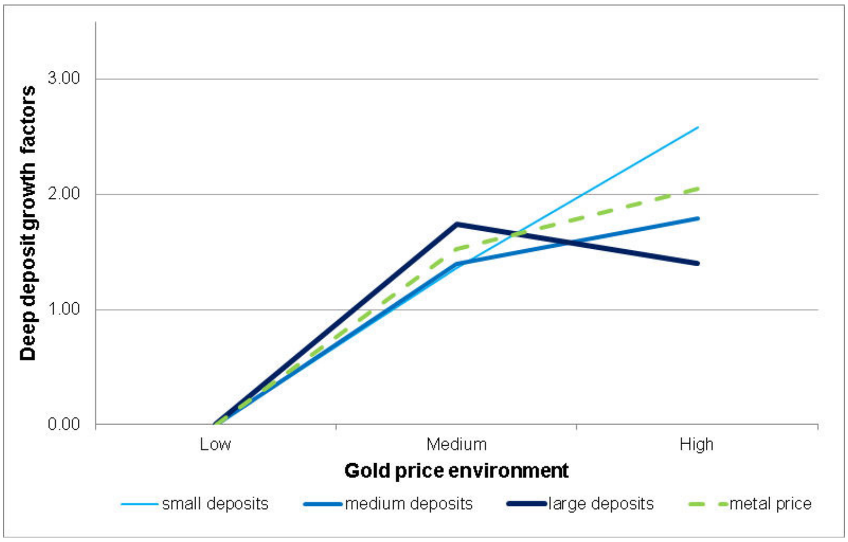


Figure 32. Size based price appreciation factors using only deep deposit transactions

The grade-based differences between Table 30 and Table 31 are represented in Figure 33 and Figure 34. An analysis of these differences suggests that in the shift from the low to medium price environment there is limited differentiation based on grade, which appears slightly unorderly for deep environments. However, there are noticeable differences between the low and high price environments such as the near surface deposits not showing any significant differentiation based on grade, yet deep deposits show a marked differentiation based on grade. None of the near-surface deposit price appreciation kept pace with the gold price growth, and only the deep low-grade deposits managed to outperform the gold metal price, whereas the deep high-grade deposits were the worst performer relative to the growth in the gold price.

Figure 33. Grade based price appreciation factors using only near surface deposit transactions

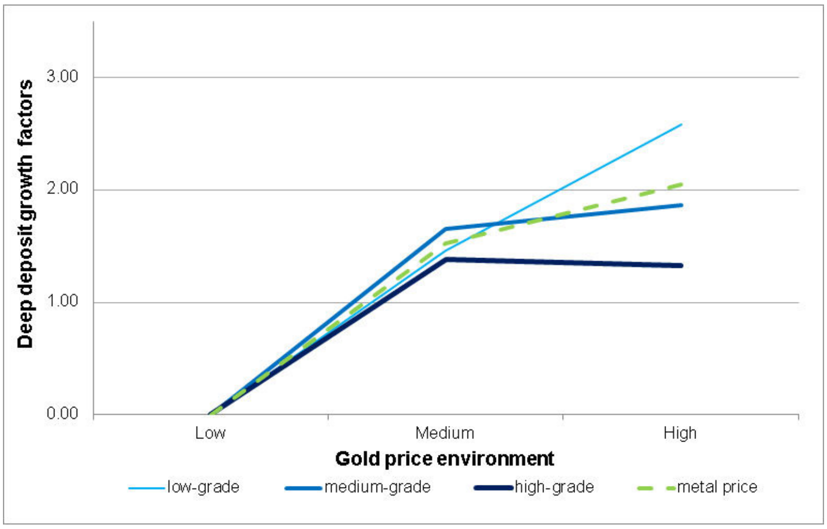


Figure 34. Grade based price appreciation factors using only deep deposit transactions

Based on an analysis of the size, grade and depth below the surface, it appears that the market is quite distinct in apportioning different value based on these technical measures. Deposits with technical characteristics that are "inferior", such as being small, low-grade and deep, appear to gain the most in a rising price environment. Conversely, the "superior" qualities of higher grade, large and near surface deposits have relatively lower price appreciation rates. This is because the deposits with inferior characteristics start from a lower base and undergo step changes from uneconomic to economic viability. This is likely to change the pattern of demand for deposits with inferior characteristics as:

- there are always buyers for good deposits, across all price environments. This leads to a comparatively stable demand, which is reflected in the price appreciation profiles.
- buyers that may have shunned sub-economic deposits with inferior characteristics in a low-price environment are willing to compete for the same deposits in a high-price environment given the change in the perceived economic viability. Consequently, the increased competition for these deposits leads to a higher price appreciation than for those that have superior qualities.

4.3.2.4 Other sub-analysis

A gold price adjusted block model sub-analysis on segregating partial and 100% equity transactions was undertaken. The results of this sub-analysis are presented in Appendix 10 and are consistent with the results presented in section 4.2, which directly addresses this aspect.

4.3.3 Discussion on the commodity price risk investigations

The research in this section supports the hypothesis that the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction, although the magnitude of the movements are disproportionate to one another and contingent on the differences in the qualities of the various deposits. Confirming this hypothesis has direct importance in industry practice as evidenced by the common acceptance of the Yardstick method, which assumes a gold deposit transacts as a percentage of the prevailing market price of gold. When a more realistic three-dimensional analysis is undertaken, gold deposit unit prices are affected by the prevailing gold price in the following manner:

- The unit prices for small deposits have the potential to appreciate at a higher rate than the metal price, and conversely, large deposits may fail to keep pace with the prevailing metal price.
- Grade has a weakened positive relationship between unit price appreciation and the prevailing market price of gold. The price of low-grade deposits appreciated the most and outperformed the growth in the gold price.
- Deep deposits appear to better track movements in the prevailing metal price than their near-surface equivalents. The price of small and low-grade deep deposit outperformed the gold price.

This analysis suggests that in a rising metal price environment, the price of deposits with inferior characteristics (small, low-grade or deep) has the potential to appreciate more than deposits that have superior characteristics (large, high-grade, near-surface), reflecting an increased number of buyers in a high-price environment. Conversely, in a falling price environment, the number of buyers for deposits with inferior qualities will decrease at a faster rate than those for deposit with superior qualities, as well as an overall drop in the number of buyers across the market. While industry practitioners are correct in making unit price adjustments to reflect changes in the prevailing metal price, the empirical evidence suggests that the heuristic price-price methods, such as Yardsticks, may distort the outcomes as they fail to recognise the different behaviours relating to size and grade of a deposit. This block model evidence, along with the linear analysis presented in Appendix 9, challenges the validity of the 1:1 price relationship implied by the Yardstick method. In so doing, it confirms the hypothesis that that the price of a gold deposit is correlated with the prevailing market price for gold metal at the time of the transaction through disproportionate movements.

4.4 Certainty risk

4.4.1 Background

This section investigates the certainty risk hypothesis that the price of a gold deposit increases disproportionately with increases in the certainty of the quantity and quality estimate of a deposit. Despite being one of the fundamental aspects of project price, the market premia and discounts relating to the confidence in the estimates of mineral Resource/Reserve are poorly described in the asset-pricing literature. Invariably, the revenue function has a greater impact on the economic viability of a mining project than its cost function does. For gold deposits, revenue is also sensitive to the uncertain quantity (size) and quality (grade) of *in situ* mineralisation. Even though there are significant monetary amounts at stake, there appears to be little research devoted into quantifying the price of reducing the uncertainty surrounding the resources of a deposit. The present research presents a methodology to identify the likely market premia relating to increased confidence levels in the estimates of resources and reserves.

The confidence in a mineral estimate is a result of a wide range of compounding factors. These include interpretive errors in assessing the continuity, geology, and structure of the orebody; the variability in assay data; inadequate sample density; and spatial surveying of sample points and allocation of areas of influence (Wang et al. 2010; Dimitrakopoulos and Sabour 2007). The confidence in the quantity and quality estimates of a deposit is communicated by the industry according to the qualitative classifications outlined in the CRIRSCO Template equivalents (Evatt et al. 2012; Weatherstone 2008). These uncertainties are exacerbated by the uncertainty around metal prices used to estimate an Ore Reserve (Evatt et al. 2012). Valuing such uncertainty and mineral potential may in some instances be possible using DCF and Bayesian probability methods (Kreuzer et al. 2008) or conditional and Monte-Carlo simulation (Nicholas et al. 2006). However, no literature, other than Hodos (2004), who identifies a stratified market, has been identified that discusses the influence of mineral estimate uncertainty on prices, which helps explain why Specialists largely rely on subjective judgement to estimate value and price (Liu et al. 2012; Ajibola 2010; Gilbertson 2001; Smith and Smith 2005).

The CRIRSCO Template language used to convey uncertainty is not quantitative, and thus its interpretation is subjective (Jewell 2009; Ashgari and Esfahani 2011; Stephenson 2001). Qualitative risk descriptions lend themselves to substantial interpretational variance even in restricted contexts (Bryant and Norman 1980; Mazur and Mers 1994; Reagan et al. 1989; Timmermans 1994; Eiser 1998), which is due to many factors including demographics (Berry et al. 2003) and the frequency of reporting (Jewell 2009). To quantify subjective terminology, Jones and Hillis (2003) use the Sherman Kent scale to ascribe verbal probabilities to geological characteristics. For this purpose, a modified version of the Sherman Kent scale was created by the author to convey the potential economic viability of each classification based on the CRIRSCO classifications (Table 32). To verify the author’s interpretation in Table 32 is reasonable, the table was compared to the probabilities published by Cranston et al. (1994). As there is subjectivity and user interpretation in what defines the each CRIRSCO-type classification, the probabilities in Table 32 are not absolute.

Table 32. Sherman Kent scale with CRIRSCO analogies

Numerical Weight	Corresponding verbal prediction of near-term economic viability	Approximate JORC Code equivalent
0.98 - 1.00	Proven, definitely true.	No analogy
0.90 - 0.98	Virtually certain, convinced.	Proved Reserve
0.75 - 0.90	Highly probable, strongly believed, highly likely.	Probable Reserve Measured Resource
0.60 - 0.75	Likely; probably true, about twice as likely as untrue, chances are good.	Indicated Resource
0.40 - 0.60	Chances are about even or slightly better or slightly less than even.	Inferred Resource
0.20 – 0.40	Could be true but more probably not, unlikely, chances are fairly poor, two or three times more likely to be untrue than true.	No analogies
0.02 – 0.20	Possible but very doubtful, only a slight chance, very unlikely indeed, very improbable.	
0.00 – 0.02	Proven untrue, impossible.	

Modified from: Jones and Hillis (2003)

Lilford (2004) eschews a Sherman Kent style scale in favour of a simpler scheme of weights. Consequently, this investigation includes alternate models that use weights akin to those of Lilford and Minnitt (2002) and Lilford (2004), which are:

- Proved Reserve = 6
- Probable Reserve = 5
- Measured Resource (exclusive of Reserves) = 4
- Indicated Resource (exclusive of Reserves) = 3
- Inferred Resource = 2
- ‘*other*’ estimates = 1.

Where historical estimates with close analogies to the current CRIRSCO classifications were reported (e.g. historical “measured resource” reported in 2001), a weight of one was deducted from the index score to reflect the potential cost required to bring them to current reporting standards.

4.4.2 Certainty block models

For the purpose of discussion, the confidence (Z) dimension in the following block models is divided into three domains using the Lilford (2004) weightings, such that:

- **High-confidence** – corresponds to a confidence rank of more than 3.5 (i.e. on a weighted basis, being approximately equivalent to a Measured Resource or higher). Using the Sherman Kent scale, this would have a description of virtually convinced or certain, to highly probable, strongly believe or highly likely.

- **Medium-confidence** – corresponds to a weight between 2.5 and 3.5 (i.e. broadly analogous to an Indicated Resource). The Sherman Kent description for this is that it is likely, probably true, about twice as likely as untrue or the chances are good.
- **Low-confidence** – corresponds to a weight of less than 2.5 (i.e. broadly equal to, or less than an Inferred Resource). The Sherman Kent analogy would be that the chances are about even, slightly better or slightly less than even.

These domains approximate the CRIRSCO based categories. As there is scope for alternative interpretations of what weights are appropriate for mineral estimate classifications, these are analysed in sections 4.4.2.2 and 4.4.2.3.

4.4.2.1 Base-case

By applying the Sherman Kent style probabilities to the CRIRSCO classification framework, a mineral estimate certainty block model was created (Table 33).

Table 33. Block prices of various confidence brackets

Grade (g/t Au)		Low-confidence index <2.5 (Sherman Kent 0.4 – 0.67) ($)			Medium-confidence index 2.5-3.5 (Sherman Kent 0.67 – 0.80) ($)			High-confidence index >3.5 (Sherman Kent 0.80 – 0.98) ($)		
High	>6	58	34	31	29	45	57	45	53	125
Medium	3-6	53	15	18	24	22	33	36	48	94
Low	<3	23	13	12	16	23	29	26	31	68
Size (Moz Au)		<0.25 Small	0.25-1.00 Medium	>1.00 Large	<0.25 Small	0.25-1.00 Medium	>1.00 Large	<0.25 Small	0.25-1.00 Medium	>1.00 Large

An analysis of the patterns within Table 33 suggests that prices:

- increase with grade in most instances (vertically within the table)
- generally increase with combined size and grade increases (diagonally rising from left to right across the table)
- usually increase with size in high and medium-confidence blocks (horizontally from left to right within the table).

In the low-confidence domain, prices are highest for small deposits (i.e. **$58** to $53 to $23 for small deposits versus **$34** to $15 to $13 and **$45** to $36 to $26 for medium and large deposits respectively). However, as the confidence increases the small deposit effect largely disappears. This may imply that with an increase in the mineral estimate confidence, the projects are closer to the stage of being mined, and as such have a different market dynamic.

While the absolute prices in Table 33 provide an interesting snapshot in time, market sentiment can change quickly resulting in the estimated prices being no longer relevant. A more resilient measure is the proportional relationship between each of the block prices, as presented in Table 34 and Figure 35. In Table 34, the low-confidence block model domain is used as the key reference point as it is the most populous domain (hosting 55% of the dataset). Its use as a common denominator is a logical way to present by how much the confidence premia increases or decreases as a function of higher confidence indices. As will be demonstrated in the following sections, the relationships between each of the block prices may have a more enduring relevance compared to absolute prices when economic cycles and depth to mineralisation are considered.

Table 34. Certainty factors using the base-case domains

Grade (g/t Au)		Low-confidence index <2.5 (Sherman Kent 0.4 – 0.67)			Medium-confidence index 2.5-3.5 (Sherman Kent 0.67 – 0.80)			High-confidence index >3.5 (Sherman Kent 0.80 – 0.98)		
High	>6				0.50	1.32	1.84	0.78	1.56	4.03
Medium	3-6	100%			0.45	1.47	1.83	0.68	3.20	5.22
Low	<3				0.70	1.77	2.42	1.13	2.38	5.75
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

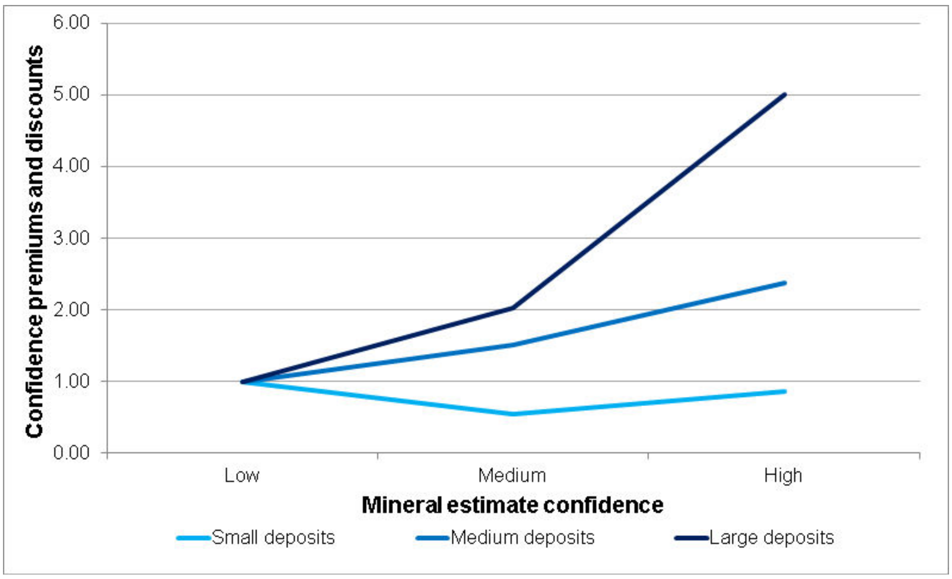


Figure 35. Certainty factors using base case assumptions

The patterns in Table 34 suggest that market behaviour associated with small deposits is different to that of larger ones. Increasing the confidence of medium and large deposits results in a market premium that likely reflects the higher certainty; reduced time to potential production; ability to attract additional project finance; and the project having greater promotional appeal. In contrast, small projects incur a discount with increased confidence in the resource. In part, this may reflect an increase in confidence being perceived by the market as decreasing the potential to discover “blue-sky” mineralisation that will see them expand to the proportions predicted by a Zipf curve (Guj et al. 2011). This upside potential is a price driver that many investors look for in a mineral project. An elevated level of confidence may be interpreted as limiting the potential growth of small deposit and therefore negatively affects its unit price. On this basis, the manager of a small deposit may create higher unit prices by diverting exploration funds to increasing the deposit size rather than increasing confidence in its mineral estimate.

4.4.2.2 Confidence domain shift

To test the sensitivity of changes in the confidence domains, the block model was re-analysed using domains based on:

- <2.0 (low-confidence) – at best is equivalent to an Inferred Resource
- 2.0 to 3.0 (medium-confidence) – better than Inferred but has an absolute maximum confidence equivalent to an Indicated Resource
- >3.0 (high-confidence) – at least equivalent to that of an Indicated Resource.

Importantly, this shift ensures that all size-grade-confidence combinations are supported by underlying data points. The premia that result from this block model are shown in Table 35.

Table 35. Certainty factorsusing domains with lower limits

Grade (g/t Au)		Low-confidence index <2.5 ($)			Medium-confidence index 2.5-3.5 ($)			High-confidence index >3.5 ($)		
High	>6	58	34	31	29	45	57	45	53	125
Medium	3-6	53	15	18	24	22	33	36	48	94
Low	<3	23	13	12	16	23	29	26	31	68
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

Similar to Table 33, the patterns in Table 35 and Figure 36 show that unit price tends to increase with the grade. However, Table 35 shows that small deposits in the medium-confidence domain have similar or higher prices than their larger counterparts (previously this was constrained to the low-confidence domain). As this shift in the domain appears to be blurring the implied behaviour of medium-confidence deposits with those of the lower-confidence ones, the base-case weightings as defined by Lilford (2004) and Lilford and Minnitt (2002) have been retained.

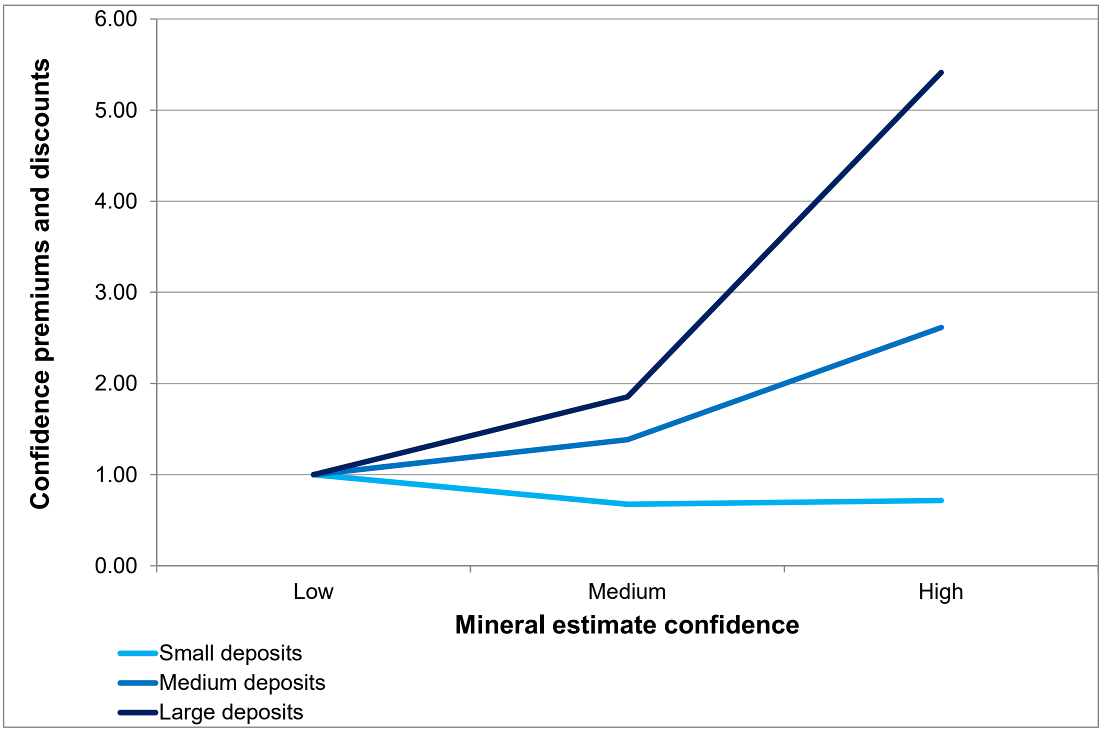


Figure 36. Certainty factors using domains with lower limits

4.4.2.3 Sherman Kent index analogies

Sections 4.4.2.1 and 4.4.2.2 used confidence classifications with weightings akin to those used by Lilford (2004). This section presents a CPI-adjusted model created using the mid-points of the Sherman Kent weightings presented in Table 32. As the weightings of the reserves and resources using the Sherman Kent scale are different, Block models were generated using both the previous and new relationships determined by the variography. A review of the prices and relationships in the resultant block models (Table 36) indicates that in broad terms:

- The observations that small, low-confidence deposits are relatively expensive was maintained. Also, increasing their confidence without increasing the size of the deposit may erode the price, as is consistent with other block model variations.

- For low and medium-confidence domains, the implied prices of the medium-sized deposits were less than those of the smaller, equivalents. This reflects the small-deposit effect, whereby the pool of potential buyers for a deposit increases to the point that the unit price is driven up. Not only does the increased competition push up the price, but the acquiring party may also have a view that exploration upside warrants paying a unit premium over the larger equivalents.
- The premia shown in Figure 37, are generally much less than those presented in Table 34.

Table 36. Certainty factors using a Sherman Kent analogy scale

Grade (g/t Au)		Low-confidence index (Sherman Kent 0.40 – 0.60) ($)			Medium-confidence index (Sherman Kent 0.60 – 0.75) ($)			High-confidence index (Sherman Kent 0.75 – 0.98) ($)		
High	>6	77	25	69	42	50	91	39	76	98
Medium	3-6	63	15	44	35	23	66	30	39	76
Low	<3	35	13	34	22	19	49	20	21	60
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

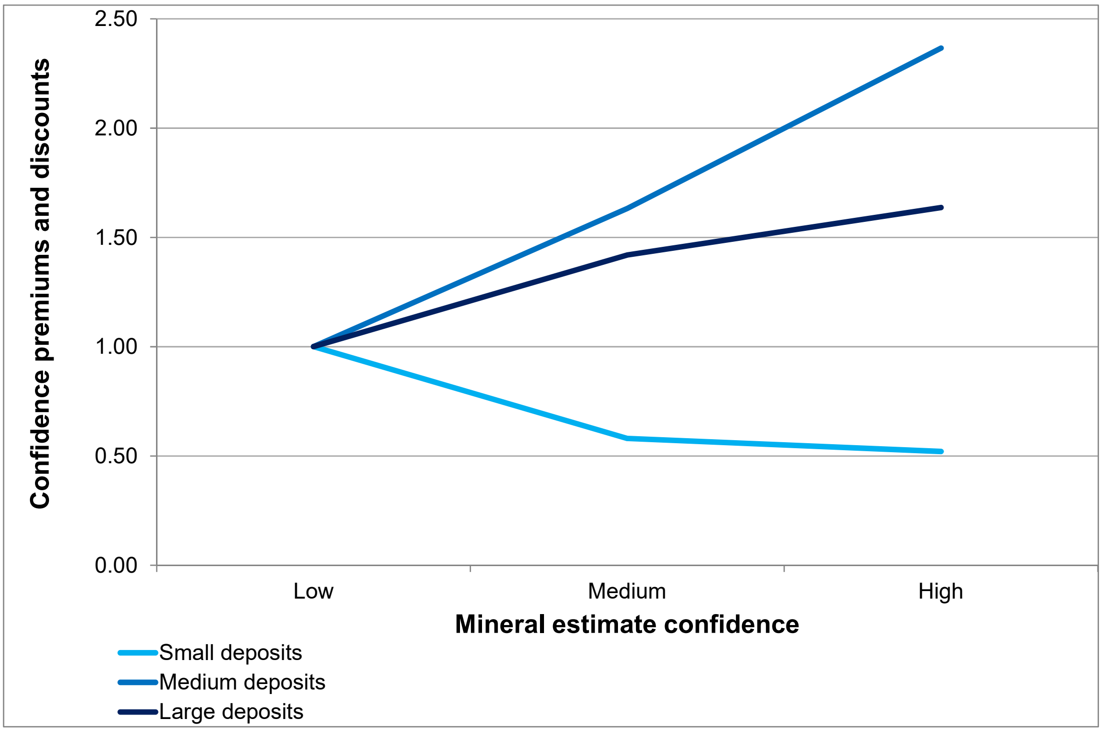


Figure 37. Certainty factors using the Sherman Kent analogy scale

While on the surface, the Sherman Kent based confidence index is appealing in that it may reflect the uncertainty relating to the various mineral estimate classifications. However, using the Sherman Kent scale results in large deposits attracting lower premia than the medium size equivalents (e.g. 2.00 vs. 1.32 for high-grade, medium and large sized, medium confidence deposits). While it is possible that the market attributes premia in this manner, it seems a less plausible outcome. The lower premia for large, confident deposits may be a function of the reduced number of data points. On this basis, and on the notion that value may not equal price, the market may have a simpler perception of the confidence in estimation of the size and grade of a gold deposit than what is implied by the Sherman Kent scale (e.g. it either believes in a classification or not), the market may better reflected by an equal weightings used by Lilford (2004).

4.4.2.4 Other sub-analysis

Additional mineral estimate confidence block models were generated and analysed. These models used data subsets concerned with:

- making metal price adjustments akin to the Yardstick method
- examining the market behaviour before and after June 2007
- segregating the deposits that are near surface from those more likely to be amenable to underground mining.

The observations within these sub-analyses are consistent with those noted and discussed elsewhere in this thesis and are presented in Appendix 11.

4.4.3 Discussion on the certainty risk investigation

The investigation on the effect of mineral estimate certainty on the price of a gold deposit confirms the hypothesis that prices increase disproportionately with increases in the certainty. The research suggests that the market appears to apportion premia in step-changes that may not correlate directly with the confidence implied by measures such as those using the Sherman Kent scale. The premia payable for increasing confidence in a mineral estimate are relatively robust over time, even though the underlying unit prices may change substantially and the market for highly confident deposits is thin. The strength of the premia over time allows the pricing Specialist to take advantage of larger datasets, which may span across macroeconomic shocks, as the proportional relationship between the low and high-confidence estimates did not fundamentally change in this study. The headline observations were consistent in all the subset block models generated, including depth to mineralisation, specific time intervals capturing different stock market sentiment, gold price adjustments, and domain and index models. However, the relationship is not equal across all size-grade combinations, as one of the counter-intuitive behaviours observed in the models is that increasing confidence in a small deposit had the effect of eroding their unit price.

Confirming the certainty hypothesis has a practical application using the EV method (Kreuzer et al. 2008), which considers cost, probability and pay-offs. For example, project managers may use the block model method to help decide whether to drill for additional mineralisation or raise the confidence of a current Mineral Resource or Ore Reserve by modelling the benefit of increasing the certainty against extensional drilling (Figure 38). The ability to gauge the market premia and discounts associated with mineral estimate confidence may enable a project manager to be better informed when deciding whether to allocate their available funds to either increasing the size of a known deposit or raising the level of confidence in its resources. In this manner, the results of a block model can be used by professionals with a technical role, such as exploration geologists, in addition to those in the consulting, finance and legal sectors

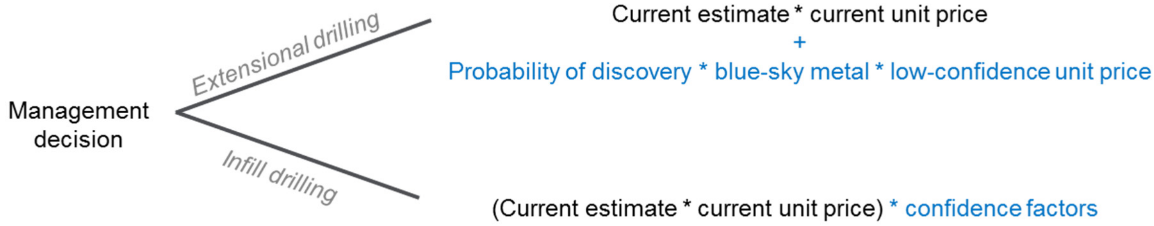


Figure 38. Price maximisation choice using the confidence factors

4.5 Country risk

4.5.1 Background

This section investigates whether the prevailing risk tolerance of the market influences the impact that the risk inherent in different countries will have on the price of a gold deposit (the country risk hypothesis). Country risk can have a significant impact on the market price of the mineral asset. However, this impact is difficult to quantify due to influences from systematic global risks (Ferson and Harvey 1994; Harvey and Zhou 1993; Bali and Cakici 2010; Hueng 2014). There are some techniques that attempt to quantify country risk (Bali and Cakici 2010), with a common method for estimating the appropriate risk discount being the international CAPM (Bali and Cakici 2010; Warner and Warner 2014). However, investors are not fully diversified, and markets are not as perfect as the CAPM suggests (Chatterjee et al. 1999). Also Chatterjee et al. (1999) and Heung (2014) find that global systematic risk is important to the market, while country risk is barely priced. Consequently, this investigation uses hedonic pricing to investigate how gold prices are affected by different level or changes in country risk.

In defining the dimensions of a country risk block model, the Z-axis is used to represent the country risk, with size and grade being represented on the X and Y axes respectively. Country risk incorporates a wide range variables, which have different relevance to mineral assets. Aside from expert opinion, measures of country risk are derived from publicly available surveys and indexes or can be based on quantitative financial analysis (i.e. number of loan defaults). An example of the former is the *Mineral Potential Assuming Current Regulations/Land Use Restrictions* index derived from the Fraser Institute's *Annual Survey of Mining Companies* (Fraser Survey), and of the latter the Organisation for Economic Development and Co-operation's (OECD) credit risk rating. While fundamentally different, both approaches have merit and inherent weakness, as:

- The Fraser Survey is based on the opinions of between 300 and 700 survey participants and relies on their perceptions of a broad spectrum of considerations, such as mineral prospectivity, regulatory conditions and country risk (Jones et al. 2002; Fredricksen and McCahon 2003; 2004; McMahonet al. 2005; McMahon et al. 2006; McMahon et al. 2007; McMahon et al. 2008; McMahon et al. 2009; 2010). Each jurisdiction in the survey is ranked on a scale of zero (high risk) to one (low risk). Given the relatively low sample 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 financial risk irrespective of the mineral prospectivity and regulatory attractiveness of the mineral regime (OECD 2010). Each country is ranked on a scale of seven (high risk) to zero (low risk). This may result in the OECD credit risk rating over or understating the mining industry specific risk of a country.

Other measures of risk can be included as deemed relevant at the time of assessment. The country risk in this thesis is constrained to financial and regulatory measures to avoid the inter-related complexities of the variables. For this research, the Fraser Survey and OECD credit risk rating are rebased to a scale of zero (high risk) to one (low risk) and combined using an equal weighting to derive a combined Fraser-OECD (CFO) index. The CFO index has the advantage of accounting for mineral prospectivity, the regulatory environment and financial risk (which is important when seeking debt-funding arrangements). The CFO index is given a low to high-risk range of 0 to 1 (where 0 is the highest risk, and 1 is the lowest risk). Although the preference is for an equal weighting, a different weighting can be adopted by the user to emphasise the prospectivity/regulatory elements (i.e. higher Fraser Survey weighting) or the creditworthiness of a country. The fourth dimension against which this XYZ model is cast is the sales price of a gold deposit using a price equivalent to 1 October 2010.

4.5.2 Country risk block models

The dataset used to test the impact of country risk on price post-June 2007 uses a risk classification scheme that is consistent with Bell et al. (2008), where safe countries have a CFO of more than 0.66, and risky countries are defined by a CFO of less than 0.33. The lowest scores in Australia, Canada and the USA are 0.77, 0.695 and 0.665 respectively, which provide support for >0.66 defining safe. A CFO score of between 0.33 and 0.66 captures countries such as Ghana (0.49 to 0.53) and Burkina Faso (0.33 to 0.46). Mali scored between 0.31 (year 2002) and 0.53 (year 2008). The countries Ghana, Burkina Faso and Mali are useful for validating the country risk boundaries as they adjoin one another, share analogous mineral potential but as indicated by Euler Hermes (2016), have progressively higher risk profiles (Ghana being classified as medium risk and Mali high risk).

4.5.2.1 Pre- and Post-June prices

Based on an analysis using grade, size, and country risk (mineral potential and credit worthiness) the post-June 2007 market is shown to be broadly consistent in the way it attributes price in low-risk countries (Table 37). By ignoring the country risk differences, the small deposit effect does not appear to be expressed in this case, which may reflect that a materially different population has been sampled (i.e. other investigations are only within low-risk countries); or as shall be shown, that there is significant variance across the country risk axis.

Table 37. Block model price factors relative to small, low-grade deposits in safe countries, post-June 2007

Grade (g/t Au)	Size (Moz Au)		
	Small (<1.0)	Medium (1.0-4.75)	Large (>4.75)
High (>6)	2.47	2.52	2.64
Medium (3-6)	1.48	1.39	1.40
Low (<3)	1.00	1.06	1.18

In comparison with the pre-June 2007 block model, the post-June 2007 block model shows a notable change in both the prices paid and market preferences (Table 38). The strongest observation is that in the pre-June 2007 model the deposits in countries classified as low-risk appreciated substantially over their equivalents in higher risk countries. This became more marked when only 100% equity transactions were reviewed (Table 39), which is consistent with the risk diversification and price benefit of partial transactions (section 4.2). The price appreciation of 100% transactions in countries classified as low-risk after June 2007 is in the order of five-fold when compared with the pre-June equivalents. This contrasts the prevalence of heavy price falls in those countries classified as medium- and high-risk, which, depending on the size-grade combination of the deposit, was around half of the pre-June equivalent.

Table 38. Post-June 2007 Block model prices relative to the pre-June 2007 equivalents

Country risk	Grade (g/t Au)	Size (Moz Au)		
		Small (<1.0)	Medium (1.0-4.75)	Large (>4.75)
High	High (>6)	1.8	0.4	0.7
	Medium (3-6)	1.4	0.7	0.9
	Low (<3)	1.5	1.0	1.0
Medium	High (>6)	2.8	2.2	2.8
	Medium (3-6)	1.2	0.6	0.7
	Low (<3)	0.8	0.4	0.4
Low	High (>6)	3.9	4.2	4..4
	Medium (3-6)	2.6	3.0	2.9
	Low (<3)	1.8	2.7	2.8

Table 39. Post-June 2007 Block model prices relative to the pre-June 2007 equivalents, using only 100% equity transactions

Country risk	Grade (g/t Au)	Size (Moz Au)		
		Small (<1.0)	Medium (1.0-4.75)	Large (>4.75)
High	High (>6)	0.9	0.4	0.4
	Medium (3-6)	1.2	0.7	0.8
	Low (<3)	1.8	1.7	1.4
Medium	High (>6)	2.0	2.2	2.5
	Medium (3-6)	0.4	0.4	0.5
	Low (<3)	0.5	0.5	0.5
Low	High (>6)	4.6	4.7	4.8
	Medium (3-6)	4.9	5.0	5.0
	Low (<3)	6.0	6.0	6.2

4.5.2.2 Pre-June discounts and premia

In the pre-June 2007 analysis, the market appears to favour gold deposits located in countries with medium or high levels of risk, with a preference for size over the grade. Table 40 (visually expressed in Figure 39) shows a strong and universal preference for gold deposits in countries classified as having higher levels of risk. This preference for country risk is consistent with the observation by Warnes and Warnes (2014), who through an analysis of CAPM based models, identified that international investors might, counterintuitively, seek exposure to country risk. Furthermore, the small deposit effect is largely absent, and it appears that the market favoured larger deposit transactions. Before June 2007, debt was cheap and easy to obtain, and equity was easy to raise (Petrosky-Nadeau 2013). It appears that the market sought exposure to riskier assets in the expectation of commensurately higher returns during this period.

Table 40. Country risk factors using all available transaction, relative to size-grade equivalent combinations in safe countries, pre-June 2007.

Risk (CFO)	Grade (g/t Au)	Size (Moz Au)		
		Small (<1.0)	Medium (1.0-4.75)	Large (>4.75)
High-risk	High (>6)	2.61	3.55	3.72
	Medium (3-6)	1.47	2.87	4.02
	Low (<3)	1.21	1.91	2.05
Medium-risk	High (>6)	2.15	1.82	1.58
	Medium (3-6)	2.14	2.24	2.20
	Low (<3)	2.54	3.69	3.94

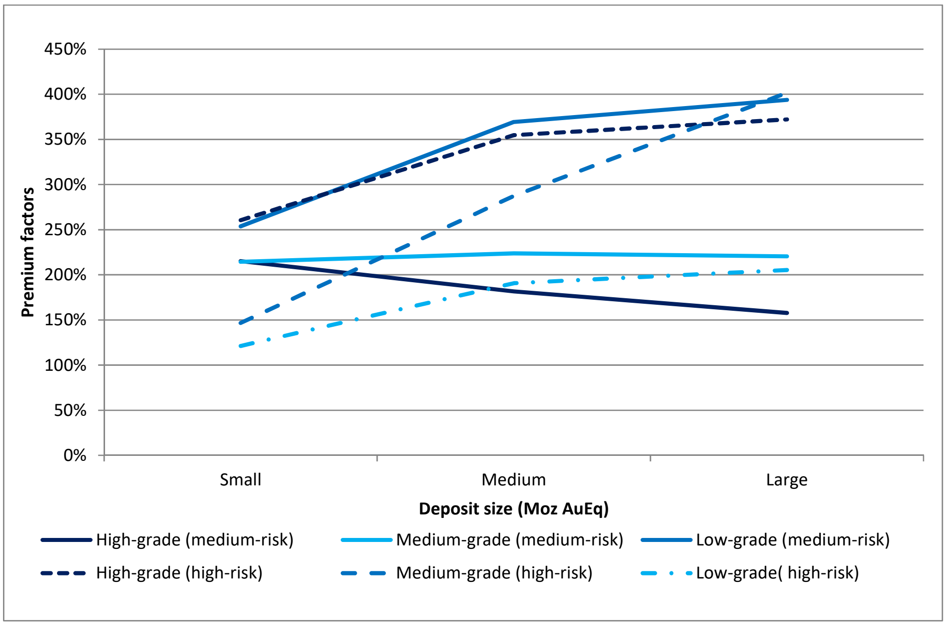


Figure 39. Country risk factors using all transactions, pre-June 2007

4.5.2.3 Post-June discounts and premia

In the post-June 2007 analysis, the market appears to favour gold deposits located in countries classified as being low-risk (Table 41), with small deposit prices being impervious to increasing country risk while large deposit transactions incurred substantial discounts. Unlike the pre-2007 analysis, Table 42 shows a strong expression of the small-deposit effect. This preference may reflect the time-exposure and limited capital at risk associated with the mining of small deposits. Furthermore, there are substantial discounts applied to medium and large deposits that exist outside of countries classified as low-risk, with little distinction between the level of risk (i.e. a binary response to risk). However, when partial interest transactions are excluded from the dataset (Table 42 and Figure 40), the country risk-tolerance of small deposits largely disappears. This is explained by the benefits and strong premia relating to partial transactions discussed in section 0. However, this observation must be tempered with the knowledge that the 100% equity block models shown in Table 42 and Figure 41 have a significantly reduced data density (55% of the transactions) that may affect the results.

Table 41. Country risk factors using all available transaction, relative to size-grade equivalent combinations in safe countries, post-June 2007.

Risk (CFO)	Grade (g/t Au)	Size(Moz Au)		
		Small (<1.0)	Medium (1.0-4.75)	Large (>4.75)
Medium-risk	High (>6)	1.51	0.97	1.00
	Medium (3-6)	1.00	0.42	0.50
	Low (<3)	1.07	0.50	0.50
High-risk	High (>6)	1.19	0.31	0.60
	Medium (3-6)	0.81	0.71	1.17
	Low (<3)	1.00	0.72	0.73

Table 42. Country risk factors relative to 100% equity transaction equivalents in safe countries, post-June 2007.

Risk (CFO)	Grade (g/t Au)	Size (Moz Au)		
		Small (<1.0)	Medium (1.0-4.75)	Large (>4.75)
Medium-risk	High (>6)	1.10	1.01	1.02
	Medium (3-6)	0.18	0.18	0.22
	Low (<3)	0.25	0.29	0.33
High-risk	High (>6)	0.61	0.37	0.36
	Medium (3-6)	0.44	0.48	0.76
	Low (<3)	0.44	0.38	0.51

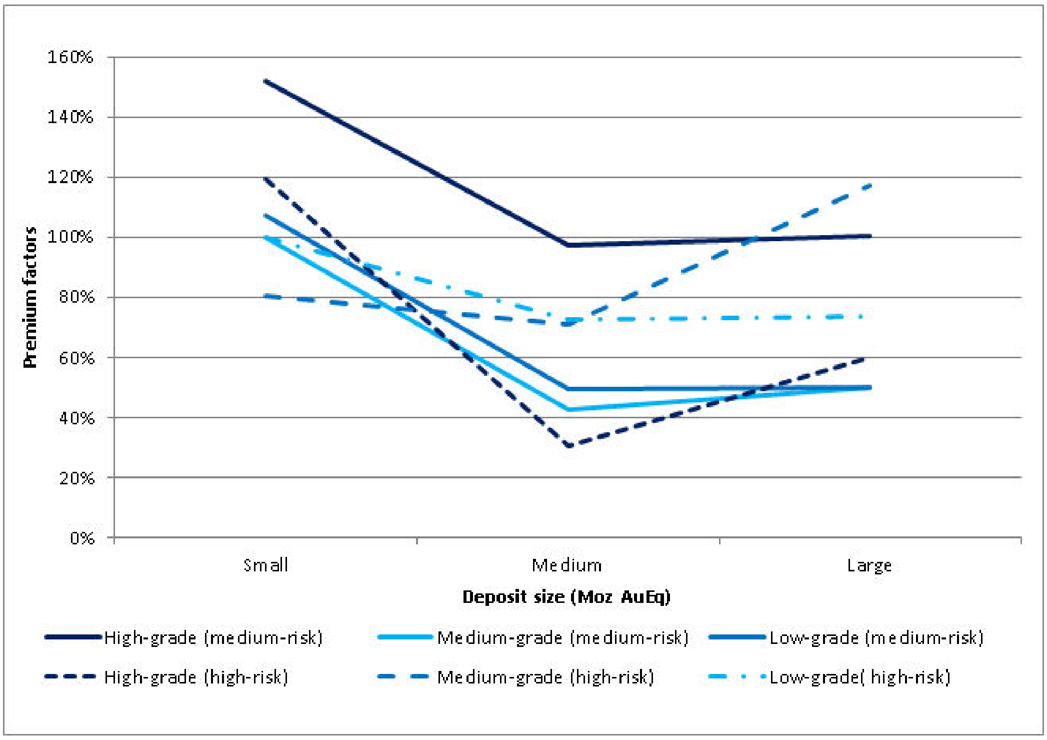


Figure 40. Country risk factors using all transactions, post-June 2007

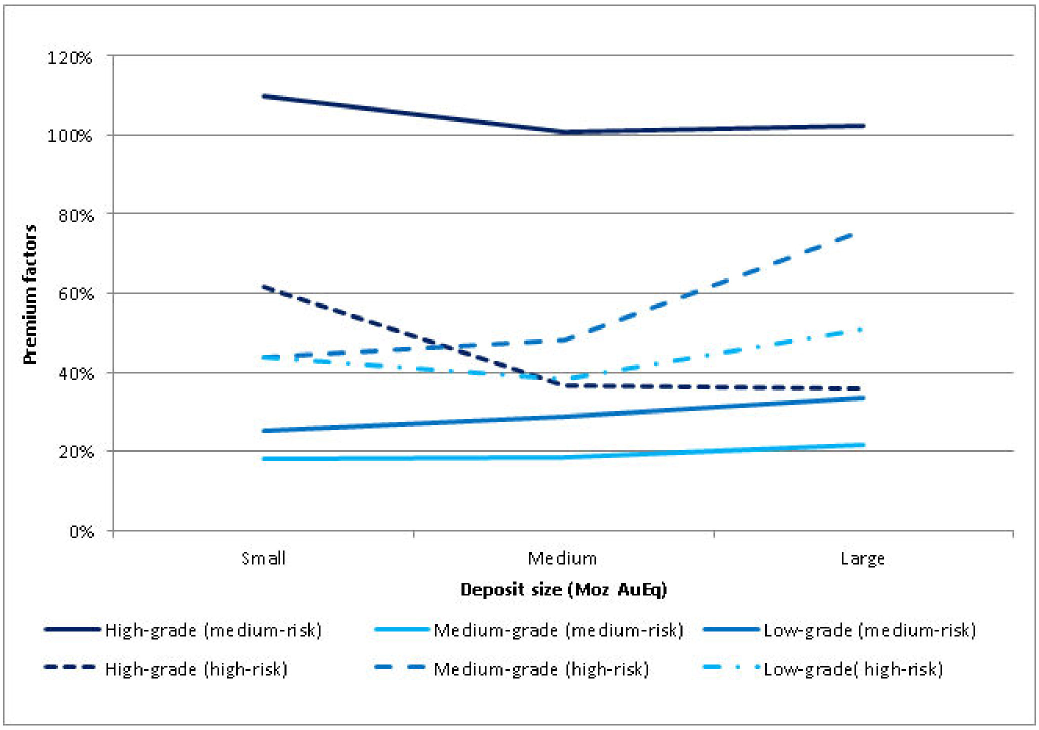


Figure 41. Country risk factors using only 100% equity transactions

4.5.2.4 Various adjustments

There are many adjustments that could have been made to the dataset that informs the block modelling process. These may include:

- adjustments for changes in the prevailing gold price

- discriminating and comparing staged and non-staged transactions
- observing how the prices of transactions based on cash and scrip compare to those that include expenditure commitments
- determining the price effect of having mineralisation near-surface (i.e. likely to be amenable to open-pit mining methods).

Given the issue relating to data density, no such adjustments were attempted for the above factors in this country risk investigation. The earlier investigations (ownership, commodity price and certainty risk) are better reflections of market characteristics given they were undertaken using datasets where country risk is a minimal influence.

4.5.3 Discussion on country-risk investigation

This section tested the hypothesis that the prevailing risk tolerance of the market influences the impact that the risk inherent in different countries will have on the price of a gold deposit (the country risk hypothesis). Following the research in Bell et al. (2008) looking at country risk block models during a risk-tolerant period, this analysis shows that the market tolerance to country risk can change, both significantly and rapidly. The proportionally fewer transactions (reduced liquidity) and reduced unit prices paid for gold deposits in riskier countries supports the hypothesis that the prevailing risk tolerance of the market influences the impact that the country risk will have on the price of a gold deposit.

The relative prices between the pre- and post-June 2007 models demonstrate that risk tolerance is heterogeneous and is an important price driver as noted by Beaudry and Lahiri (2014). In the pre-June 2007 block models of Bell et al. (2008), it has been shown that the market appeared to be (country) risk-seeking in a manner that is akin to optimising financial returns through the introduction of debt into a financial model, as similarly observed by Warnes and Warnes (2014). However, as the global tolerance to risk shifted in the GFC, the market became strongly averse to country risk with Fuerst et al. (2014) also noting a similar flight to quality. This is despite the apparent 'safe' countries being the source of much of the financial risk (Min and Hwang 2012). This is because bank performance between July 2007 and December 2008 (Beltratti and Stulz 2012) was the worst since the Great Depression, which resulted in a credit crisis that severely limited the availability of capital (Petrosky-Nadeau 2013). This change in time and circumstance is a result of the stratification (premia and discounts) of the market changing substantially, despite relatively small changes in country risk ranks. This confirms the country risk hypothesis and the conclusions of the Beaudry and Lahiri (2014), Chan and Kogan (2002) and Storesletten et al. (2007) studies, who found that risk tolerance is equally important, if not more, than relative country risk ranks.

When combined with partial transactions, small deposits achieved higher prices and higher premia in countries with riskier classifications after the GFC. As a partial transaction of a small deposit is a relatively small capital outlay, it is this quality that allows the investor to diversify a portfolio and in so doing, become consistent with Warnes and Warnes (2014) who argue that investors are country risk seeking. In contrast, the large capital outlays required for medium and large deposits achieved lower prices and substantial discounts that appear to be a function of reduced liquidity and access to capital. Given the complexity of the gold deposit transactions market, which changes substantially with time and circumstance, the block model method provides an important reality check to values derived using the CAPM method, which despite being relatively easy to determine in a statistical sense, is prone to generating unrealistic conclusions (Jensen 1968; Dybvig and Ross 1985; Jagannathan and Wang; 1996; Lewellen and Nagel 2006).

4.6 Conclusion from the investigations

The numerous block models used in the testing of the four hypotheses demonstrate that price behaviour of gold deposits may be significantly different to that observed in securities that may relate to a gold deposit. The four hypotheses are:

- **Ownership risk** – the price of a gold deposit on a $/oz basis does not necessarily increase with increasing ownership. The research shows that before June 2007, ownership premia behaved like that observed in consolidating ownership in a corporation. However, after this time, the world became risk averse, and the market shows a strong preference for partial ownership structures. Consequently, the ownership risk hypothesis is confirmed.
- **Commodity price risk** - the price of a gold deposit changes directly but disproportionally to the prevailing market price for gold metal at the time of the transaction. This hypothesis is found to be true, as price growth of gold deposits does not keep pace with increases in the market price for gold metal. In so doing, this research calls into question the validity of the industry

practice of expressing gold deposit transactions as a percentage of the prevailing price of the metal.

- **Certainty risk** - the price of a gold deposit increases disproportionally to increases in the certainty of the quantity and quality estimates of a deposit. The block models show that the market may reward increases in mineral estimate confidence, providing that the deposits are large enough to support a commercial-scale mining operation; however, the market may penalise the price of the gold deposit [in what instance]. Furthermore, the rate of price appreciation does not appear to match increases in the implied certainty conveyed in the language of the CRIRSCO Template classification scheme. This division within the market and the disconnect with the risk profile confirms the certainty risk hypothesis.
- **Country risk** - the prevailing risk tolerance of the market influences the impact of the risk of various countries on the price of a gold deposit. The country risk investigation shows that this holds true, with the market having turned from risk-seeking (premia) before June 2007 to risk averse (discounts) after this time. The research supports Beaudry and Lahiri (2014), Chan and Kogan (2002), and Stroresletten et al. (2007), who state that risk tolerance is equal if not more important than the actual risk exposure.

Across the four main investigations, it was observed that the gold deposit market is stratified, with a major finding that small deposits often trade at higher unit prices than those of larger deposits of an equivalent grade. Surprisingly, it is shown that deep deposits tend to trade at a premium to the equivalent near-surface deposits in what can only be attributed to exploration optionality. These observed stratifications are not only important regarding price, but to how premia and discounts are apportioned. The study demonstrates that there is no single “going rate” for an ounce of gold, but rather there are complex relationships that drive its price.

5 Limitations and future research

5.1 Limitations

Mooya (2009) states that hedonic pricing methods are limited by the availability, quality and relevance of available data. This research is no different. As the trading frequency of gold deposits is relatively illiquid compared to securities, it is difficult to obtain many market observations that have reasonable level comparability. Less liquid markets are less efficient, and consequently, there is greater price dispersion. This uncertainty must be taken into account when analysing market behaviours. As such vagaries are unlikely to be resolved in the absence of a step change in how mineral assets transact, it is necessary to use methodologies that can handle imperfect population samples (such as block modelling). Furthermore, while minimising assumptions, the block model method does not eliminate the need to use assumptions (e.g. cash, scrip, expenditure commitments being equally weighted in the offer consideration). On balance, such approach has the potential to reduce the accuracy of the total price paid for the resources. This potential distortion is not considered significant in the context of the current analysis given that overall market trends are sought rather than precise price prediction, and could be overcome if, or when better information becomes available. Similar shortcomings can be levelled at all market-based methodologies, and the reader should consider that the proposed methodology helps reduce some of the difficulties associated with real-world processes.

In each variation of the ownership block models, the influence on the price associated with different subsets increasingly screened to achieve greater homogeneity, was tested. However, each time a subset of the data is analysed, the representativeness of the data and its statistical rigour reduces. While there is a temptation to filter the dataset to the highest resolution possible, data exclusion must not undermine the representative of the market aspect being analysed. For example, by filtering the ownership risk data such that only post-June 2007 data, non-staged, open-pit deposit transactions are used, the population would drop from 316 transactions to 88, of which only 37 would be partial acquisitions; 15 small deposits; 17 medium deposits; and five large deposits. A block model based on such a constrained dataset would be highly sensitive to anomalous data points and may not be a reliable measure (in this example, 39% of the blocks have no underlying data points). Consequently, it is not easy to overcome the trade-off between data density and data comparability.

The use of powerful interpolation and analysis algorithms within the block model method does not negate the need for experience-based reality checks. As the market-based approach uses historical information to help predict a future sales price under different macroeconomic conditions, there is an implicit assumption that the past is a reliable predictor of the future, which may not be the case. Furthermore, the size-grade (X, Y-axis) domains used to define the blocks within a model can significantly alter the outcomes. Simply defining domains by population qualities (e.g. thirds) may produce nonsensical results. Instead, boundaries based on market perceptions are likely to reflect where market behaviour/price may change. This results in a partial reliance on heuristic interpretation in what would otherwise be a purely statistical analysis, and as such, the same level of caution needs to be applied to the block modelling as other hedonic pricing methods.

5.2 The opportunity

Mineral asset pricing is poorly described in the literature, and the investigations show that the price behaviour of gold deposits can behave differently to those of securities. Consequently, there are opportunities to expand the body of knowledge in this commercially important field. Such opportunities include:

- Expanding on the sub-analyses undertaken in the investigations. This includes casting drivers such the proportion of cash in a transaction or the deposits depth below surface against the size and grade. These are peripherally investigated as part of the internal validation process through sub-setting the datasets at the expense of data density. There is scope to undertake stand-alone evaluations using larger datasets whereby of consideration type and depth below the surface are plotted on the Z-axis of a block model.

- Researching commodities that have similar research merits to gold deposits. Appendix 12 presents an attempt to determine if there is a coherent price differential between gold deposits and base-metal deposit transactions. Appendix 13 considers the exploration potential for discovering a gold deposit. Alternatively, further research may extend into oil and gas transactions or other commodities with similar research qualities to mineral assets.

- Using more advanced estimation techniques. The standard geostatistical analysis yields a preferred interpretation; however, it is but one of many possible outcomes. Consequently, conditional simulation (akin to what a DCF is to a Monte Carlo simulation) or multi-indicator kriging, which considers more than four variables may yield insight it the impact of price dispersion. Should the data support it and using the baseline learnings from the geostatistical methods, alternative methods such as multivariate analysis may be used to determine whether higher levels of precision can be achieved.

Furthering this line of research is a major opportunity as it is both academically and commercially important. In the ten years between 2008 and 2014, the total price paid for gold deposits around the world amounted to $144,700 M; or $426,712 M if base-metal transactions are included (Wright 2015). As a consequence of this vested commercial interest, there is an opportunity to further this line of research through collaboration between industry and academia.

6 Conclusion

This thesis shows that the characteristics of a gold deposit transaction affect its price and demonstrates that there is no single going rate for an in-situ ounce of gold. It is shown that the price of a gold deposit is affected by its size and grade. The price of a gold deposit is also shown to vary dynamically between size and grade, and the certainty of the underlying estimate of quantity and quality, ownership structure, the prevailing metal price as well as the country in which it locates. The price impact of these variables is substantial. The sensitivity to changes in the variables is non-linear, which debases the validity of some of the commonly encountered 'rules of thumb'. Furthermore, some of the observed price behaviours are counterintuitive and contrary to the received wisdom, but logically explained by option theory. It is also shown that there is a distinct behavioural difference for small deposits relative to the rest of the market. The learnings are of direct significant to commercial activity and have the potential to improve market efficiency.

6.1 Outcomes

This research successfully tested four hypotheses, and the process also resulted in the identification of ancillary findings. This thesis is for the most part a first-foray into gold deposit price research and it is important as it establishes a baseline upon which future can develop, as well as providing insights that are of direct commercial relevance.

This research shows that the partial acquisition of a gold deposit (51%, 75% etc), results in a different price on a $/oz Au basis. In risk-tolerant market conditions it is shown that small discounts are applied for ownership levels less than 100%. However, in risk-averse markets, disproportionately large premia are paid for partial ownership transactions. The strong preference for partial transactions in a risk-averse market is consistent with the risk-diversification benefits described in portfolio theory. This finding is important as it is not described in the mineral asset pricing literature, and is contrary to the common industry practice of applying pro-rata adjustments that do not change the implied price on a $/oz Au basis.

This research also shows that price behaviour of gold deposits in countries with different risk profiles is dependent on market sentiment. Building on from existing research, it is shown that after mid-2007 there was a reversal of premia being paid for gold deposits in high risk countries, with steep discounts being applied after that point in time. This change in market appetite for risk was also observed in the ownership risk study.

Another research outcome is that a rise in the gold price elicits an asymmetric rise in the price of a gold deposit. The rate at which the price of a gold deposit increases relative to the prevailing metal price is dependent on the size and quality of the deposit. Small gold deposits tend to appreciate in price at a rate greater than the gold metal itself, whereas larger deposits fail to keep pace. In a similar manner, deep gold deposit prices appreciated at higher rates than their near surface equivalents. These observations may reflect the fact that the value of deposits with more upside potential or marginal economic qualities, offer greater leverage to the prevailing metal price. The leverage and price behaviour is consistent with option theory. These observations are not reported elsewhere in the literature, and are contrary to the industry practice of ascribing a fixed percentage of the prevailing metal price as a means of estimating a transaction price for a gold deposit.

The fourth major outcome of this research is that it shows that increasing the confidence in a mineral estimate generally improves the price paid for a gold deposit. However, the $/oz Au price improvement does not hold true if the deposit is ‘small’, which may reflect that increasing certainty decreases the perceived potential of the deposit growing to a size needed to make it economically viable. The rate at which gold deposit prices improve with more certain estimates does not match the level of certainty implied in the descriptive language of the CRIRSCO family of codes. The learnings are useful for industry practice as it may help project managers optimise their drilling budgets by making risk-informed decisions on whether drill holes designed to infill or extend area of known mineralisation will be most beneficial to a potential price uplift.

In addition to the outcomes of testing the hypotheses, this research yields important ancillary findings. It was observed that on a $/oz Au basis, small gold deposits often trade at higher prices than larger deposits of an equivalent grade. This ‘small deposit’ effect was evident in all the models generated in this research and is partially attributed to such deposits having a higher level of liquidity, possibly due to their relative affordability, or ‘upside’ potential. The price behaviour of small gold deposits is also shown to often to the rest of the market, and should be regarded as a distinct point of stratification. Another ancillary but strong finding is that gold deposits that are deep below the surface trade at premiums to their size and grade equivalent near-surface deposits. As deep deposits have relatively large upfront capital costs and tend to have higher operating costs on a $/tonne ore basis, the expectation from a value perspective is that they would attract market discounts. However, as deep deposits appear to counter-intuitively attract premiums, it is postulated that the observations are due to optionality to expand the Ore Reserve base once the mine infrastructure is in place. The small deposit price behaviour, stratification, and deep deposit ancillary findings are significantly prominent in the data and of material commercial relevance to warrant being the subject of future research.

6.2 Research process

To arrive at the outcomes of this thesis, four hypotheses were formulated. These hypotheses were formed through a review of both the formal literature, as well as industry practice. The hypotheses were based on knowledge gaps on how gold deposit prices change in response to variations in ownership, metal price, mineral estimate certainty, and the overarching country risk. Having formulated hypotheses, the market-based approach was identified as being the most suitable to observing price as it is observational and requires the least amount of assumption (e.g. compared to a cost-based approach such as discounted cashflow modelling). Due to the low-level of knowledge of gold deposit price behaviour, the block-modelling method was selected from within the market-approach. As the hypotheses test fundamental knowledge gaps in a market that is illiquid compared to securities and sensitive to many technical nuances that are difficult to record and standardise, the research methodology is designed to focus on accuracy rather than precision.

6.2.1 Knowledge gaps

It is concluded that the field of mineral asset pricing is significantly under researched, and poorly understood, despite the substantial monetary value of its topic, The four knowledge gaps underpinning the hypotheses are fundamental considerations in a gold deposit transaction, yet surprisingly, there is little direct research upon which knowledge refinement can be made. Consequently, a review of industry practice was required as well as of literature relating to other asset classes and fields of knowledge.

The literature on price behaviour largely relates to securities or is described as price when it refers to value (the terms are often used interchangeably). Much of the research into security prices does not directly relate to corporations that own gold deposits, which tend to be regarded as a separate asset class even within the natural resource sector. Similarly, research that focuses on non-security related transactions often does not involve monetary amounts as large as for gold deposits. For example, a parcel of shares may be purchased for \$5,000; a piece of real estate for \$500,000; and a mineral deposit \$50,000,000 – each of these transactions involve substantially different processes and therefore transferring knowledge from one of these markets to the next is fraught with risk. Securities convey significantly different ownership qualities compared owning a monetarily large, and relatively illiquid asset such a as a gold deposit. Securities can be sold quickly without affecting their price. However, securities convey a much lower level of managerial control. For example, a private owner of a brewery may help themselves to a case of been whenever they like, however a shareholder has no such benefit. However, the shareholder can generally sell their shares quickly (e.g. should they discover management is inappropriately helping itself to beer and other company assets), or replace management. Consequently, it cannot be assumed that knowledge about the price behaviour of gold company securities is directly translatable to the price behaviour of direct ownership in a gold deposit.

This review of the formal literature, informal literature and industry practice resulted in the identification of gaps in the knowledge base and the formulation of four hypotheses:

- **Ownership risk** – the price of a gold deposit on a \$/oz basis does not necessarily increase with increasing ownership. Industry practice is to apportion a pro-rata adjustment to the purchase price of an asset, relative to a 100% sales equity equivalent. That is, 50% of a gold deposit is assumed to trade at 50% of a 100% equivalent. However, the literature on security pricing shows that premia and discounts may apply to various stakes in a corporation, an aspect that has not been adequately tested in the pre-existing deposit pricing literature, nor in industry practice. Furthermore, portfolio theory suggests that there may be a benefit in partial ownership. The evidence from security-based research combined with the behaviours modelled using portfolio and option theory contrast with industry practice and the existing literature. As a result, ownership risk was identified as a measurable and important gap that required further research.
- **Commodity price risk** – the price of a gold deposit changes disproportionately to the prevailing market price for gold metal at the time of the transaction. An industry pricing method implies that gold deposits trade at a relatively fixed proportion of the prevailing gold metal price. While the gold metal price is a major value driver for a deposit, gold metal is different from most other commodity types in that its production from mines may not sway its

price (Hassani et al. 2015). In general, rises in gold price are associated with risk-averse markets. Consequently, there is a tension between changes in value due to metal price fluctuations and the market appetite for inherently risky investments such as mining. The proportional assumption used in industry practice is also inconsistent with the option theory that describes how price behaves in a non-linear fashion as it transitions from out of the money (analogous to low metal prices) to in the money (high metal prices). Consequently, the commodity price risk is an important influence for deposit price prediction and is not adequately defined in the pre-existing literature.

- **Certainty risk** – the price of a gold deposit increases disproportionately in response to change in the certainty of a deposit's estimate of quantity and quality. Industry pricing Specialists go into detail in describing and reviewing the certainty of a mineral estimate, but this level of detail is not mirrored in the price estimation process. Instead, small datasets are often presented with little statistical validation or analysis, and conclusions are drawn on what appear to be heuristic judgements. Given that certainty in the mineral estimate can improve the value proposition, it also has the potential of reducing future upside optionality associated with resource extension, expansion or improvements in quality (e.g. higher-grade lodes). This non-linear relationship between tangible value and optionality is reflected in the project price curve originally conceived by Hope (1971) (as attributed by Lilford and Minnitt 2002), where price rises and falls as a project moves from discovery through to production. Given that the certainty of a mineral estimate of a deposit can be identified using the CRIRSCO-family of mineral reporting codes, a knowledge gap between mineral estimation and its relation to price was identified.
- **Country risk** – the geopolitical characteristics of a country affect the price of a gold deposit. Furthermore, prevailing risk tolerance of the market influences the impact of a country's systematic risk on the price of a gold deposit. Country risk covers a wide range of value drivers that may affect all business activities or may be sector-specific (e.g. mining codes). As country risk does not easily lend itself to quantification, it is often difficult to consider in the price prediction process. The market behaviour in relation to country risk may be contrary to intuitive/heuristic estimates. For example, Bell et al. (2008) determined that before June 2007, the market was risk-seeking when it came to country risk. Since that time, the GFC changed the market's tolerance for risk, which is postulated to include country risk. This potential reversal in behaviour is untested. As such, a follow-up study was required to expand this knowledge base.

These knowledge gaps were selected from other potential areas of study as they are fundamental, and concern aspects that are of direct commercial relevance.

6.2.2 Approach

It is concluded that the paucity of knowledge on mineral asset pricing is in part due to it being an inherantly difficult topic to research. Gold deposit transaction data is not simple to analyse, as it is heteroscedastic and does not lend themselves to simple regression due to the influence of multiple price drivers and the influence of price dispersion. Furthermore, there is little previous research to provide guidance in setting up model ‘rules’ for analysing a gold deposit price dataset. To overcome these challenges posed by these qualities and to minimise the use of assumptions, a positive *(this is how it is)* methodology was used instead of a normative one (*this is what it should be*). To do this, an empirical observation approach is used (hedonic pricing) instead of the income- and cost-based approaches. It was necessary to collate a customised dataset for this research as no readily available source was identified that contained enough technical detail to address the knowledge gaps. Creating the data set was labour intensive and time consuming, however the process promoted the develop a tacit knowledge of the nature of gold deposit transactions and the limitations of the available information. This tacit knowledge helped to form a sound understanding of the limitations of the data availability, its resolution, and the inconsistency in which it is reported (if at all). The data density and limitations are a significant point of different compared to more data rich, and widely researched security price research.

Focussing on asset level transactions results in smaller datasets than those of securities, creating inherent data representativity challenges. Asset level research also means that incomparable technical nuances have a bigger impact on price compared to the securities of companies that own multiple gold deposits. Such sampling and representativity issues are a common in mineral deposit estimation.

6.2.3 Method

While there are many established methods for data analysis, it is concluded that many are not suited to mineral asset price research. As such, the application of a method hereunto used to analyse market data is suited can be used to model identify and characterise high-level behaviour.

Having defined the appropriate approach, a review of the potential market-based methods was undertaken to identify which methods were most suited to testing the hypotheses. It was determined that applying geostatistics and block-modelling, as introduced by Bell et al. (2008), is most suited to gold deposit price behaviour analyses. This method is novel application of geostatistics, a method widely used throughout the mining industry. The methods that may be used within eh block-model method typically involve the incorporation of four variables. The strength of this method is that there is extensive knowledge and experience in dealing data where sample variability can be significant. Furthermore, as the behaviour of gold deposit prices is poorly described, it is important to be able to relate the input parameters with output. The block-modelling input-output relationships are relatively easy to understand compared to other methods such as multivariate analysis. Furthermore, gold deposit transaction datasets with a high degree of variability/availability in the supporting information, which limits how many variables can be analysed at once without excessive reduction of sample size, a quality that is otherwise a strength of multivariate analysis. Furthermore, the visual nature of block-models may help in the identification of anomalous patterns that the researcher may otherwise not consider; and to aid experimentation with the measurement of semi-parametric variables. While the block-modelling method may not have the same functionality as of multivariate analysis techniques, it is well suited to the first-mover nature and the limitations of the data used in this research.

To apply the block-modelling method to gold deposit transactions it is necessary to cast four variables into spatial (X-Y-Z dimensions), and a magnitude of the point described by the co-ordinates. By casting the size (millions of ounces) and grade (grams per tonne) of a deposit in the respective X and Y dimensions, the most fundamental variables of a deposit can be consistently described in a two-dimensional space. A third variable can then be introduced in the Z dimension which in this case are variables described by the hypotheses (equity ownership, prevailing gold price, mineral estimate certainty, and the overarching country risk). By analysing the spatial relationships between the data points and creating a block-model of estimates, it is possible to quantify the behavioural changes (price) in response to changes in the three X-Y-Z variables, and in doing so, test the hypotheses. The mechanics of the block model method are shown in Figure 42s**Error! Reference source not found.**.

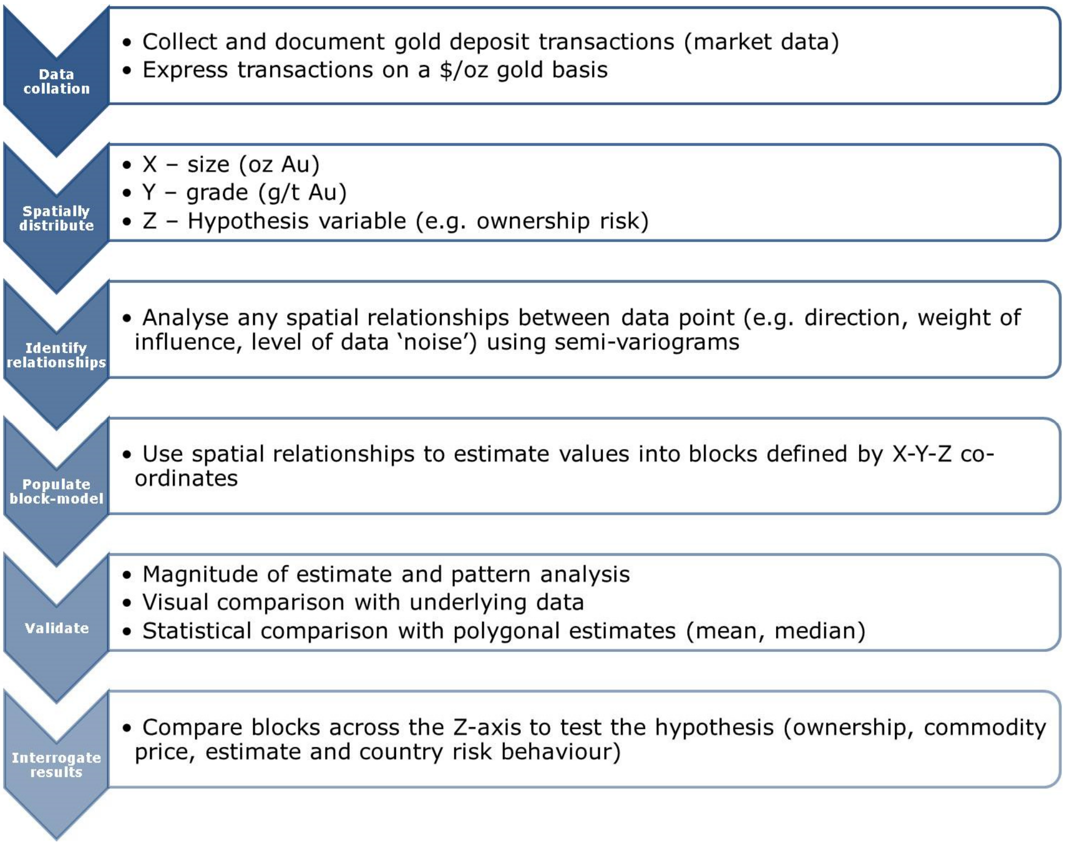


Figure 42. Flowsheet of the research methodology

6.3 Importance

The outcomes of this research are important from a point of view of addressing knowledge gaps, their commercially relevance, and in an ancillary manner, demonstration of how an established statistical method can be used in its own right, or as a vanguard to more sophisticated multivariate methods.

This research shows that despite a common industry perception, there is no single "going rate" for an ounce of gold bought in a transaction. Instead, the market behaviour fluctuates with changes market sentiment, the size and grade of the deposit, and in the context of this research, the hypotheses variables considered (ownership risk, certainty risk, commodity price risk, and country risk). It is shown that these variables have a significant impact on the $/oz Au price and that in some instances, the observed behaviour is substantially different to that assumed in commercial practice. Furthermore, the recognition that there is distinct stratification within the market has implications for both how data may be treated in future, and how it is commercially used to estimate the price of a deposit. As the addressed knowledge gaps concern fundamental variables that affect the price of a gold deposit, this research is important for providing a reference point upon future knowledge can be built.

The research is of direct and significant commercial relevance. In the five years from 2008 to 2012, Wright (2015) identifies that global mineral asset transactions were worth $426,712,000,000. However, Wright (2015) excluded transactions under $10 M, so this is an underestimate. Based on the figures published by Wright (2015), gold deposits represent between 21% and 60% of the total mineral deposit market in any given year, a substantial amount by most investment standards. A review of industry reports identified that an accuracy of ±20% is generally attributed to gold deposit price estimates, a figure that is consistent with literature into other market price predictions. However, Kahneman and Lovallo (1993) caution that even when people are 99% sure, predictions are only correct 80% of the time. Similarly, Man and Ng (2007) identify that price predictions may fall outside of a ±20% confidence band 70% of the time during periods of high volatility. Given that there are numerous price drivers that may affect a gold deposit (size, grade, depth, metallurgy, etc.) there is no reason to consider that gold deposit price estimates would be any more precise than those of other sectors; indeed, they may be less precise. Despite this, using the ±20% confidence band and Wright's (2015) statistics, the median risk in any single transaction worth $3 M ($15 M x 20%). Consequently, even modest improvements in the price analysis of gold deposits have the potential to yield significant monetary benefit to the recipients of a price prediction. Improvement in the knowledge relating to gold deposit transactions is impactful.

Research into gold deposit transactions is important relative to other mineral commodity transactions. Gold deposits transactions are good research medium as relative to other mineral commodities, they are weakly affected by considerations such as logistics, illiquid or unsophisticated markets, or involve the sale of intermediate products such as mineral concentrates. These market qualities mean that fewer assumptions or adjustments need to be made for gold deposit transactions, yet the learnings may be applicable to a large proportion of the trade in mineral deposits. Consequently, the findings from this research may have benefit beyond the gold deposit market and worthy of note.

This research is also important as it demonstrates how the block-modelling method can be used to analyse relatively noisy and imperfect market data. It is shown how data with different qualities can be used, experimented, and validated visually and in relation to the input data. This methodology is also shown to be useful as it can handle data with significantly different data without a need to change the techniques or data. For example, the block-model method easily handled parametric to semi-parametric data, and exogenous and endogenous variables without a need for change in how the data was analysed.

This is because the four hypotheses all have unique interactions with the transacted deposits, and how they are expressed. Specifically, ownership risk is precise in its measurement and is directly related to the transaction (parametric and endogenous); mineral estimate certainty risk as it is imprecise in its quantification, and is unique to the deposit in question (semi-parametric and endogenous); commodity price is precise in its measurement but unrelated to the deposit (parametric an exogenous); and country risk is difficult to quantify objectively and is not intrinsic to the deposit itself (semi-parametric and exogenous).

6.4 Future direction

It is concluded that the paucity of knowledge on gold deposit price behaviour, and the successful application of an alternative research method present substantial and diverse opportunity for future research. There are a number of future research opportunities that can build on from this thesis. These can grouped into extensions on peripheral observations made in this research, retesting the hypotheses under different market conditions or by extending the research into other areas. Such opportunities include:

- **Hypotheses updates** based on a period of falling, rather than rising gold metal price. From September 2001 to June 2012, the gold price increased nearly seven-fold. However, after June 2012, when the last data point in this research was collected, the gold metal price began a downward trajectory from around $1,800 to $1,100 (as at November 2015). A study re-examining the four hypotheses in a falling gold metal price market will help determine whether market behaviours are symmetrical given different metal price trajectories.

- **Expanding on ancillary findings** such as determining the price behaviour difference between near-surface and deep deposits. This depth aspect was investigated in the sub-analyses of this thesis but was not directly the subject of a hypothesis. As this research results in the counter-intuitive finding that deeper deposits may attract higher prices over the near surface equivalents, there is a need to confirm this through a direct study. Similarly, the strong prices observed in the small-deposits, and the different market behaviours they elicit relative to their larger grade-equivalents, justifies a better understanding of market demarcation.

- **Determining whether market behaviours are consistent between mineral commodity types**. Other potential research areas include determining whether the base-metal deposit market displays similar patterns to the gold deposit market and determining if there is a quantifiable difference in the price paid for a gold deposit relative to a base-metal deposit (the "gold premium"). The preliminary investigation into this gold premium is presented in Appendix 12 and is intended to be a useful first-pass learning upon which future research can build. Determining whether gold deposit transaction behaviour can be applied to base-metal deposit equivalents is of significant commercial importance as Wright (2015) identifies that between 2005 and 2014 this market was worth an additional $282,013 M – just under twice the size of the gold deposit market.

- **Expanding the hypothesis into other non-mineral commodities**. There is a research opportunity to step out beyond the mineral sector into other commodity types such as petroleum. In this particular market, it may be possible to populate the X and Y axes of a spatial model using the sulphur content ("sweet" to "sour" classifications) and density ("light" to "heavy" classifications); and the Z-axis with whatever hypothesis being tested and the point defined by X-Y-Z as the price.

In addition to the points above, there is research opportunity to refine and extend the methodology used in this thesis. There are many experienced professionals with advanced estimation skills, which are incentivised as the industry can benefit from the research in a manner that they are familiar. As such, there is not only opportunity to expand the knowledge base into market behaviour, but also to refine the methodologies by which it is done. For example, indicator kriging may give insights into the reliability of the block models, and multi-indicator kriging can expand the number of price drivers considered at any one time. If the multi-indicator kriging method is pursued, it would be useful to understand the differences to a more conventional multivariate analysis.

6.5 Closing statement

The confirmation of the hypotheses on ownership, commodity price, mineral estimate certainty and country risk using block models represents a significant step towards a better understanding of a commercially significant yet poorly understood field – mineral asset pricing. Much of the present body of literature is limited in use for gold deposit price prediction because of the interchangeable use of the concepts of value and price and the assumption that the behaviours observed in security prices are directly transferrable to asset level transactions. The strengths of the methodology used to test the hypotheses in this research are due to it being objective, observational, requiring minimal assumptions (e.g. future gold metal prices) and is well understood by the key stakeholders - the mining industry and its investors. The results of the investigations show that the gold deposit market is stratified and that there can be substantial differences in response to a change in a price driver, depending on the size and quality of the deposit. Such observations show that it is not possible to ascribe market behaviours on a generic ounce of gold basis, such as those often observed in industry practice. In addition to being intellectually important, this research is commercially important given it was worth $144,700 M in the decade between 2005 and 2014, with what may be a somewhat optimistic ±20% predictive confidence interval. To the author's knowledge, this is an early attempt into this research area within the minerals industry and therefore creates future research opportunities in the form of an extension of the current knowledge, refinement of the methodology, improved resolution of the findings, as well as expansion into other commodity types. The economic relevance of such future research along with the potential for industry-academic collaboration may create an opportunity for rapid expansion of the knowledge base.

7 Publications

The initial research into country risk was published in the *AIG Quarterly Newsletter* (Bell et al. 2009), presented at the *2008 Australian Earth Sciences Convention*, and subject to industry media reports (Fraser 2008). The follow-up investigation was presented at and published in the peer-reviewed *VALMIN Seminar Series* (Bell et al. 2012), which were co-hosted by the AIG and AusIMM. Together, the AIG and AusIMM represent the bulk of the Australian geologists, mining engineers and metallurgists (3,000 and 12,000 members respectively (AusIMM 2012)).

The investigation into the price behaviour of mineral estimate confidence was presented to 180 delegates at *the AIG Mineral Asset Reporting and Valuation Seminar* held in Perth on 19 October 2009. The findings were summarily published in Edition 101 of the *AIG Quarterly Newsletter* in August 2010.

Versions of the ownership premia and discounts research were published in the June 2011 edition of the *AusIMM Bulletin* (Bell et al. 2011) and the 105th edition of the *AIG Quarterly Newsletter* (August 2011). The outcomes were also presented in front of industry peers at the Perth *VALMIN Seminar* in October 2011.

The results on the gold metal price's impact on gold deposit prices were published in the May 2013 *AIG Quarterly Newsletter* (Bell et al. 2013a) and June 2013 edition of the *AusIMM Bulletin* (Bell et al. 2013b).

Aspects of the research into pricing exploration projects were presented at the *AusIMM 2012 Project Evaluation Conference* and published in its peer-reviewed proceedings (Bell and Guj 2012) and in the 103rd edition of *the AIG Quarterly Newsletter*, February 2011; and the 110th edition of the *AIG Quarterly Newsletter*, November 2012.

No adverse or contrary comments were received regarding the methodology or investigations of this thesis. Accolades were received from Keith Spence (the co-chair of the CIMVAL Committee) following the presentation of this research at the Perth VALMIN Seminar held on 18 October 2011. All other related discussions were positive and no challenges to the methodology, interpretations or conclusions were raised

8 Disclaimer

The research presented in this thesis relates to the price behaviour of mineral assets. It does not concern the value or price of securities and the reader is cautioned not to assume that its findings are transferable to securities. Furthermore, the information contained within this thesis is not intended to be and does not constitute financial advice, investment advice, trading advice or any other advice. The information and research is general in nature and is not specific to the reader or anyone else. The reader should not make any decision, financial, investments, trading or otherwise, based on any of the research presented without undertaking independent due diligence and consultation with a professional advisor.

9 Glossary

This thesis is largely written in a language that is familiar to someone who has mineral mining and exploration industry experience. However, there are certain terms that are used with variable meanings or interchangeably. Consequently, for consistency and clarity this section sets out the definitions and terms that are used in this thesis.

9.1 Abbreviations

The abbreviations used in this thesis are outlined in Table 43 below.

Table 43. Abbreviations

Abbreviation	Term
$	United States Dollars (unless stated otherwise)
%	Percentage
AICD	Australian Institute of Company Directors
AIG	Australian Institute of Geoscientists
ANN	Artificial neural network
ASIC	Australian Securities and Investments Commission
Au	Gold
AUD	Dollars (Australian)
AuEq	Gold equivalent
AusIMM	Australasian Institute of Mining and Metallurgy
Australian dollar	AUD
BAC	Base acquisition cost
BComm	Bachelor of Commerce
BHC	Base holding cost
BSc	Bachelor of Science
CAD	Dollars (Canadian)
CAPM	Sharpe-Linter-Black Capital Asset Pricing Mode
CET	Centre for Exploration Targeting
Curtin	Curtin University of Technology
DCF	Discounted cashflow (method)
EQ	Equivalent
EV	Expected value (method)
FAIG	Fellow of the AIG
FAusIMM	Fellow of the AusIMM
FIMMM	Fellow of the Institute of Materials, Minerals and Mining
Fraser Survey	Annual Survey of Mining Companies
FRSS	Fellow of the Royal Statistical Society
g	Grams (metric)
g/t	Grams per tonne

Abbreviation	Term
GAICD	Graduate of the AICD
JV	Joint-venture
LOESS	Locally weighted scatterplot smoothing
M	Million
MAIG	Member of the AIG
MAIME	Member of the American Institute of Mining, Metallurgical and Petroleum Engineers
MAP	Modern asset pricing
MAusIMM	Member of the AusIMM
MBA	Master of Business Administration
MBS	Member of the Biometrics Society
MEE	Multiples of expenditure method
MMMSA	Member of the Mining and Metallurgical Society of America
Moz	Million ounces
MSc	Master of Science
NAV	Net asset value
NPV	Net present value
OECD	Organisation for Economic Development and Co-operation
OP	Open-pit
oz	Ounce (Troy)
PhD	Doctor of Philosphy
RG	Regulatory Guide (ASIC)
ROV	Real options value analysis
S&P	Standards and Poor's
t	Tonne (metric)
UG	Underground
USD	Dollars (USD)
UWA	University of Western Australia

9.2 Common terms

Asset: means all property, including but not limited to real property, intellectual property, mining and exploration tenements held or acquired in connection with the exploration, development and production from those tenements together with all plant, equipment and infrastructure owned or acquired for the development, extraction and processing of a deposit (VALMIN 2005).

Base-metals: Is a generic term, which in this case relates to lead, zinc, copper and nickel metals.

Blue-sky – the upside potential.

Brownfields exploration projects – Exploration projects for which there are no current indications of significant mineralisation but are located in a geologically favourable mineral belt or in close proximity to a known mineral deposit. Brownfield deposit discoveries are more probable than those in greenfield analogies, but are usually smaller (Schodde and Guj 2012).

Deposit: is a generic term to describe a mineral asset containing a Resource or a Reserve. It also relates to historical estimates, foreign resources/reserves and exploration targets as described in ASX (2007; 2011; 2012) and JORC (2012).

Greenfields exploration projects – An early-stage exploration project that is located in a region not previously associated with known deposits or significant mineralisation. Often deposit discoveries in greenfields projects tend to be larger than those in brownfields equivalents (Schodde and Guj 2012).

Independent Expert: Means the holder of an Australian Financial Services License who was the appropriate experience and qualifications necessary for estimating the price of securities; making judgements on the fairness and reasonableness of an offer; and is in a position to give financial advice. Typically, a Specialist will report to an Independent Expert, but in some instances a single person or entity is in the position to assume both roles.

JORC: is the accepted abbreviation for the *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (JORC 2004). The JORC Code conforms to the CRIRSCO Template, which is the International reporting template for such items (CRIRSCO 2006). The CRIRSCO Template also underpins the Canadian CIM Definition Standards and South African SAMREC Code (CIM 2010; SAMREC 2009) and a host of other international reporting codes. For the purpose of this thesis, the term “JORC” is used instead of the full title of The JORC Code.

Price: The estimated amount for which an asset or liability should exchange on the date of valuation between a willing buyer and a willing seller in an arm’s length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion (IVSC 2012a).

Project: is singular or a grouping of tenements that may or may not contain a deposit. This term is used interchangeably with mineral asset.

Reserve: a Mineral Reserve and Ore Reserve is the economically mineable part of a Measured and/or Indicated Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Mineral Reserves are sub-divided in order of increasing confidence into Probable Mineral Reserves and Proved Mineral Reserves (CRIRSCO 2006). This term can largely be used interchangeably with the JORC Code term “Ore Reserve”. To simplify the language, the term “Reserve” is used to refer to both Mineral and Ore Reserves.

Resource: formally known as a Mineral Resource, a Resource is a concentration or occurrence of material of economic interest in or on the Earth’s crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, continuity and other geological characteristics of a deposit are known, estimated or interpreted from specific geological evidence, sampling and knowledge. Mineral Resources are subdivided, in order of increasing geological confidence into Inferred, Indicated and Measured categories (CRIRSCO 2006). For shorthand purposes, the ‘*mineral*’ is dropped from the front of the term “Resource”.

Specialist: refers to a professional who meets the criteria of ‘*Expert*’ in the 2005 edition of VALMIN. In common language, such a person may also be deemed a “valuer” or “valuator”. As VALMIN was undergoing revision at the time of writing this thesis, the VALMIN (2015) proposed term of “Specialist” has been used in this thesis. Furthermore, this helps to reduce confusion with Securities Experts (often accountancy-based roles)

Tenement: is any form of title or right such as a license, permit or lease granted by the responsible government in accordance with its mining legislation that confers on the holder certain rights to explore for and/or extract minerals or petroleum that may be, or is known to be contained under the surface of the land. “Tenure” and “title” have the same connotation as Tenement.

Unit price: The price of an asset expressed as dollars per measurement unit, such as \$/oz or \$/km^2.

VALMIN: refers to the *Code for the Technical Assessment and Valuation of Mineral and Petroleum Assets and Securities for Independent Expert Reports*, the “VALMIN Code” (VALMIN 2005). The VALMIN Code applies to the Technical Assessment and/or Valuation of Mineral and Petroleum Assets intended for public release such as disclosure documents, prospectus; compensation for compulsory acquisitions) protection of the rights of shareholders in transactions between associated parties; pricing a vendor’s consideration in a public float; and fairness and reasonableness reports relating to the acquisition or disposal of assets. As with JORC, the abbreviated term VALMIN is in this document.

Value: the future benefit of a mineral asset to the owner or a prospective owner for individual investment or operational objectives.

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11 Attributions

The research presented in this thesis is the result of extensive collaboration with a number of individuals and organisations. A collaborative approach was used so as to draw on the industry and academic experience and perspectives that are impossible to gain through the efforts of a single person's lifetime. This approach is in keeping with that of a mineral asset Specialist, whose specialisation is generalisation (i.e. "Jack of all trades, master of none") and work often involves multidisciplinary teams. This process provides benefits in the form of:

- years of real-world experience and knowledge
- greater confidence that 'the right buttons were pressed'
- outsider perspectives
- disseminating knowledge through influential persons
- garnering champions for the concepts and applications
- allowing a focus on what the number actually mean and what drives them
- playing to the strengths of all the individuals involved.

The co-researchers engaged to help with this research are all specialists in their own right, be it in academic or industry circles. These people not only add credibility to the outcomes, but act as ambassadors for change and advancement. This thesis would not have been possible without the help of these individuals and their related organisations, for which the author offers his thanks.

Dr Pietro Guj and **Dr Bryan Maybee** were the supervisors for this thesis. Dr Guj was the primary supervisor from 2008 to 2013, during which time the research and analyses components were undertaken. From mid-2013 onward, Dr Maybee provided a new perspective and oversaw the refinement and write up. The input from Dr Guj and Dr Maybe is invaluable to this thesis and they both have my gratitude.

Dr Waqar Asad assumed the role of chairperson in 2016. Without Dr Asad's support, the process of completing my PhD Candidature may have been much more difficult. I thank Dr Asad for coming to my aid during a time of need.

In testing the hypotheses on ownership risk, commodity price, certainty and country risk, expertise and assistance was obtained from five well-regarded industry experts in geostatistical estimation:

- **Mr Stefan Mujdrica** of Xstract Mining Consultants Pty Ltd assisted in the research into ownership risk;
- **Ms Stephanie Gotley** of Xstract Mining Consultant Pty Ltd assisted in the research of commodity price risk;
- **Ms Susan Havlin** under the guidance of **Mr Ian Glacken** of Optiro Pty Ltd (Optiro) assisted in the certainty risk research; and
- **Ms Christine Standing** of Optiro Pty Ltd (Optiro) provided assistance in the research relating to country risk.

Each of these experts assisted by undertaking the geostatistical analysis and generation of the transactions-based block models. They provided both knowledge and experience to ensure that the models were correctly generated and acted as peer reviewers. The author was responsible for the data collation, direction of the analysis, the interpretation of the outcomes and writing up the results and literature review. Each person is an industry practitioner and assisted on a pro bono basis. Without the help of each of the contributors above, I would not have been able to undertake this interdisciplinary thesis. The tireless hours that they each contributed did not go unnoticed, nor shall it be forgotten.

This ancillary research contained in Appendices 10 and 11 also used expert input. Mr Mark Murphy of then AMEC Foster Wheeler (currently Independence Group NL) was responsible for statistical advice, generating and analysing the semi-variograms and population of the regression models in Appendix 12 (cross-commodity analysis). Dr José Saavedra-Rosas assisted in Appendix 12 which concerns exploration project price behaviour. Dr. Saavedra-Rosas expertise as a mathematical engineer was used to test the theory and concepts using multivariate analysis and artificial neural network analysis. The author was responsible for providing Mr Murphy and Dr. Saavedra-Rosas the data and directing his analysis and undertook the literature review, data compilation, result analysis and write-up.

The abbreviations used in this thesis are outlined in Table 44 to Table 49 below.

Table 44. Attribution - Stefan Mujdrica

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Mr Stefan Mujdrica	4.2 Ownership risk				X		
I acknowledge that thee represent my contribution to the above research output. Signed:							

Table 45. Attribution - Stephanie Gotley

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Ms Stephanie Gotley	4.3 Commodity price risk				X		
I acknowledge that thee represent my contribution to the above research output. Signed:							

Table 46. Attributions - Susan Havlin and Ian Glacken

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Ms Susan Havlin	4.4 Certainty risk				X		
Mr Ian Glacken	4.4 Certainty risk				X		
I acknowledge that thee represent my contribution to the above research output. Signed: Signed:							

Table 47. Attribution - Christine Standing

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Ms Christine Standing	4.5 Country risk				X		
I acknowledge that thee represent my contribution to the above research output. Signed:							

Table 48. Attribution – Mark Murphy

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Mr Mark Murphy	Appendix 12 Cross-commodity price analysis				X		
I acknowledge that thee represent my contribution to the above research output. Signed: M. Murphy 25 May 2019							

Table 49. Attribution – Jose Saveedra Rosas

Contributor	Relevant section	Conception and design	Data acquisition & method	Data conditioning & manipulation	Analysis & statistical method	Interpretation & discussion	Final Approval
Dr José Saavedra-Rosas	Appendix 13 Exploration price analysis				X		
I acknowledge that thee represent my contribution to the above research output. Signed:							

Appendix 1. Permission to Use Data

Figure A-1.1. Permission from Alexander Research Pty Ltd

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ACN 128 790 885
PO Box 3344, Broadway-Nedlands LPO
Crawley, Western Australia, 6009

PERMISSION TO USE DATA

I Jonathan Alexander Bell, the sole owner of Alexander Research Pty Ltd ('Alexander), grant permission to myself to use a subset of the Alexander database for original research relating to the undertaking of a Doctor of Philosophy. Specifically, the permission is granted for use in the thesis entitled 'Risk Adjusted Evaluation of Mineral Assets Using Transaction Based Statistical Models'.

Jon Bell
Managing Director

29 July 2017

www.alexanderresearch.com.au

Appendix 2. Australian gold deposit price estimates

Table A-2.1. Sample of Australian gold deposit price estimates

Price Estimates (AUD)			Confidence Metrics			Industry (non-academic) sources
Low	Preferred	High	Downside (%)	Upside (%)	Low - high range multiple	Deposits and authors
320	N/A	502	22	22	1.57	Mt Monger and Murchison (Gillett and Gregory 2012)
234	N/A	264	6	6	1.13	Randalls, Mt Monger and Aldiss (Gillett and Gregory 2012)
148	195	208	24	7	1.41	Challenger (Dunham et al. 2012)
150	166	174	10	5	1.16	McPhillamys (Williams and Gossage 2012)
133	162	192	18	18	1.45	Paddington (Parker 2012)
112	114	117	2	2	1.04	Frog's Legs (Spicer et al. 2009)
65	95	125	31	32	1.92	Central Murchison (Hancock and McIntyre 2012)
50	80	118	38	48	2.36	Laverton (Maynard 2007a)
48	72	96	33	34	1.98	South Kalgoorlie (Spicer et al. 2009)
30	49	60	38	22	1.96	Big Bell, (Onley et al. 2011)
21	39	60	46	53	2.86	Rover (Hancock and McIntyre 2012)
10	38	52	73	38	5.1	Bullabulling (Jones et al. 2011)
31	34	39	8	15	1.25	Coolgardie (Dunham et al. 2012)
28	34	39	16	16	1.37	Carnegie (Castle 2012)
27	32	39	18	19	1.45	Kalgoorlie (Dunham et al. 2012)
25	31	37	18	18	1.44	Bullabulling (Reidy 2011)
7.6	13.8	18.3	45	33	1.33	Wilsons, Premium and Swift, Kingfisher and Gidgee (Morley and Kentwell 2007)
8.2	9.9	11.5	17	17	1.40	Mount Morgan (Parker 2012)
7.6	8.7	9.9	13	13	1.30	Bullant (Cole 2011)
2.6	5.6	10.9	54	95	1.19	Meekatharra (Stephens 2008)
2.6	3.1	3.6	15	15	1.36	Mount Ida (Castle 2012)
1.7	2.6	3.5	35	35	2.06	Tasmania Mine (Bremner and McDermott 2011)
1.0	1.9	1.6	47	141	4.56	Twin Hills (Barclay and Lord 2008)
0.8	0.8	3.8	0	401	5.01	Klondyke (Helm, et al. 2008)
0.3	0.5	0.8	50	50	3.00	Norton (Parker 2012)

Table A-2.2. Sample of Australian gold exploration price estimates

Price Estimates (AUD)			Confidence Metrics		Source
Low	Preferred	High	Downside (%)	Upside (%)	Project, reference
21	62	104	67	67%	Paddington (Parker 2012)
38	52	64	27	25%	Higginsville (Mazzonie et al. 2010)
30	38	46	21	21%	Mount Monger and Murchison (Gillett and Gregory 2012)
10	38	52	73	38%	Bullabulling (Jones et al. 2011)
25	31	37	18	18%	Bullabulling (Reidy 2011)
19	23	26	16	16%	Randalls, Mt Monger and Aldiss (Gillett and Gregory 2012)
12	18	24	33	33%	Cracow, Mt Carlton, Twin Hills (Dorricott and Thomas 2011)
6	17	21	65	21%	Southern Cross (Spicer et al. 2009)
14	17	19	14	15%	Explorer 108 + 142 (Hancock and McIntyre 2012)
5.3	8.6	9.5	38	10%	Quartz Circle (Maynard and Pooley 2012)
5.5	8.0	12	31	50%	Tennant Creek (Maynard 2007a)
4.1	6.0	8.2	32	37%	Mount Hope (Randell et al. 2012)
1.9	4.5	7.1	58	59%	Majors Creek (Fairfield et al. 2012)
2.7	3.8	5.1	29	34%	Camel Hills (Castle 2010)
1.3	2.0	3.6	33	80%	Meekatharra (Stephens 2008)
2.7	3.5	4.3	24	24%	Carnegie, Siberia, Mt Ida (Castle 2012)
2.4	3.1	4.7	23	53%	Treasure Island (Ulrich et al. 2012)
1.7	2.6	3.5	345	35%	Tasmania Reef (Bremner and McDermott 2011)
1.2	2.1	3.0	43	43%	Tennant Creek (Varndell 2007)
0.4	1.5	2.6	75	75%	Mount Morgan (Parker 2012)
1.4	1.4	2.0	6	35%	Blue Spec (Hyland et al. 2012)
0.9	1.2	1.5	25	25%	McPhillamys (Williams and Gossage 2012)
0.6	1.2	1.8	50	50%	Tennant Creek (Maynard 2007b)
0.9	1.1	1.8	18	64%	Yarrol, Mount Steadmand, Pyramid, Gooroolba(Davis 2009)
0.2	0.6	1.9	72	217%	Eugowra (Fairfield 2012)
0.3	0.5	1.0	32	95%	Klondyke (Helm et al. 2008)
0.1	0.4	1.0	74	166%	Booths Reward(Fairfield 2012)
0.3	0.4	0.5	29	29%	Lakeside and Lake Lefroy-Hogans (Onley et al. 2011)
0.1	0.1	0.2	52	51%	Norton (Parker 2012
0.04	0.1	0.1	56	44%	Christmas Gift (Fairfield 2012)
Average			38%	51%	
Median			32%	35%	

Appendix 3. Cost methods

1.1. Multiples of Exploration expenditure method

The Multiples of Exploration Expenditure (MEE) methodology is largely based on vendor psychology and is a method that appears entirely within industry literature and is absent from the formal literature. Where possible, vendors will seek a return on sunk costs, and as a result, multipliers are used to estimate the possible price (Onley 1994). Some Specialists may also include warranted future expenditure in the calculations, thereby accounting for some of the acquirer's position. However, Wastell et al. (2010) found that there was no statistically significant relationship between probability estimates of finding a commercially viable deposit and justified future expenditure commitments. It was also suggested that despite mounting negative exploration results, expenditure commitments do not affect the probability estimation in a manner that is akin to "gambler's ruin". Wastell et al. (2010) noted the illogical interaction between mounting exploration expenditure and statistical probability estimates raises concern over what constitutes warranted expenditure. Therefore, the MEE method is considered by some Australian Specialists as the method of last resort for estimating a price (Etheridge 2009); yet, the method appears to be more accepted by Canadian Specialists even though the regulatory authorities are more resistant (Spence 2007).

The multipliers within the MEE method are generally only applied to sunk costs, however, the origin of the weights appears to be subjective (Thompson 2000), with little or no supporting empirical evidence to validate them. This lack of transparency is partly due to the lack of publicly available information that can directly be correlated with the comparable transactions method. The MEE is not currently falsifiable as no empirical evidence has been cited. Given the difficulty in obtaining empirical data and the questionable logic, the MEE method does not lend itself for use in analysing gold deposit transactions and what affects their price.

1.2. Kilburn method

The most common geoscientific methods for pricing an exploration project in Australia are variations of the Kilburn method (Kilburn 1990; Goulevich and Eupene 1994). This method is also one that appears exclusively within industry literature and is absent from the formal literature. The Kilburn method is an attempt to quantify the price of an exploration project by considering the mandated exploration expenditure and applying factors that recognise the qualities of a project (ATO 2013), such as:

- **location** – the proximity to external areas with demonstrated exploration merit
- **maturity** – the previous level of activity within the project
- **prospectivity** – what proportion of the geology of a project is conceptually prospective (a non-uniform distribution)
- **success** – whether the project is known to contain a mineral anomaly
- **time and circumstance** – a market adjustment factor which recognises the characteristics of commodity, financial and stock markets in addition to the mineral project markets (e.g. demand vs supply).

The rationale behind the Kilburn method is that the cost incurred to stake and hold a base unit area of a mineral tenement for a period of 12 months (Rudenno 2004) (the base holding cost (BHC)), represents the absolute minimum price of a tenement, else it would be relinquished. Some literature refers to the BHC as a "base acquisition cost", but to avoid confusion later in this research the BHC term is used. Multipliers are applied in an attempt to replicate the acquiring party's evaluation process by considering location, maturity, prospectivity, success, and the market. The theory is that if the correct factors are applied, the resulting figure should replicate the price (Goulevich and Eupene 1994). In a qualitative way, this process is analogous to the quantitative EV method where the future expenditure, probability of success and ultimate pay-off derive a technical value (Sorentino 2000; Etheridge 2009). Some common descriptions used, as demonstrated by Fairfield et al. (2012), Summons (2012) and Rudenno (2012), to qualify the Kilburn weightings are shown in Table A-3.1 (after Fairfield et al. 2012).

Table A-3.1. Common qualitative descriptions used in the Kilburn method

Relative location	Maturity	Prospectivity	Success
No workings	No workings	Generally unfavourable lithology	Extensive previous exploration with poor results
Minor or weak anomalies	Minor workings	Generally unfavourable lithology with structures	No targets outlined
Several anomalies	Several workings	Generally favourable lithology (10%-20%)	Geophysical or geochemical targets
Abundant or strong anomalies	Abundant workings	Alluvium covered, generally favourable lithology (50%)	anomalous drillhole intersections
Significant deposits	Significant mine	Generally favourable lithology (50%)	Intersections of potential economic interest
Major deposit	Major mine	Generally favourable lithology (70%)	N/A
World class deposit	World class mine	Generally favourable lithology	
N/A		Generally favourable lithology with structures	
		Generally favourable lithology with structures along strike of a major mine	

(after Fairfield et al., 2012)

The strength of the Kilburn method is that it is transparent, quick, easy to apply and uses a consistent starting point (BHC) for the pricing process. While it has its merits, the Kilburn method has its weaknesses, which include:

- **Arbitrary origins** – the weights of the multipliers for each of the descriptive qualities of a project are arbitrary in origin (Sorentino 2000). Kilburn (1990) never intended to be authoritative, rather he recommended that it be used as a ranking tool and weights could be changed as deemed fit by the person applying them. This is particularly important as Kahneman and Tversky (1984) and Huffman (2012) warn that while humans tend to agree on overall ratings of projects from low to high, the scales used tend not to match monetary outcomes.

- **Application** – over twenty years since being authored, the application of the example weights provided by Kilburn have not significantly changed, despite considerable time and circumstance differences. Philosophically this is problematic as it goes against the notion that geology is an interpretive and historical science (Raab and Frodeman 2002), where there is a significant amount of inference to the best explanation (Lipton 2004; Inkpen and Wilson 2009) and geology (Rudwick 1976), hence value and price are non-uniform.

- **Sensitivity** – as each of the drivers (the columns in Table A-3.1) are multiplicative, aligning the correct factors is difficult and the compounding imperfections can result in large variations (Butler 1994).

- **Logic** – the method does not consider that with the increased maturity and exploration success, the proportion of the tenement that remains prospective may decrease (an inverse relationship).
- **Spatially limited** – the methodology does not address the different market forces at play for small, medium and large project areas, as it is reliant on standardised unit values as a starting point (Sorentino 2000).
- **Non-uniform time, size and cost base** – mineral tenements have a finite life (e.g. in Western Australia it is five years, which can be extended up to twelve years), during which there are area reduction requirements as well as escalating annual costs. Tenements are also available in many different classifications (applications, exploration, mining leases, etc.), each of which have different holding costs and risks associated with them. Unfortunately, there is no mechanism within the Kilburn method to address such factors.

While it is possible to question the logic behind the Kilburn method, its main flaw is that it does not actually mimic the decision-making process used by the vendors and acquirers of a project (Butler 1994). Simple solutions tend to be too simplistic to represent reality (Hass and Pryor 2009)

1.3. Lilford Techno-economic matrix

The Lilford Techno-economic matrix (Lilford method) (Lilford 2004; Lilford and Minnitt 2005) is a relatively new geoscientific method, particularly in Australia. The main differences of the Lilford method relative to the Kilburn method is that it:

- prices deposits where preliminary estimates of size, grade and depth have been estimated, whereas the Kilburn method is used purely to price exploration projects for which mineral estimates have not yet been made
- uses additive (rather than multiplicative) weights to locate appropriate price ranges within a comparable transactions database rather than factorise a BHC.

In effect, the Lilford method adopts the comparability aspects of the Kilburn method and hybridises it with the market approach. An example of the Lilford method is reproduced in Table A-3.2 (Lilford 2011), from which the technical qualities are multiplied through to determine ‘points’ that are then used to reference in Table A-3.3 (Lilford 2011).

Table A-3.2. Lilford method qualifiers

Depth below surface (km)	Points	Estimate category	Points	*In situ* grade (g/t)	Points	Proximity	Points
0.00-0.25	0	Proven	0	0-1	7	Contiguous to high-grade mineralisation	1
0.25-2.00	1	Probable	1	1-2	6	Adjacent to low-grade mineralisation	2
2.00-4.00	2	Measured	2	2-3	5	Non-contiguous mineralisation	3
4.00-5.00	3	Indicated	2	3-4	4	Remote and large	4
>5.00	4	Inferred	3	4-5	3	Remote and small	5
		'Blue-sky'	4	5-6	2		
			6-8	>7	1		
			>8		0		

Table A-3.3. Quantum of the Lilford method index

Points summed	Attributable rating	Attributable rating	$/ha
1	1	1	15,000
2	2	2	14,000
4	3	3	13,000
		4	11,200
6	4-5	5	9,400
		6	8,000
9	6-7	7	6,400
		8	4,800
11	8-9	9	3,600
		10	2,800
13	10-11	11	2,200
		12	1,600
15	12-13	13	1,000
		14	700
17	14-15	15	300
>17	16	>16	1

The strength of the Lilford method over the Kilburn method is that it is linked to the market and therefore circumvents that Kilburn method's main weakness. However, the method uses two-dimensions (hectares) and price to describe a three-dimensional asset (a deposit), the shape and orientation of which are highly variable.

Appendix 4. Datasets

Table A-4.1. Ownership risk dataset

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
09-Oct-07	Sleeping Giant	54,891	13.88	100.00%	129.92
22-Sep-08	Tartan Lake	165,142	8.66	100.00%	17.96
15-Oct-08	Duport	315,676	12.11	51.00%	11.70
15-Oct-08	Duport	315,676	12.11	75.00%	42.46
20-Oct-08	Spring Valley	899,710	0.61	60.00%	55.51
20-Oct-08	Spring Valley	899,710	0.61	70.00%	60.27
23-Oct-07	Chester	176,527	6.39	46.25%	30.92
23-Oct-07	Chester	176,527	6.39	75.00%	25.48
24-May-07	West Kalgoorlie	612,108	1.80	35.00%	8.79
24-May-07	West Kalgoorlie	612,108	1.80	50.00%	18.74
24-May-07	West Kalgoorlie	612,108	1.80	70.00%	17.38
20-Nov-08	Twin Hills	197,719	7.41	100.00%	84.96
12-Dec-08	Yandan	316,363	2.40	51.00%	12.60
02-Dec-02	Chariot	237,697	18.30	43.00%	45.19
03-Jun-03	Riverina	61,980	11.90	70.00%	35.73
03-May-04	Burnakura	203,916	4.30	30.00%	40.49
01-Oct-02	Paddys Flat	932,372	2.00	100.00%	3.12
01-Oct-02	Lake Carey	469,771	2.21	100.00%	6.88
03-Aug-05	Indee	494,260	1.93	51.00%	5.63
01-Sep-03	Mt Korong	25,688	3.47	100.00%	4.12
09-Oct-07	Enterprise and Penny West	733,565	4.91	100.00%	2.70
22-Sep-08	Chalice and Indee	656,975	2.14	47.34%	5.78
15-Oct-08	Millrose project	251,114	2.13	53.00%	2.54
15-Oct-08	Dingo Range project	280,114	2.78	100.00%	2.82
20-Oct-08	Higginsville project	440,208	2.80	100.00%	8.96
20-Oct-08	Woolgar	405,418	1.58	51.00%	42.90
23-Oct-07	Woolgar	405,418	1.58	60.00%	53.04
23-Oct-07	Woolgar	405,418	1.58	70.00%	73.88
24-May-07	Menzies	172,012	2.55	100.00%	5.34
24-May-07	Minjar	406,413	2.46	100.00%	19.37
24-May-07	Penfold	261,659	2.12	100.00%	10.89
20-Nov-08	Dargues Reef	313,727	4.10	100.00%	19.57
12-Dec-08	Hollister Development Block	936,296	44.65	50.00%	105.59
02-Dec-02	Duquesne Gold Mines Ltd	298,657	6.03	100.00%	188.13

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
03-Jun-03	Comet -Webb's Patch	164,933	6.09	100.00%	10.81
03-May-04	Eureka	63,800	4.40	100.00%	25.03
01-Oct-02	British King	15,432	20.00	100.00%	51.73
01-Oct-02	Mt Ida	111,219	24.02	100.00%	30.31
03-Aug-05	Ravenswood	2,652,437	1.00	100.00%	15.42
01-Sep-03	Lupin	224,092	8.68	100.00%	24.03
14-May-03	Dogpay Lake	26,660	15.43	100.00%	26.13
01-Oct-03	Toms Gully	768,810	7.32	100.00%	48.48
01-Oct-03	Eastmain	272,534	10.64	100.00%	13.79
02-Jan-04	Beaconsfield	423,342	15.47	29.46%	28.73
01-Apr-04	Mount Morgan tails	137,477	0.97	100.00%	24.13
15-Feb-06	Taurus	720,000	1.00	100.00%	7.48
15-Feb-06	Jerritt Canyon	2,874,019	8.72	100.00%	19.73
15-Feb-06	Buffalo Gulch, Friday/Petsite, Deadwood	708,763	1.00	100.00%	5.07
03-Mar-06	Buffalo Gulch	708,763	1.00	100.00%	3.70
12-Apr-06	Buffalo Gulch	475,831	0.93	51.00%	3.78
05-Jul-06	Buffalo Gulch	653,303	1.03	51.00%	2.75
09-Feb-07	Buffalo Gulch	839,134	1.13	51.00%	2.14
21-Feb-07	Engineer	21,863	34.00	51.00%	37.24
21-Feb-07	Engineer	21,863	34.00	60.00%	42.06
21-Apr-06	Engineer	21,863	34.00	75.00%	44.75
01-Jun-06	Engineer	21,863	34.00	100.00%	50.21
01-Jun-06	Tonkin Springs	1,000,000	2.00	55.00%	29.47
26-Feb-07	Copperstone	614,563	10.47	75.00%	2.62
13-Jan-04	Lac Pelletier	122,199	7.84	100.00%	8.54
24-Feb-06	Aurbel	251,129	7.30	100.00%	29.75
11-May-06	Croinor	289,955	6.31	50.00%	14.40
15-Mar-07	Norseman	2,222,362	4.15	100.00%	26.55
27-Feb-07	Chalice	78,531	5.31	100.00%	76.23
23-Jan-07	Peak	1,368,151	7.71	100.00%	155.40
18-Jan-07	La Ronge	830,223	8.66	100.00%	1.90
02-Mar-07	Golden Heart	291,789	1.78	50.10%	6.44
20-May-03	Grew Creek	234,457	9.43	100.00%	7.35
02-Mar-07	Vinsale	1,028,280	1.95	100.00%	5.25
25-Aug-04	Barry	45,000	4.50	100.00%	14.23
24-Aug-05	Norlartic North	99,093	3.46	100.00%	29.49
24-Aug-05	Norlartic North	99,093	3.46	100.00%	29.49
24-Aug-05	Vault	116,643	5.56	45.45%	6.03
19-Jan-07	Vault	116,643	5.56	100.00%	2.74
19-Jan-07	Lapa	748,428	7.78	20.00%	52.57
19-Jan-07	Paddington	1,400,000	1.91	100.00%	27.74
19-Jan-07	Dubenski	72,192	6.32	100.00%	66.95
05-May-03	Mt Korong	92,498	2.74	80.00%	24.38
04-Mar-02	Menzies	170,851	2.50	100.00%	4.96

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
27-Sep-05	Kirkalocka	139,084	2.10	100.00%	42.34
05-May-03	Peak Hill	987,671	2.40	51.00%	9.65
01-May-07	Eucalyptus	174,330	2.51	100.00%	10.14
10-Jan-07	Laverton	81,859	4.10	100.00%	46.67
01-May-07	Riverina	196,451	3.73	100.00%	20.44
19-Feb-07	Mt Magnet	2,726,705	3.25	100.00%	22.68
24-Apr-02	Coolgardie	8,681	2.70	100.00%	50.70
15-Aug-06	Mt Gibson	877,072	2.20	100.00%	4.31
14-Jul-04	Mt Gibson	557,266	1.98	75.00%	20.68
02-Mar-07	Gidgee	492,791	5.95	100.00%	19.15
16-Jan-07	Youanmi	952,178	3.60	100.00%	9.01
24-Jan-06	Aphrodite	287,042	6.20	100.00%	20.92
24-Jan-06	Wiluna	745,579	5.67	100.00%	34.79
06-Mar-03	South Kalgoorlie	1,913,227	1.80	100.00%	20.94
06-Mar-03	Pajingo	485,685	7.50	100.00%	47.48
16-Jun-03	Mt Monger, Moyagee	549,826	9.89	100.00%	21.43
26-Apr-07	Stawel, Bendigo	3,737,878	3.08	100.00%	72.19
08-May-07	White Dam	328,779	1.12	100.00%	32.40
17-Jan-08	Mt Bundy	710,080	1.33	85.00%	8.88
03-Mar-06	Lefroy	280,626	8.22	100.00%	3.45
10-Jan-08	Burnakura	395,036	3.22	100.00%	17.62
20-Dec-07	Tuckabianna	236,887	3.27	100.00%	4.22
20-Dec-07	Rothsay	132,783	7.00	85.00%	7.07
29-Apr-05	Rothsay	132,783	7.00	85.00%	11.57
06-Aug-07	Randalls	275,853	3.90	100.00%	22.43
08-Nov-07	Bronzewing	386,946	2.47	100.00%	18.16
02-Aug-07	White Dam	329,770	1.13	50.00%	54.42
02-Aug-05	Comet	208,633	3.58	100.00%	6.97
08-May-07	Davyhurst	795,856	2.21	100.00%	7.73
03-May-07	Kalgoorlie Southeast	288,392	3.90	65.00%	20.26
03-May-07	Kalgoorlie Southeast	288,392	3.90	70.00%	19.20
03-May-07	Tirigniaq	3,092,217	7.92	15.21%	48.25
20-Jun-07	Lord Henry and Lord Nelson	348,506	2.64	100.00%	3.99
31-Jul-07	Hodgkinson Basin	43,835	1.47	90.00%	6.09
14-Feb-08	Wallbrook	607,470	1.53	100.00%	9.79
17-Aug-07	Minjar	406,900	2.46	100.00%	25.24
29-Oct-07	Springfield	66,205	1.43	51.00%	29.33
17-Dec-07	Springfield	1,000,000	1.43	100.00%	5.94
19-Feb-08	Durack	42,632	2.33	85.00%	13.25
28-Feb-08	Kalgoorlie West	680,991	1.77	100.00%	14.44
17-Oct-07	Three Rivers	131,175	2.40	100.00%	9.59
22-Aug-07	Burnakura	170,000	7.35	70.00%	103.16
03-Sep-07	Constellation	13,889	2.70	100.00%	10.59
03-Sep-07	White Well	83,592	1.30	70.00%	12.20

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
16-Mar-05	White Well	112,528	1.00	70.00%	9.06
15-Jun-04	White Well	112,528	0.70	70.00%	9.06
28-Mar-08	Illipah	30,598	1.10	100.00%	11.96
25-Mar-08	Quartz Mountain and Hope Butte	589,275	0.80	58.00%	7.91
08-Nov-05	Senore	50,156	8.60	100.00%	11.75
30-May-01	Blue Hill Creek	235,831	0.56	10.00%	27.22
28-Feb-01	Blue Hill Creek	235,831	0.56	20.00%	19.99
22-Dec-06	Blue Hill Creek	235,831	0.56	30.00%	18.29
23-Jun-05	Blue Hill Creek	235,831	0.56	40.00%	16.90
14-Oct-04	Blue Hill Creek	235,831	0.56	50.00%	16.59
22-Mar-07	Blue Hill Creek	235,831	0.56	60.00%	15.95
08-Apr-08	Blue Hill Creek	235,831	0.56	70.00%	15.92
15-Apr-08	Blue Hill Creek	235,831	0.56	85.00%	13.51
15-Apr-08	Blue Hill Creek	235,831	0.56	100.00%	11.91
29-May-08	Kilgore, Hai and Gold Bug	487,000	0.91	50.00%	18.14
29-May-08	Bounty	338,954	4.33	100.00%	2.98
29-May-08	Damoti Lake	43,534	23.19	100.00%	38.15
22-Oct-03	Bingo	105,652	14.06	80.00%	33.61
16-Apr-02	Abo	220,538	2.79	75.00%	44.85
12-Jun-08	Abo	220,538	2.79	75.00%	37.05
12-Jun-08	Nixon Fork	154,757	19.86	100.00%	3.32
12-Jun-08	Abo	220,538	2.79	75.00%	38.84
28-Aug-06	Abo	220,538	2.79	75.00%	56.66
02-Jul-08	Garrison	309,826	5.33	50.00%	26.15
16-Jul-08	Garrison	309,826	5.33	80.00%	32.69
22-Apr-08	Garrison	2,238,871	2.19	50.00%	3.62
22-Apr-08	Garrison	2,238,871	2.19	30.00%	6.03
22-Apr-08	Wallace South, Citroy Flagship, The Pinnacles, Weatherly Grid, City Girl and Brilliant-China Wall	72,873	2.34	100.00%	4.55
22-Apr-08	Cargo	224,669	0.82	70.00%	12.51
22-Apr-08	Constellation	13,889	2.70	100.00%	10.82
22-Apr-08	Mt Morgans	205,173	3.75	100.00%	19.25
22-Apr-08	Mt Morgans	205,173	3.75	80.50%	23.91
22-Apr-08	Yundamindera	47,397	2.35	70.00%	29.97
22-Apr-08	Mets	167,561	11.31	100.00%	2.17
10-Jun-08	Mets	167,561	11.31	100.00%	4.64
01-Aug-08	Commodore	51,698	2.40	100.00%	3.84
05-Aug-08	Anglo-Rouyn	46,794	1.32	100.00%	15.35
06-Aug-08	Yellowjacket	149,595	10.26	40.00%	27.17
28-Nov-08	Yellowjacket	149,595	10.26	40.00%	54.35
28-Nov-08	South Laverton	44,456	1.89	100.00%	5.19
18-Dec-08	Georgetown	96,342	20.91	100.00%	10.71
18-Dec-08	Back River	2,353,113	10.50	100.00%	6.37

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
29-Nov-07	Bronzewing	882,200	2.49	100.00%	7.72
21-Jan-09	Cadiscor Resources Inc	450,044	6.21	100.00%	16.29
21-Jan-09	Golden Promise	89,425	3.02	60.00%	36.72
21-Jan-09	Golden Promise	89,425	3.02	70.00%	44.60
21-Jan-09	Musgrove Creek	313,791	1.22	50.00%	15.71
31-Oct-02	Mick Adam and Wadi	226,012	1.31	50.00%	7.09
03-Sep-02	Mooseland	787,716	13.37	100.00%	20.11
16-Apr-02	Mooseland	787,716	13.37	95.00%	21.17
24-Feb-09	Hog Range	76,471	1.29	100.00%	13.76
24-Feb-09	Dohertys	19,665	23.80	90.00%	12.35
26-Feb-09	Terrain Minerals Ltd	358,952	2.13	98.80%	3.98
05-Feb-09	Box and Athona	1,256,580	1.16	100.00%	4.15
05-Feb-09	Elmtree	237,267	1.42	60.00%	17.26
10-Feb-09	Elmtree	237,267	1.42	70.00%	20.34
17-Feb-09	Castle-Black Rock	309,506	0.47	100.00%	16.10
27-Feb-09	Scheelite Dome, Ogopogo and Willoughby	143,232	1.35	100.00%	4.78
27-Feb-09	Brewery Creek	287,405	1.45	51.00%	24.50
12-Mar-09	Brewery Creek	287,405	1.45	65.00%	24.03
12-Mar-09	Brewery Creek	287,405	1.45	75.00%	24.99
30-Mar-09	Kookynie	424,240	2.34	100.00%	4.01
02-Apr-09	Georgetown alluvial	42,500	0.50	100.00%	50.62
31-Mar-09	Scorpio Mining Corp	212,032	7.24	49.00%	44.19
09-Apr-09	Premier	387,523	8.15	100.00%	46.70
09-Apr-09	Yarnell	325,800	0.34	70.00%	16.21
09-Apr-09	Simkar - 2 g/t cut off	105,112	5.10	50.00%	78.07
20-Apr-09	Xplor Ltd	23,909	6.39	100.00%	25.62
20-Apr-09	Davyhurst and Mt Ida	1,566,259	2.53	100.00%	27.49
20-Apr-09	Kirkalocka	262,881	1.96	20.00%	7.59
06-May-09	Kirkalocka	183,259	1.68	51.00%	12.81
19-May-09	Red Mountain	683,930	5.78	100.00%	15.24
10-Mar-09	Chester	68,370	14.74	50.00%	18.95
26-May-09	Chester	68,370	14.74	60.00%	18.80
01-Jun-09	Chester	68,370	14.74	70.00%	18.70
01-Jun-09	Nixon Fork	154,757	19.86	100.00%	23.45
26-Mar-09	Twin Hills	198,179	7.43	100.00%	7.13
05-Jun-09	Monroe Lakes	165,273	8.67	64.73%	9.90
08-Jun-09	Henty	145,027	7.82	100.00%	44.05
08-Jun-09	Shoal Lake	699,898	7.95	51.00%	9.87
08-Jun-09	Shoal Lake	699,898	7.95	75.00%	26.46
10-Jun-09	Sugarloaf	67,500	3.70	100.00%	7.68
11-Jun-09	Windarra	131,604	0.80	100.00%	13.03
03-Nov-08	Summit Lake	74,091	19.20	100.00%	2.33
15-Jun-09	Kalgoorlie North	266,709	1.82	70.00%	8.77
26-Aug-08	Prospect Valley	1,644,511	1.10	70.00%	5.85

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
16-Jun-09	Klondex Mines Ltd	2,147,911	9.72	100.00%	24.74
12-Jun-09	Klondex Mines Ltd	2,147,911	9.72	100.00%	22.85
23-Jun-09	Souart	110,000	6.17	25.00%	14.33
24-Jun-09	Souart	110,000	6.17	40.00%	17.38
24-Jun-09	Souart	110,000	6.17	50.00%	20.65
25-Jun-09	Souart	110,000	6.17	80.00%	21.33
26-Jun-09	Souart	110,000	6.17	100.00%	19.17
26-Jun-09	Dingman	413,087	0.89	100.00%	11.77
26-Jun-09	Ardeen	442,073	12.50	75.00%	27.16
29-Jun-09	North Bullfrog	81,564	0.85	70.00%	15.40
01-Jul-09	Crocodile Gold Inc	4,142,063	2.54	100.00%	10.30
30-Jun-09	Lancefield and Beasely Creek	1,699,209	4.12	100.00%	3.98
06-Jul-09	Golden Zone	267,705	2.92	51.00%	12.51
09-Jul-09	Golden Zone	267,705	2.92	100.00%	12.11
09-Jul-09	Simkar	143,419	3.01	50.00%	54.47
09-Jul-09	Chester	193,880	7.03	92.50%	6.19
12-Jun-09	Metallic Ventures Gold Inc	5,945,517	0.61	100.00%	5.68
06-Jul-09	Destiny	100,684	5.12	60.00%	56.53
22-Jul-09	Eureka	63,800	4.40	100.00%	28.50
21-Jul-09	Almaden	881,815	0.68	100.00%	4.40
20-Jul-09	Garrison	2,238,871	2.19	50.00%	4.12
15-Jun-09	Garrison	2,238,871	2.19	80.00%	5.15
27-Jul-09	REN	723,392	10.00	100.00%	5.06
27-Jul-09	Aphrodite	287,042	6.20	100.00%	21.92
27-Jul-09	Augusta	244,764	23.00	100.00%	38.10
27-Jul-09	Regcourt	10,767	5.49	100.00%	11.55
27-Jul-09	Aphrodite	287,042	6.20	20.00%	21.66
31-Jul-09	Goldboro	802,922	4.06	50.00%	21.45
03-Aug-09	Rocmec 1	543,674	6.10	49.00%	20.87
04-Aug-09	Golden Star and Nipigon	34,111	10.76	12.50%	65.60
17-Apr-09	Golden Star and Nipigon	34,111	10.76	29.00%	63.62
14-Aug-09	Golden Star and Nipigon	34,111	10.76	49.00%	66.94
19-Aug-09	Metallic Ventures Gold Inc	5,977,532	0.62	100.00%	7.33
19-Aug-09	Roxmark Mines Ltd	1,064,769	9.99	34.26%	155.36
17-Aug-09	Jackson Minerals Ltd	330,717	2.09	17.20%	12.73
21-Aug-09	Golden Rose	624,000	8.09	100.00%	2.93
24-Aug-09	Lac Laura	30,608	5.83	100.00%	28.06
01-Sep-09	New Britannia	766,085	5.31	100.00%	42.60
04-Sep-09	Egerton	23,909	6.39	100.00%	20.13
08-Sep-09	Egerton	23,909	6.39	100.00%	16.47
14-Sep-09	Maldon	182,488	12.00	100.00%	27.27
14-Sep-09	Hidefield Gold Plc	275,975	3.04	100.00%	39.88
16-Sep-09	Metallic Ventures Gold Inc	5,954,945	0.61	100.00%	6.89
24-Sep-09	Easter	198,697	2.03	65.00%	16.96

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
24-Sep-09	Hyland	113,171	1.10	100.00%	20.71
24-Sep-09	X-Ore Resources Inc	424,860	5.50	100.00%	17.82
28-Sep-09	Stairs	36,326	30.38	100.00%	41.13
29-Sep-09	Hazard Lake	16,352	8.76	100.00%	6.61
30-Sep-09	Duparquet	3,508,556	3.64	50.00%	58.23
01-Oct-09	Ren	1,653,487	13.44	64.00%	39.69
01-Oct-09	Big Bell	1,495,006	4.05	100.00%	6.86
01-Oct-09	Big Bell	1,495,006	4.05	100.00%	3.85
13-Oct-09	Indee	1,000,000	7.50	49.00%	11.26
13-Oct-09	Indee	1,000,000	7.50	49.00%	17.33
16-Oct-09	Gold Dust	104,940	12.00	100.00%	14.61
19-Oct-09	Emerald Lake	624,000	8.09	100.00%	2.67
20-Oct-09	Desantis	46,283	7.89	51.00%	86.26
20-Oct-09	Desantis	46,283	7.89	100.00%	92.08
22-Oct-09	Spargoville	4,866	1.81	100.00%	18.77
10-Aug-07	Emerald Lake	624,000	8.09	30.00%	7.05
16-Oct-09	Dioro Exploration NL	2,796,589	2.55	78.29%	43.14
20-Oct-09	Firstgold Corp	921,384	0.41	38.25%	42.76
29-Oct-09	Cameron Lake	449,298	5.41	100.00%	19.19
04-Nov-09	Valentine Lake	443,847	10.50	50.00%	25.57
09-Nov-09	Charters Towers	10,709,414	14.03	18.00%	17.40
12-Nov-09	Island	671,307	9.23	45.00%	58.23
16-Nov-09	Meadowbank	3,995,412	4.76	100.00%	159.12
16-Nov-09	Young-Davidson	1,354,452	2.82	100.00%	13.28
16-Nov-09	Cripple Creek and Victor	7,352,826	0.72	33.00%	62.66
18-Nov-09	Celtic, Coogee, Redcastle and Euro	231,386	2.15	19.77%	3.45
23-Nov-09	Spanish Mountain	1,848,680	0.81	30.00%	29.73
10-Nov-09	Cochrane Hill and Caribou	212,032	7.24	66.80%	37.03
23-Nov-09	Big Springs	1,200,000	2.43	100.00%	5.47
23-Jun-08	Detour Lake	13,202,286	1.34	42.40%	6.81
24-Nov-09	Mesquite	4,380,322	0.52	100.00%	55.62
27-Nov-09	Cadiscor Resources Inc	450,044	6.21	100.00%	31.21
01-Dec-09	Crocodile Gold Inc	4,142,063	2.54	100.00%	6.18
01-Dec-09	Greywacke	93,893	9.80	49.00%	6.36
08-Dec-09	Nordeau	145,076	6.31	100.00%	43.70
16-Dec-09	Duquesne West	304,980	8.89	50.00%	43.51
18-Dec-09	Tunkillia	742,682	2.20	51.00%	11.23
20-Jul-09	Vogel	643,422	12.70	100.00%	4.35
23-Dec-09	Schumacher	30,043	5.99	100.00%	22.73
23-Dec-09	Duport	626,315	10.91	100.00%	12.51
22-Sep-08	Hycroft	711,375	0.65	100.00%	16.74
27-Oct-08	Mt Dimer	70,222	5.79	100.00%	19.14
14-Feb-07	Corinthian, Pioneed, Mt Dimer North, Ubini and Brown Lake	106,056	2.52	97.51%	23.24

Date	Project	X- Size (oz Au)	Y -Grade (g/t Au)	Z -Equity (% acquired)	Magnitude (US$/oz Au)
14-Sep-05	Aquarius	1,042,865	2.16	86.00%	13.66
14-Jan-08	East Amphi and Fourax	890,491	4.72	100.00%	13.19
23-May-08	Ulu	568,206	12.91	100.00%	48.26
05-Dec-07	Coyote	411,883	5.41	100.00%	28.21
29-Jul-08	Mesquite	1,424,900	0.71	100.00%	7.83
17-Sep-08	Rocky Dam	10,465	9.30	51.00%	370.06
17-Sep-08	Rocky Dam	10,465	9.30	70.00%	431.39
17-Nov-08	Bounty	338,954	4.33	100.00%	0.49
03-Feb-03	Mikado	782,707	2.37	40.00%	1.55
01-Sep-03	Karonie	455,887	2.29	100.00%	0.68
19-Apr-06	Kasagiminnis Lake	401,240	4.80	100.00%	0.35
12-May-03	McKinnon	965,881	8.35	100.00%	0.31
04-Apr-08	Cracow	1,000,277	8.57	70.00%	262.24
17-Jun-04	Raeside, Cardinia and Mertondale	221,503	1.94	100.00%	0.40
18-Mar-08	Santa Anna	165,207	3.18	100.00%	0.63
26-Jan-09	Haile extension	85,313	1.30	100.00%	0.21
20-Apr-09	Mick Adam and Wadi	226,012	1.31	50.00%	0.64
03-Sep-09	Abo	220,688	2.79	100.00%	0.35
03-Sep-09	High Lake	84,496	9.77	100.00%	1.51
08-Oct-09	Davidson-Tisdale	56,918	7.90	31.50%	204.78
03-Nov-09	Little Stull Lake	248,365	10.30	71.60%	0.55

Table A-4.2. Ownership risk dataset

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
17-Sep-08	Rocky Dam	9.30	10,465	813	228.42
22-Sep-08	Sleeping Giant	13.88	54,891	889	115.09
09-Oct-07	Sleeping Giant	13.88	54,891	728.8	138.02
22-Sep-08	Tartan Lake	8.66	165,142	889	19.08
15-Oct-08	Duport	12.11	315,676	847	37.38
15-Oct-08	Duport	12.11	315,676	847	37.38
20-Oct-08	Spring Valley	0.61	899,710	795	29.73
23-Oct-07	Chester	6.39	176,527	757.5	17.74
24-May-07	West Kalgoorlie	1.80	612,108	659	15.37
17-Nov-08	Bounty	4.33	338,954	734	0.52
20-Nov-08	Twin Hills	7.41	197,719	738	90.25
12-Dec-08	Yandan	2.40	316,363	826.5	9.67
03-Jun-03	Riverina	11.90	61,980	365	37.96
01-Oct-02	Paddys Flat	2.00	932,372	324.66174	3.31
01-Oct-02	Lake Carey	2.21	469,771	324.66174	7.31
03-Aug-05	Indee	1.93	494,260	434.6	5.98
01-Sep-03	Mt Korong	3.47	25,688	376.25	4.38
01-Sep-03	Karonie	2.29	455,887	376.25	0.72

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
14-May-03	Enterprise and Penny West	4.91	733,565	353.55	2.86
01-Oct-03	Millrose project	2.13	251,114	383.5	2.70
02-Jan-04	Dingo Range project	2.78	280,114	415.25	3.00
01-Apr-04	Higginsville project	2.80	440,208	427.25	9.52
15-Feb-06	Woolgar	1.58	405,418	540.5	46.57
3-Mar-06	Menzies	2.55	172,012	565	5.68
12-Apr-06	Minjar	2.46	406,413	597.25	20.58
5-Jul-06	Penfold	2.12	261,659	623	11.57
20-Sep-04	Dreadnought	3.00	93,559	404.3	4.52
14-Jun-05	Coolgardie	3.40	41,539	426.85	105.41
9-Feb-07	Dargues Reef	4.10	313,727	664.5	20.79
21-Feb-07	Duquesne Gold Mines Ltd	6.03	298,657	661.25	194.59
21-Apr-06	Comet -Webb's Patch	6.09	164,933	623.5	11.49
01-Jun-06	Eureka	4.40	63,800	625	26.59
01-Jun-06	British King	20.00	15,432	625	54.96
26-Feb-07	Mt Ida	24.02	111,219	685.75	32.20
13-Jan-04	Ravenswood	1.00	2,652,437	425.5	16.38
24-Feb-06	Lupin	8.68	224,092	554.15	25.53
11-May-06	Dogpay Lake	15.43	26,660	715.5	21.73
15-Mar-07	Toms Gully	7.32	768,810	648.5	51.50
27-Feb-07	Eastmain	10.64	272,534	676.2	14.65
18-Jan-07	Mount Morgan tails	0.97	137,477	635	25.64
2-Mar-07	Taurus	1.00	720,000	651.9	7.95
20-May-03	Jerritt Canyon	8.72	2,874,019	366.3	19.21
02-Mar-07	Buffalo Gulch, Friday/Petsite, Deadwood	1.00	708,763	651.9	2.02
25-Aug-04	Buffalo Gulch	1.00	708,763	406	2.57
19-Jan-07	Engineer	34.00	21,863	629	53.34
19-Apr-06	Kasagiminnis Lake	4.80	401,240	624.75	0.37
05-May-03	Tonkin Springs	2.00	1,000,000	340.5	19.46
12-May-03	McKinnon	8.35	965,881	351.1	0.32
04-Mar-02	Copperstone	10.47	614,563	298.5216	2.79
27-Sep-05	Lac Pelletier	7.84	122,199	464.1	6.60
05-May-03	Aurbel	7.30	251,129	340.5	31.60
10-Jan-07	Norseman	4.15	2,222,362	608.4	28.21
01-May-07	Chalice	5.31	78,531	677.5	80.98
19-Feb-07	Peak	7.71	1,368,151	670.75	165.09
24-Apr-02	La Ronge	8.66	830,223	303.304261	2.02
15-Aug-06	Golden Heart	1.78	291,789	625.5	6.84
14-Jul-04	Grew Creek	9.43	234,457	403.8	4.58
02-Mar-07	Vinsale	1.95	1,028,280	651.9	3.09
16-Jan-07	Barry	4.50	45,000	627.05	15.11
24-Jan-06	Norlartic North	3.46	99,093	557.25	23.55
06-Mar-03	Vault	5.56	116,643	354.7	2.91
26-Apr-07	Paddington	1.91	1,400,000	673	29.47

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
08-May-07	Dubenski	6.32	72,192	685.9	71.12
17-Jan-08	Mt Korong	2.74	92,498	888.25	13.09
03-Mar-06	Menzies	2.50	170,851	565	5.26
10-Jan-08	Kirkalocka	2.10	139,084	884.25	44.98
20-Dec-07	Peak Hill	2.40	987,671	799.5	10.25
20-Dec-07	Eucalyptus	2.51	174,330	799.5	10.77
29-Apr-05	Laverton	4.10	81,859	435.7	49.58
06-Aug-07	Riverina	3.73	196,451	671.5	21.73
08-Nov-07	Mt Magnet	3.25	2,726,705	832.25	24.10
02-Aug-07	Coolgardie	2.70	8,681	666.25	53.86
02-Aug-05	Mt Gibson	2.20	877,072	431	4.57
08-May-07	Mt Gibson	1.98	557,266	685.9	8.80
03-May-07	Gidgee	5.95	492,791	675.9	20.34
03-May-07	Youanmi	3.60	952,178	675.9	9.57
03-May-07	Aphrodite	6.20	287,042	675.9	22.22
20-Jun-07	Wiluna	5.67	745,579	657.7	36.96
31-Jul-07	South Kalgoorlie	1.80	1,913,227	665.5	22.24
14-Feb-08	Pajingo	7.50	485,685	906	50.44
17-Aug-07	Mt Monger, Moyagee	9.89	549,826	657.5	22.77
29-Oct-07	Stawel, Bendigo	3.08	3,737,878	792.5	76.69
17-Dec-07	White Dam	1.12	328,779	787	34.42
19-Feb-08	Mt Bundy	1.33	710,080	924	9.44
28-Feb-08	Lefroy	8.22	280,626	959.75	3.66
17-Oct-07	Burnakura	3.22	395,036	759.75	18.72
22-Aug-07	Tuckabianna	3.27	236,887	659.5	4.49
03-Sep-07	Rothsay	7.00	132,783	672	7.51
16-Mar-05	Randalls	3.90	275,853	443	23.83
15-Jun-04	Bronzewing	2.47	386,946	393.25	19.29
25-Mar-08	Comet	3.58	208,633	926.75	7.41
8-Nov-05	Davyhurst	2.21	795,856	461.6	8.21
04-Apr-08	Cracow	8.57	1,000,277	905.5	278.59
30-May-01	Kalgoorlie Southeast	3.90	288,392	275.08	12.02
23-Jun-05	Lord Henry and Lord Nelson	2.64	348,506	439.15	4.24
14-Oct-04	Hodgkinson Basin	1.47	43,835	415.35	6.47
22-Mar-07	Wallbrook	1.53	607,470	663	10.40
08-Apr-08	Minjar	2.46	406,900	915	26.81
15-Apr-08	Springfield	1.43	66,205	929.75	53.99
17-Jun-04	Raeside, Cardinia and Mertondale	1.94	221,503	386.1	0.43
29-May-08	Durack	2.33	42,632	883	7.97
29-May-08	Kalgoorlie West	1.77	680,991	883	15.34
29-May-08	Three Rivers	2.40	131,175	883	10.18
22-Oct-03	Burnakura	7.35	170,000	384.75	109.59
16-Apr-02	Constellation	2.70	13,889	301.257726	11.25
12-Jun-08	White Well	1.00	112,528	862.25	8.08

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
28-Aug-06	Illipah	1.10	30,598	621.25	12.71
02-Jul-08	Quartz Mountain and Hope Butte	0.80	589,275	935.25	5.53
18-Mar-08	Santa Anna	3.18	165,207	1006.75	0.67
16-Jul-08	Senore	8.60	50,156	977	10.42
22-Apr-08	Blue Hill Creek	0.56	235,831	918	12.65
01-Aug-08	Bounty	4.33	338,954	912.5	3.16
05-Aug-08	Damoti Lake	23.19	43,534	882	40.53
06-Aug-08	Bingo	14.06	105,652	879.5	33.65
28-Nov-08	Abo	2.79	220,538	814.5	24.97
18-Dec-08	Nixon Fork	19.86	154,757	855.25	3.53
23-Dec-08	Taurus	1.00	1,041,684	843.5	2.16
24-Oct-05	Venus	1.50	25,000	466.1	34.53
07-Apr-08	Dargues Reef	4.10	313,727	926.5	5.34
12-Jun-08	White Well	1.00	112,528	862.25	6.39
21-Jan-09	Garrison	5.33	309,826	849.25	18.64
21-Jan-09	Garrison	2.19	2,238,871	849.25	3.46
26-Jan-09	Haile extension	1.30	85,313	910.25	0.23
31-Oct-02	Wallace South, Citroy Flagship, The Pinnacles, Weatherly Grid, City Girl and Brilliant-China Wall	2.34	72,873	318.62005	4.83
3-Sep-02	Cargo	0.82	224,669	311.253696	8.43
16-Apr-02	Constellation	2.70	13,889	301.257726	11.49
24-Feb-09	Mt Morgans	3.75	205,173	984.25	25.40
26-Feb-09	Yundamindera	2.35	47,397	936.5	23.79
05-Feb-09	Mets	11.31	167,561	920	2.31
10-Feb-09	Commodore	2.40	51,698	909.5	4.08
11-Feb-09	Valentine Lake	10.50	443,847	938	11.89
17-Feb-09	Anglo-Rouyn	1.32	46,794	968	16.30
12-Mar-09	South Laverton	1.89	44,456	925.25	5.51
12-Mar-09	Georgetown	20.91	96,342	925.25	11.38
30-Mar-09	Back River	10.50	2,353,113	928	6.77
02-Apr-09	Bronzewing	2.49	882,200	897.75	8.21
31-Mar-09	Cadiscor Resources Inc	6.21	450,044	916.5	17.31
09-Apr-09	Golden Promise	3.02	89,425	880.5	29.31
20-Apr-09	Mooseland	13.37	787,716	877	14.37
06-May-09	Hog Range	1.29	76,471	910	14.62
19-May-09	Dohertys	23.80	19,665	924.75	10.83
10-Mar-09	Terrain Minerals Ltd	2.13	358,952	901.5	4.22
26-May-09	Box and Athona	1.16	1,256,580	945	4.41
01-Jun-09	Elmtree	1.42	237,267	981.75	17.93
26-Mar-09	Castle-Black Rock	0.47	309,506	938.25	17.10
05-Jun-09	Scheelite Dome, Ogopogo and Willoughby	1.35	143,232	962	5.08
08-Jun-09	Brewery Creek	1.45	287,405	943.75	16.57

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
10-Jun-09	Kookynie	2.34	424,240	953.75	4.27
11-Jun-09	Georgetown alluvial	0.50	42,500	947.5	53.77
15-Jun-09	Premier	8.15	387,523	932.25	37.45
26-Aug-08	Yarnell	0.34	325,800	827	17.22
12-Jun-09	Xplor Ltd	6.39	23,909	937.25	27.22
23-Jun-09	Davyhurst and Mt Ida	2.53	1,566,259	920.75	29.21
24-Jun-09	Kirkalocka	1.68	183,259	933.5	11.27
25-Jun-09	Red Mountain	5.78	683,930	937.25	16.19
26-Jun-09	Chester	14.74	68,370	942	19.86
29-Jun-09	Nixon Fork	19.86	154,757	935.5	24.18
01-Jul-09	Twin Hills	7.43	198,179	938.25	7.57
30-Jun-09	Monroe Lakes	8.67	165,273	934.5	10.52
06-Jul-09	Henty	7.82	145,027	924.5	46.80
09-Jul-09	Sugarloaf	3.70	67,500	911.75	5.62
12-Jun-09	Windarra	0.80	131,604	937.25	13.84
06-Jul-09	Summit Lake	19.20	74,091	924.5	2.48
22-Jul-09	Kalgoorlie North	1.82	266,709	948.25	9.32
21-Jul-09	Prospect Valley	1.10	1,644,511	947.75	4.34
20-Jul-09	Klondex Mines Ltd	9.72	2,147,911	952.75	26.28
27-Jul-09	Souart	6.17	110,000	955	13.99
31-Jul-09	Dingman	0.89	413,087	939	12.09
03-Aug-09	Ardeen	12.50	442,073	959.75	26.32
04-Aug-09	North Bullfrog	0.85	81,564	960.5	16.36
17-Apr-09	Crocodile Gold Inc	2.54	4,142,063	870.5	10.95
14-Aug-09	Lancefield and Beasely Creek	4.12	1,699,209	953.6	3.94
03-Jul-09	Gateway Mining Ltd	1.66	463,865	932.5	16.01
19-Aug-09	Golden Zone	2.92	267,705	943	8.62
21-Aug-09	Chester	7.03	193,880	952.5	6.58
01-Sep-09	Destiny	5.12	100,684	955	42.30
04-Sep-09	Eureka	4.40	63,800	989	24.68
03-Sep-09	Abo	2.79	220,688	983	0.28
03-Sep-09	High Lake	9.77	84,496	983	1.60
08-Sep-09	Almaden	0.68	881,815	1000.7	4.68
14-Sep-09	Garrison	2.19	2,238,871	999.25	2.57
16-Sep-09	REN	10.00	723,392	1015.7	5.13
24-Sep-09	Aphrodite	6.20	287,042	1009.7	23.29
24-Sep-09	Augusta	23.00	244,764	1009.7	40.48
24-Sep-09	Regcourt	5.49	10,767	1009.7	11.76
19-Oct-09	Golden Rose	8.09	624,000	1047.5	2.80
20-Oct-09	Lac Laura	5.83	30,608	1061.7	25.11
20-Oct-09	New Britannia	5.31	766,085	1061.7	45.22
22-Oct-09	Egerton	6.39	23,909	1053	21.37
10-Aug-07	Egerton	6.39	23,909	668.5	17.50
16-Oct-09	Maldon	12.00	182,488	1050.5	28.95

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
22-Oct-09	Bell Creek West	10.00	100,000	1053	253.55
29-Oct-09	Metallic Ventures Gold Inc	0.61	5,954,945	1040.5	7.32
03-Nov-09	Little Stull Lake	10.30	248,365	1061	5.75
04-Nov-09	Easter	2.03	198,697	1090	11.57
09-Nov-09	Hyland	1.10	113,171	1106.7	16.91
12-Nov-09	X-Ore Resources Inc	5.50	424,860	1114.75	18.97
16-Nov-09	Stairs	30.38	36,326	1130	32.92
16-Nov-09	Hazard Lake	8.76	16,352	1130	5.17
18-Nov-09	REN	13.44	1,653,487	1149	34.96
23-Nov-09	Big Bell	4.05	1,495,006	1169.5	7.10
24-Nov-09	Gold Dust	12.00	104,940	1163.2	11.21
27-Nov-09	Emerald Lake	8.09	624,000	1166.5	2.37
02-Dec-09	Mt Perry	2.00	1,000,000	1212.5	7.16
01-Dec-09	Desantis	8.64	50,722	1192.5	90.00
08-Dec-09	Spargoville	1.81	4,866	1146.75	20.11
23-Dec-09	Cameron Lake	5.41	449,298	1085.2	20.56
14-Feb-07	Meadowbank	4.76	3,995,412	668.25	169.03
14-Sep-05	Young-Davidson	2.82	1,354,452	449.3	14.10
29-Jul-08	Cochrane Hill and Caribou	7.24	212,032	916.75	39.34
19-Aug-08	Big Springs	2.43	1,200,000	796.25	5.82
04-Mar-09	Mesquite	0.52	4,380,322	908.5	59.09
10-Feb-09	Cadiscor Resources Inc	6.21	450,044	909.5	33.15
06-Aug-09	Crocodile Gold Inc	2.54	4,142,063	964	6.56
29-Dec-09	Dioro Exploration NL	2.55	2,796,589	1106	49.68
25-May-06	Nordeau	6.31	145,076	642.5	35.19
05-Apr-05	Tunkillia	2.20	742,682	424.6	7.32
07-Mar-05	Vogel	12.70	643,422	433	4.62
01-Dec-05	Schumacher	5.99	30,043	499.75	15.15
31-Jan-07	Bell Creek	7.90	136,529	650.5	70.45
06-Jul-04	Duport	11.96	686,372	394.5	12.12
24-Jan-05	Hycroft	0.65	711,375	427.35	17.69
30-Dec-04	Mt Dimer	5.79	70,222	435.6	20.33
30-Dec-04	Corinthian, Pioneed, Mt Dimer North, Ubini and Brown Lake	2.52	106,056	435.6	24.69
29-Dec-05	Aquarius	2.16	1,042,865	513	14.51
09-Dec-03	East Amphi and Fourax	4.72	890,491	407.75	13.29
03-Dec-03	Ulu	12.91	568,206	401.8	51.27
03-Nov-03	Coyote	5.41	411,883	383.25	29.57
15-Jul-03	Mesquite	0.71	1,428,175	348.25	1.21
07-Jan-10	Bullabulling	1.44	416,578	1130.25	4.13
08-Jan-10	Kerr-Addison	4.72	695,193	1126.7	3.36
20-Jan-10	Triton	15.00	600,000	1120.2	2.08
20-Jan-10	Borealis - heaps	1.84	2,275,905	1120.2	11.34
05-Feb-10	Mt Korong, Mt Zephyr and Mt Goose	2.70	92,000	1058	6.38

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
05-Feb-10	Eucalyptus and Malcolm	2.86	207,800	1058	3.84
08-Feb-10	Hope Brook	4.76	772,003	1064	0.40
08-Feb-10	DeSantis	6.75	80,055	1064	47.34
09-Feb-10	Clavos	6.83	147,470	1071.2	30.33
05-Mar-10	Ballarat	11.85	1,485,364	1135	2.88
04-Mar-10	Terra	12.55	172,737	1134.5	50.19
08-Mar-10	Sugar Zone	9.75	283,502	1125.7	32.38
11-Mar-10	Underworld Resources Inc	2.96	1,412,323	1104	95.26
15-Mar-10	Souart	6.17	110,000	1104.2	60.17
11-Mar-10	Eureka and British King	8.23	158,323	1104	18.19
26-Mar-10	Webbs Patch	4.68	6,692	1096.5	30.16
29-Mar-10	Kalgoorlie North	1.40	360,088	1107.5	9.99
23-Mar-10	Staccato Gold Resources Ltd	1.47	262,618	1101.5	36.48
01-Apr-10	Burnakura	6.91	91,371	1123.5	44.97
01-Apr-10	Comaplex Minerals Corp	7.35	5,039,050	1123.5	148.92
07-Apr-10	Golden Arrow	1.02	524,540	1142	18.17
15-Apr-10	Gold Summit Corp	3.33	441,759	1154.5	6.79
20-Apr-10	Vezza	5.61	409,588	1144.75	25.33
27-Apr-10	Afgan-Kobeh	1.00	92,031	1154.5	4.22
30-Apr-10	Bluff	2.67	557,012	1166.75	9.51
06-May-10	Paulsens	12.75	128,757	1185.25	111.05
24-Sep-09	Costerfield	20.49	330,746	1009.7	29.96
07-May-10	Coogee	4.00	35,681	1202.25	30.14
18-May-10	Fayolle	6.33	66,314	1216.75	301.95
01-Jun-10	Wildrose	9.94	9,277	1227.75	257.61
03-Jun-10	New Island Resources Inc	2.93	248,221	1215	19.68
09-Jun-10	Bendigo Creek	0.58	33,565	1233.5	36.18
14-Jun-10	Springfield	1.43	66,205	1223.75	5.67
22-Jun-10	X-Cal Resources Ltd	0.59	1,860,692	1236	18.03
18-Jun-10	West Kalgoorlie	1.84	595,638	1256	5.56
28-Jun-10	Georgia River	19.12	75,581	1261	1.68
29-Jun-10	Paulsens	12.75	128,757	1234.5	126.25
29-Jun-10	McWatters	5.93	77,194	1234.5	49.09
05-Jul-10	Tagish Lake Gold Corp	7.29	561,919	1207.75	25.15
07-Jul-10	Bullant	5.35	69,700	1201.55	68.36
07-Jul-10	Mt Magnet	2.19	3,586,607	1201.55	8.80
09-Jul-10	North Queensland Metals Ltd	4.01	1,396,001	1209.8	33.75
20-Jul-10	Gullewa	6.69	714,373	1183	13.88
10-Aug-10	Blackburn	1.12	238,131	1192.5	2.52
10-Aug-10	Duverny	2.57	504,469	1192.5	3.61
26-Aug-10	Tagish Lake Gold Corp	7.37	567,668	1237	34.54
31-Aug-10	Golden Goose Resources Inc	7.24	1,741,939	1246	7.20
07-Sep-10	Fenelon, Northway-Noyon and Northshore	1.62	1,053,792	1256.75	36.21
15-Sep-10	Penny's Find	5.18	52,340	1267	71.12

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
24-Sep-10	Rolling Rock Resources Corp	5.98	1,212,016	1297	8.78
27-Sep-10	Shoal Lake East	7.85	691,606	1297	11.28
28-Sep-10	Lorena	8.89	78,012	1308.9	271.57
28-Sep-10	Buckingham and Moore-MacDonald	11.66	85,000	1308.9	4.37
01-Oct-10	Caribou	5.83	65,661	1316.25	34.70
06-Oct-10	Mt Dimer	4.63	102,734	1346.5	23.34
06-Oct-10	Golden Zone	3.89	231,743	1346.5	12.88
14-Oct-10	Crowshore	10.97	29,004	1373.25	7.07
21-Oct-10	Challenger - low grade stockpile	6.78	951,669	1343.5	390.55
28-Oct-10	Ironstone	1.61	79,943	1333.5	26.21
29-Oct-10	Western Standard Metals Ltd	0.98	1,843,450	1346.75	16.13
26-Nov-10	Cowarra	2.30	36,973	1355	15.66
30-Nov-10	Kilgore, Hai and Gold Bug	0.91	487,000	1383.5	6.24
03-Dec-10	Coogee	3.91	34,872	1403.5	34.23
09-Dec-10	Bullant	5.35	69,700	1391.25	140.28
15-Dec-10	Lapaska	3.14	22,210	1388.75	355.96
16-Dec-10	Nudulama	4.46	47,970	1363	2.50
23-Dec-10	Kerr-Addison	4.71	703,536	1373.5	3.52
12-Jan-11	Meekatharra	1.72	2,466,207	1378.75	10.42
11-Jan-11	Marmion South	2.06	4,860	1374	251.52
21-Jan-11	Spring Hill	2.34	273,847	1343.5	26.36
24-Jan-11	Mt Porter-Frances Creek	3.02	34,498	1343	89.67
31-Jan-11	Gidgee	5.51	326,861	1327	49.11
07-Feb-11	Aragon Resources Ltd	4.33	1,632,602	1347.5	38.59
04-Apr-11	Black Cat	1.90	27,306	1435.5	25.91
13-Apr-11	Cheritons	2.40	108,027	1457.5	1.83
15-Jun-11	Cracow and Mt Rawdon	1.32	1,791,598	1529.75	266.49
15-Jun-11	Catalpa Resources Ltd	1.42	2,508,263	1529.75	178.93
23-Jun-11	Weerianna	2.17	70,127	1523	61.38
22-Jul-11	Bundarra - Celtic	2.13	273,368	1602	7.98
29-Jun-11	Laverton	2.12	2,090,187	1504.25	34.57
18-Jan-11	Bond	7.46	70,000	1369.5	1.10
02-Feb-11	Standard	4.25	18,651	1337	50.77
23-Dec-10	Standard	4.25	18,651	1373.5	339.75
05-Aug-11	Radio	1.89	438,838	1658.75	7.18
10-Aug-11	Boorara	1.36	83,618	1772	37.65
07-Mar-11	Reef	12.28	162,831	1437.5	0.27
23-Mar-11	Grassy Mountain	1.51	43,460	1439.5	54.01
24-Mar-11	Alcourt	14.00	9,000	1447	46.23
04-Apr-11	Blackwater	1.09	6,158,989	1435.5	94.21
18-Apr-11	Clarence Stream	6.57	426,955	1493	30.91
09-May-11	Lupin and Ulu	9.89	581,678	1502	14.47
12-Aug-11	Rothsay	7.00	133,053	1736	9.41

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
17-Aug-11	Die Hardie and Red Legs	2.54	139,945	1790	15.06
09-Dec-11	Souart	6.83	112,425	1709	18.35
12-Sep-11	Frasergold	0.52	1,839,544	1820	3.36
28-Mar-11	Monte Cristo and Sugarloaf	4.11	339,315	1417	70.97
22-Jun-11	Golden Ridge, Angel's Camp and Mineral hill	1.23	44,280	1552.5	85.08
22-Jun-11	Castle Black Rock	0.46	293,110	1552.5	19.99
26-Aug-11	Hillgrove	8.41	1,717,581	1788	24.78
17-Oct-11	Preview and Wedge Twin	8.35	297,060	1682	9.71
22-Nov-11	Mt Gibson	1.98	558,218	1699	12.54
22-Dec-11	Golden Crown and Faugh-a-Ballagh	3.22	33,450	1606.5	6.14
09-Jan-12	Fortnum	2.28	1,218,327	1615	29.62
10-Jan-12	Coogee	3.90	34,845	1637	27.00
26-Sep-11	Lemhi	1.29	1,213,500	1598	13.39
17-Oct-11	3T	6.37	193,004	1682	182.40
28-Sep-11	Mt Dittmer	49.93	311,280	1643	1.92
27-Sep-11	Coogee	3.90	34,845	1659	21.04
04-Aug-11	Mt Martin	2.19	335,025	1669.25	14.35
13-Oct-11	Boorara	1.36	83,618	1656	37.14
15-Dec-11	Colomac	1.78	759,306	1574	6.46
26-Jan-12	Pine Tree-Josephine	2.88	829,248	1727	6.26
05-Dec-11	Tunkillia	1.69	841,028	1744	13.49
08-Dec-11	Barlee	6.00	74,075	1715	70.59
05-Dec-11	Eureka	4.40	63,800	1744	63.40
25-Jan-12	Geko	1.30	145,189	1650	23.49
09-Feb-12	Vivien	8.30	154,507	1748	70.56
09-Feb-12	METS	10.30	52,298	1748	77.08
27-May-11	Mt Fisher	3.00	75,000	1533	61.46
13-Dec-11	Livengood Placer	1.00	230,000	1672.5	108.48
02-Mar-12	Gold Creek	1.50	24,113	1714	109.45
13-Mar-12	Mt Jewell	1.54	187,104	1697.5	41.38
29-Apr-11	Shining Tree	6.90	140,245	1540.25	275.96
22-Mar-12	Matagami	2.74	11,914	1635.5	500.17
24-Nov-09	Gold Dust	12.00	104,940	1163.2	10.90
26-Mar-12	Philips River - Kundip	3.33	957,349	1680.25	12.28
27-Mar-12	Fosterville	2.95	2,325,736	1692	43.78
10-Apr-12	Cove	20.23	231,300	1644	106.28
12-Apr-12	Malartic	5.80	68,000	1668.5	8.43
16-Apr-12	Castlemaine Goldfields Ltd	7.46	812,112	1653	53.44
27-Apr-12	Trelawney Mining and Exploratoin Inc	0.95	7,359,111	1653.5	69.50
15-May-12	Karratha Metals Ltd	12.23	35,789	1556.5	76.69
29-May-12	AU 81	1.42	60,000	1579.5	5.75
31-May-12	Keystone	11.52	209,242	1558	113.73
06-Jun-12	Cove	20.25	231,254	1635	111.01

Date	Asset	X (grade)	Y (size)	Z (Commodity)	Magnitude (US$/oz Au Price)
25-May-12	Mill Canyon	28.52	69,000	1569.5	275.36
31-May-12	Paddington	1.72	6,602,744	1558	21.99
31-Mar-11	Blue Funnel	3.90	38,000	1439	32.38
19-Jun-12	Fontana	5.29	164,560	1625.5	167.17
26-Jun-12	Mt Henry	1.60	1,352,313	1576	23.33
########	Wilsons	6.97	326,243	1549	23.97

Table A-4.3. Commodity price risk dataset

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
17-Sep-08	Rocky Dam	10,465	9.30	813	228.42
22-Sep-08	Sleeping Giant	54,891	13.88	889	115.09
09-Oct-07	Sleeping Giant	54,891	13.88	728.8	138.02
22-Sep-08	Tartan Lake	165,142	8.66	889	19.08
15-Oct-08	Duport	315,676	12.11	847	37.38
15-Oct-08	Duport	315,676	12.11	847	37.38
20-Oct-08	Spring Valley	899,710	0.61	795	29.73
23-Oct-07	Chester	176,527	6.39	757.5	17.74
24-May-07	West Kalgoorlie	612,108	1.80	659	15.37
17-Nov-08	Bounty	338,954	4.33	734	0.52
20-Nov-08	Twin Hills	197,719	7.41	738	90.25
12-Dec-08	Yandan	316,363	2.40	826.5	9.67
03-Jun-03	Riverina	61,980	11.90	365	37.96
01-Oct-02	Paddys Flat	932,372	2.00	324.66174	3.31
01-Oct-02	Lake Carey	469,771	2.21	324.66174	7.31
03-Aug-05	Indee	494,260	1.93	434.6	5.98
01-Sep-03	Mt Korong	25,688	3.47	376.25	4.38
01-Sep-03	Karonie	455,887	2.29	376.25	0.72
14-May-03	Enterprise and Penny West	733,565	4.91	353.55	2.86
01-Oct-03	Millrose project	251,114	2.13	383.5	2.70
02-Jan-04	Dingo Range project	280,114	2.78	415.25	3.00
01-Apr-04	Higginsville project	440,208	2.80	427.25	9.52
15-Feb-06	Woolgar	405,418	1.58	540.5	46.57
3-Mar-06	Menzies	172,012	2.55	565	5.68
12-Apr-06	Minjar	406,413	2.46	597.25	20.58
5-Jul-06	Penfold	261,659	2.12	623	11.57
20-Sep-04	Dreadnought	93,559	3.00	404.3	4.52
14-Jun-05	Coolgardie	41,539	3.40	426.85	105.41
9-Feb-07	Dargues Reef	313,727	4.10	664.5	20.79
21-Feb-07	Duquesne Gold Mines Ltd	298,657	6.03	661.25	194.59
21-Apr-06	Comet -Webb's Patch	164,933	6.09	623.5	11.49
01-Jun-06	Eureka	63,800	4.40	625	26.59
01-Jun-06	British King	15,432	20.00	625	54.96
26-Feb-07	Mt Ida	111,219	24.02	685.75	32.20
13-Jan-04	Ravenswood	2,652,437	1.00	425.5	16.38
24-Feb-06	Lupin	224,092	8.68	554.15	25.53
11-May-06	Dogpay Lake	26,660	15.43	715.5	21.73
15-Mar-07	Toms Gully	768,810	7.32	648.5	51.50
27-Feb-07	Eastmain	272,534	10.64	676.2	14.65

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
18-Jan-07	Mount Morgan tails	137,477	0.97	635	25.64
2-Mar-07	Taurus	720,000	1.00	651.9	7.95
20-May-03	Jerritt Canyon	2,874,019	8.72	366.3	19.21
02-Mar-07	Buffalo Gulch, Friday/Petsite, Deadwood	708,763	1.00	651.9	2.02
25-Aug-04	Buffalo Gulch	708,763	1.00	406	2.57
19-Jan-07	Engineer	21,863	34.00	629	53.34
19-Apr-06	Kasagiminnis Lake	401,240	4.80	624.75	0.37
05-May-03	Tonkin Springs	1,000,000	2.00	340.5	19.46
12-May-03	McKinnon	965,881	8.35	351.1	0.32
04-Mar-02	Copperstone	614,563	10.47	298.5216	2.79
27-Sep-05	Lac Pelletier	122,199	7.84	464.1	6.60
05-May-03	Aurbel	251,129	7.30	340.5	31.60
10-Jan-07	Norseman	2,222,362	4.15	608.4	28.21
01-May-07	Chalice	78,531	5.31	677.5	80.98
19-Feb-07	Peak	1,368,151	7.71	670.75	165.09
24-Apr-02	La Ronge	830,223	8.66	303.304261	2.02
15-Aug-06	Golden Heart	291,789	1.78	625.5	6.84
14-Jul-04	Grew Creek	234,457	9.43	403.8	4.58
02-Mar-07	Vinsale	1,028,280	1.95	651.9	3.09
16-Jan-07	Barry	45,000	4.50	627.05	15.11
24-Jan-06	Norlartic North	99,093	3.46	557.25	23.55
06-Mar-03	Vault	116,643	5.56	354.7	2.91
26-Apr-07	Paddington	1,400,000	1.91	673	29.47
08-May-07	Dubenski	72,192	6.32	685.9	71.12
17-Jan-08	Mt Korong	92,498	2.74	888.25	13.09
03-Mar-06	Menzies	170,851	2.50	565	5.26
10-Jan-08	Kirkalocka	139,084	2.10	884.25	44.98
20-Dec-07	Peak Hill	987,671	2.40	799.5	10.25
20-Dec-07	Eucalyptus	174,330	2.51	799.5	10.77
29-Apr-05	Laverton	81,859	4.10	435.7	49.58
06-Aug-07	Riverina	196,451	3.73	671.5	21.73
08-Nov-07	Mt Magnet	2,726,705	3.25	832.25	24.10
02-Aug-07	Coolgardie	8,681	2.70	666.25	53.86
02-Aug-05	Mt Gibson	877,072	2.20	431	4.57
08-May-07	Mt Gibson	557,266	1.98	685.9	8.80
03-May-07	Gidgee	492,791	5.95	675.9	20.34
03-May-07	Youanmi	952,178	3.60	675.9	9.57
03-May-07	Aphrodite	287,042	6.20	675.9	22.22
20-Jun-07	Wiluna	745,579	5.67	657.7	36.96
31-Jul-07	South Kalgoorlie	1,913,227	1.80	665.5	22.24
14-Feb-08	Pajingo	485,685	7.50	906	50.44
17-Aug-07	Mt Monger, Moyagee	549,826	9.89	657.5	22.77
29-Oct-07	Stawel, Bendigo	3,737,878	3.08	792.5	76.69

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
17-Dec-07	White Dam	328,779	1.12	787	34.42
19-Feb-08	Mt Bundy	710,080	1.33	924	9.44
28-Feb-08	Lefroy	280,626	8.22	959.75	3.66
17-Oct-07	Burnakura	395,036	3.22	759.75	18.72
22-Aug-07	Tuckabianna	236,887	3.27	659.5	4.49
03-Sep-07	Rothsay	132,783	7.00	672	7.51
16-Mar-05	Randalls	275,853	3.90	443	23.83
15-Jun-04	Bronzewing	386,946	2.47	393.25	19.29
25-Mar-08	Comet	208,633	3.58	926.75	7.41
8-Nov-05	Davyhurst	795,856	2.21	461.6	8.21
04-Apr-08	Cracow	1,000,277	8.57	905.5	278.59
30-May-01	Kalgoorlie Southeast	288,392	3.90	275.08	12.02
23-Jun-05	Lord Henry and Lord Nelson	348,506	2.64	439.15	4.24
14-Oct-04	Hodgkinson Basin	43,835	1.47	415.35	6.47
22-Mar-07	Wallbrook	607,470	1.53	663	10.40
08-Apr-08	Minjar	406,900	2.46	915	26.81
15-Apr-08	Springfield	66,205	1.43	929.75	53.99
17-Jun-04	Raeside, Cardinia and Mertondale	221,503	1.94	386.1	0.43
29-May-08	Durack	42,632	2.33	883	7.97
29-May-08	Kalgoorlie West	680,991	1.77	883	15.34
29-May-08	Three Rivers	131,175	2.40	883	10.18
22-Oct-03	Burnakura	170,000	7.35	384.75	109.59
16-Apr-02	Constellation	13,889	2.70	301.257726	11.25
12-Jun-08	White Well	112,528	1.00	862.25	8.08
28-Aug-06	Illipah	30,598	1.10	621.25	12.71
02-Jul-08	Quartz Mountain and Hope Butte	589,275	0.80	935.25	5.53
18-Mar-08	Santa Anna	165,207	3.18	1006.75	0.67
16-Jul-08	Senore	50,156	8.60	977	10.42
22-Apr-08	Blue Hill Creek	235,831	0.56	918	12.65
01-Aug-08	Bounty	338,954	4.33	912.5	3.16
05-Aug-08	Damoti Lake	43,534	23.19	882	40.53
06-Aug-08	Bingo	105,652	14.06	879.5	33.65
28-Nov-08	Abo	220,538	2.79	814.5	24.97
18-Dec-08	Nixon Fork	154,757	19.86	855.25	3.53
23-Dec-08	Taurus	1,041,684	1.00	843.5	2.16
24-Oct-05	Venus	25,000	1.50	466.1	34.53
07-Apr-08	Dargues Reef	313,727	4.10	926.5	5.34
12-Jun-08	White Well	112,528	1.00	862.25	6.39
21-Jan-09	Garrison	309,826	5.33	849.25	18.64
21-Jan-09	Garrison	2,238,871	2.19	849.25	3.46
26-Jan-09	Haile extension	85,313	1.30	910.25	0.23
31-Oct-02	Wallace South, Citroy Flagship, The Pinnacles, Weatherly Grid, City Girl and Brilliant-China	72,873	2.34	318.62005	4.83

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
	Wall				
3-Sep-02	Cargo	224,669	0.82	311.253696	8.43
16-Apr-02	Constellation	13,889	2.70	301.257726	11.49
24-Feb-09	Mt Morgans	205,173	3.75	984.25	25.40
26-Feb-09	Yundamindera	47,397	2.35	936.5	23.79
05-Feb-09	Mets	167,561	11.31	920	2.31
10-Feb-09	Commodore	51,698	2.40	909.5	4.08
11-Feb-09	Valentine Lake	443,847	10.50	938	11.89
17-Feb-09	Anglo-Rouyn	46,794	1.32	968	16.30
12-Mar-09	South Laverton	44,456	1.89	925.25	5.51
12-Mar-09	Georgetown	96,342	20.91	925.25	11.38
30-Mar-09	Back River	2,353,113	10.50	928	6.77
02-Apr-09	Bronzewing	882,200	2.49	897.75	8.21
31-Mar-09	Cadiscor Resources Inc	450,044	6.21	916.5	17.31
09-Apr-09	Golden Promise	89,425	3.02	880.5	29.31
20-Apr-09	Mooseland	787,716	13.37	877	14.37
06-May-09	Hog Range	76,471	1.29	910	14.62
19-May-09	Dohertys	19,665	23.80	924.75	10.83
10-Mar-09	Terrain Minerals Ltd	358,952	2.13	901.5	4.22
26-May-09	Box and Athona	1,256,580	1.16	945	4.41
01-Jun-09	Elmtree	237,267	1.42	981.75	17.93
26-Mar-09	Castle-Black Rock	309,506	0.47	938.25	17.10
05-Jun-09	Scheelite Dome, Ogopogo and Willoughby	143,232	1.35	962	5.08
08-Jun-09	Brewery Creek	287,405	1.45	943.75	16.57
10-Jun-09	Kookynie	424,240	2.34	953.75	4.27
11-Jun-09	Georgetown alluvial	42,500	0.50	947.5	53.77
15-Jun-09	Premier	387,523	8.15	932.25	37.45
26-Aug-08	Yarnell	325,800	0.34	827	17.22
12-Jun-09	Xplor Ltd	23,909	6.39	937.25	27.22
23-Jun-09	Davyhurst and Mt Ida	1,566,259	2.53	920.75	29.21
24-Jun-09	Kirkalocka	183,259	1.68	933.5	11.27
25-Jun-09	Red Mountain	683,930	5.78	937.25	16.19
26-Jun-09	Chester	68,370	14.74	942	19.86
29-Jun-09	Nixon Fork	154,757	19.86	935.5	24.18
01-Jul-09	Twin Hills	198,179	7.43	938.25	7.57
30-Jun-09	Monroe Lakes	165,273	8.67	934.5	10.52
06-Jul-09	Henty	145,027	7.82	924.5	46.80
09-Jul-09	Sugarloaf	67,500	3.70	911.75	5.62
12-Jun-09	Windarra	131,604	0.80	937.25	13.84
06-Jul-09	Summit Lake	74,091	19.20	924.5	2.48
22-Jul-09	Kalgoorlie North	266,709	1.82	948.25	9.32
21-Jul-09	Prospect Valley	1,644,511	1.10	947.75	4.34
20-Jul-09	Klondex Mines Ltd	2,147,911	9.72	952.75	26.28

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
27-Jul-09	Souart	110,000	6.17	955	13.99
31-Jul-09	Dingman	413,087	0.89	939	12.09
03-Aug-09	Ardeen	442,073	12.50	959.75	26.32
04-Aug-09	North Bullfrog	81,564	0.85	960.5	16.36
17-Apr-09	Crocodile Gold Inc	4,142,063	2.54	870.5	10.95
14-Aug-09	Lancefield and Beasely Creek	1,699,209	4.12	953.6	3.94
03-Jul-09	Gateway Mining Ltd	463,865	1.66	932.5	16.01
19-Aug-09	Golden Zone	267,705	2.92	943	8.62
21-Aug-09	Chester	193,880	7.03	952.5	6.58
01-Sep-09	Destiny	100,684	5.12	955	42.30
04-Sep-09	Eureka	63,800	4.40	989	24.68
03-Sep-09	Abo	220,688	2.79	983	0.28
03-Sep-09	High Lake	84,496	9.77	983	1.60
08-Sep-09	Almaden	881,815	0.68	1000.7	4.68
14-Sep-09	Garrison	2,238,871	2.19	999.25	2.57
16-Sep-09	REN	723,392	10.00	1015.7	5.13
24-Sep-09	Aphrodite	287,042	6.20	1009.7	23.29
24-Sep-09	Augusta	244,764	23.00	1009.7	40.48
24-Sep-09	Regcourt	10,767	5.49	1009.7	11.76
19-Oct-09	Golden Rose	624,000	8.09	1047.5	2.80
20-Oct-09	Lac Laura	30,608	5.83	1061.7	25.11
20-Oct-09	New Britannia	766,085	5.31	1061.7	45.22
22-Oct-09	Egerton	23,909	6.39	1053	21.37
10-Aug-07	Egerton	23,909	6.39	668.5	17.50
16-Oct-09	Maldon	182,488	12.00	1050.5	28.95
22-Oct-09	Bell Creek West	100,000	10.00	1053	253.55
29-Oct-09	Metallic Ventures Gold Inc	5,954,945	0.61	1040.5	7.32
03-Nov-09	Little Stull Lake	248,365	10.30	1061	5.75
04-Nov-09	Easter	198,697	2.03	1090	11.57
09-Nov-09	Hyland	113,171	1.10	1106.7	16.91
12-Nov-09	X-Ore Resources Inc	424,860	5.50	1114.75	18.97
16-Nov-09	Stairs	36,326	30.38	1130	32.92
16-Nov-09	Hazard Lake	16,352	8.76	1130	5.17
18-Nov-09	REN	1,653,487	13.44	1149	34.96
23-Nov-09	Big Bell	1,495,006	4.05	1169.5	7.10
24-Nov-09	Gold Dust	104,940	12.00	1163.2	11.21
27-Nov-09	Emerald Lake	624,000	8.09	1166.5	2.37
02-Dec-09	Mt Perry	1,000,000	2.00	1212.5	7.16
01-Dec-09	Desantis	50,722	8.64	1192.5	90.00
08-Dec-09	Spargoville	4,866	1.81	1146.75	20.11
23-Dec-09	Cameron Lake	449,298	5.41	1085.2	20.56
14-Feb-07	Meadowbank	3,995,412	4.76	668.25	169.03
14-Sep-05	Young-Davidson	1,354,452	2.82	449.3	14.10
29-Jul-08	Cochrane Hill and Caribou	212,032	7.24	916.75	39.34

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
19-Aug-08	Big Springs	1,200,000	2.43	796.25	5.82
04-Mar-09	Mesquite	4,380,322	0.52	908.5	59.09
10-Feb-09	Cadiscor Resources Inc	450,044	6.21	909.5	33.15
06-Aug-09	Crocodile Gold Inc	4,142,063	2.54	964	6.56
29-Dec-09	Dioro Exploration NL	2,796,589	2.55	1106	49.68
25-May-06	Nordeau	145,076	6.31	642.5	35.19
05-Apr-05	Tunkillia	742,682	2.20	424.6	7.32
07-Mar-05	Vogel	643,422	12.70	433	4.62
01-Dec-05	Schumacher	30,043	5.99	499.75	15.15
31-Jan-07	Bell Creek	136,529	7.90	650.5	70.45
06-Jul-04	Duport	686,372	11.96	394.5	12.12
24-Jan-05	Hycroft	711,375	0.65	427.35	17.69
30-Dec-04	Mt Dimer	70,222	5.79	435.6	20.33
30-Dec-04	Corinthian, Pioneed, Mt Dimer North, Ubini and Brown Lake	106,056	2.52	435.6	24.69
29-Dec-05	Aquarius	1,042,865	2.16	513	14.51
09-Dec-03	East Amphi and Fourax	890,491	4.72	407.75	13.29
03-Dec-03	Ulu	568,206	12.91	401.8	51.27
03-Nov-03	Coyote	411,883	5.41	383.25	29.57
15-Jul-03	Mesquite	1,428,175	0.71	348.25	1.21
07-Jan-10	Bullabulling	416,578	1.44	1130.25	4.13
08-Jan-10	Kerr-Addison	695,193	4.72	1126.7	3.36
20-Jan-10	Triton	600,000	15.00	1120.2	2.08
20-Jan-10	Borealis - heaps	2,275,905	1.84	1120.2	11.34
05-Feb-10	Mt Korong, Mt Zephyr and Mt Goose	92,000	2.70	1058	6.38
05-Feb-10	Eucalyptus and Malcolm	207,800	2.86	1058	3.84
08-Feb-10	Hope Brook	772,003	4.76	1064	0.40
08-Feb-10	DeSantis	80,055	6.75	1064	47.34
09-Feb-10	Clavos	147,470	6.83	1071.2	30.33
05-Mar-10	Ballarat	1,485,364	11.85	1135	2.88
04-Mar-10	Terra	172,737	12.55	1134.5	50.19
08-Mar-10	Sugar Zone	283,502	9.75	1125.7	32.38
11-Mar-10	Underworld Resources Inc	1,412,323	2.96	1104	95.26
15-Mar-10	Souart	110,000	6.17	1104.2	60.17
11-Mar-10	Eureka and British King	158,323	8.23	1104	18.19
26-Mar-10	Webbs Patch	6,692	4.68	1096.5	30.16
29-Mar-10	Kalgoorlie North	360,088	1.40	1107.5	9.99
23-Mar-10	Staccato Gold Resources Ltd	262,618	1.47	1101.5	36.48
01-Apr-10	Burnakura	91,371	6.91	1123.5	44.97
01-Apr-10	Comaplex Minerals Corp	5,039,050	7.35	1123.5	148.92
07-Apr-10	Golden Arrow	524,540	1.02	1142	18.17
15-Apr-10	Gold Summit Corp	441,759	3.33	1154.5	6.79
20-Apr-10	Vezza	409,588	5.61	1144.75	25.33
27-Apr-10	Afgan-Kobeh	92,031	1.00	1154.5	4.22

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
30-Apr-10	Bluff	557,012	2.67	1166.75	9.51
06-May-10	Paulsens	128,757	12.75	1185.25	111.05
24-Sep-09	Costerfield	330,746	20.49	1009.7	29.96
07-May-10	Coogee	35,681	4.00	1202.25	30.14
18-May-10	Fayolle	66,314	6.33	1216.75	301.95
01-Jun-10	Wildrose	9,277	9.94	1227.75	257.61
03-Jun-10	New Island Resources Inc	248,221	2.93	1215	19.68
09-Jun-10	Bendigo Creek	33,565	0.58	1233.5	36.18
14-Jun-10	Springfield	66,205	1.43	1223.75	5.67
22-Jun-10	X-Cal Resources Ltd	1,860,692	0.59	1236	18.03
18-Jun-10	West Kalgoorlie	595,638	1.84	1256	5.56
28-Jun-10	Georgia River	75,581	19.12	1261	1.68
29-Jun-10	Paulsens	128,757	12.75	1234.5	126.25
29-Jun-10	McWatters	77,194	5.93	1234.5	49.09
05-Jul-10	Tagish Lake Gold Corp	561,919	7.29	1207.75	25.15
07-Jul-10	Bullant	69,700	5.35	1201.55	68.36
07-Jul-10	Mt Magnet	3,586,607	2.19	1201.55	8.80
09-Jul-10	North Queensland Metals Ltd	1,396,001	4.01	1209.8	33.75
20-Jul-10	Gullewa	714,373	6.69	1183	13.88
10-Aug-10	Blackburn	238,131	1.12	1192.5	2.52
10-Aug-10	Duverny	504,469	2.57	1192.5	3.61
26-Aug-10	Tagish Lake Gold Corp	567,668	7.37	1237	34.54
31-Aug-10	Golden Goose Resources Inc	1,741,939	7.24	1246	7.20
07-Sep-10	Fenelon, Northway-Noyon and Northshore	1,053,792	1.62	1256.75	36.21
15-Sep-10	Penny's Find	52,340	5.18	1267	71.12
24-Sep-10	Rolling Rock Resources Corp	1,212,016	5.98	1297	8.78
27-Sep-10	Shoal Lake East	691,606	7.85	1297	11.28
28-Sep-10	Lorena	78,012	8.89	1308.9	271.57
28-Sep-10	Buckingham and Moore-MacDonald	85,000	11.66	1308.9	4.37
01-Oct-10	Caribou	65,661	5.83	1316.25	34.70
06-Oct-10	Mt Dimer	102,734	4.63	1346.5	23.34
06-Oct-10	Golden Zone	231,743	3.89	1346.5	12.88
14-Oct-10	Crowshore	29,004	10.97	1373.25	7.07
21-Oct-10	Challenger - low grade stockpile	951,669	6.78	1343.5	390.55
28-Oct-10	Ironstone	79,943	1.61	1333.5	26.21
29-Oct-10	Western Standard Metals Ltd	1,843,450	0.98	1346.75	16.13
26-Nov-10	Cowarra	36,973	2.30	1355	15.66
30-Nov-10	Kilgore, Hai and Gold Bug	487,000	0.91	1383.5	6.24
03-Dec-10	Coogee	34,872	3.91	1403.5	34.23
09-Dec-10	Bullant	69,700	5.35	1391.25	140.28
15-Dec-10	Lapaska	22,210	3.14	1388.75	355.96
16-Dec-10	Nudulama	47,970	4.46	1363	2.50
23-Dec-10	Kerr-Addison	703,536	4.71	1373.5	3.52

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
12-Jan-11	Meekatharra	2,466,207	1.72	1378.75	10.42
11-Jan-11	Marmion South	4,860	2.06	1374	251.52
21-Jan-11	Spring Hill	273,847	2.34	1343.5	26.36
24-Jan-11	Mt Porter-Frances Creek	34,498	3.02	1343	89.67
31-Jan-11	Gidgee	326,861	5.51	1327	49.11
07-Feb-11	Aragon Resources Ltd	1,632,602	4.33	1347.5	38.59
04-Apr-11	Black Cat	27,306	1.90	1435.5	25.91
13-Apr-11	Cheritons	108,027	2.40	1457.5	1.83
15-Jun-11	Cracow and Mt Rawdon	1,791,598	1.32	1529.75	266.49
15-Jun-11	Catalpa Resources Ltd	2,508,263	1.42	1529.75	178.93
23-Jun-11	Weerianna	70,127	2.17	1523	61.38
22-Jul-11	Bundarra - Celtic	273,368	2.13	1602	7.98
29-Jun-11	Laverton	2,090,187	2.12	1504.25	34.57
18-Jan-11	Bond	70,000	7.46	1369.5	1.10
02-Feb-11	Standard	18,651	4.25	1337	50.77
23-Dec-10	Standard	18,651	4.25	1373.5	339.75
05-Aug-11	Radio	438,838	1.89	1658.75	7.18
10-Aug-11	Boorara	83,618	1.36	1772	37.65
07-Mar-11	Reef	162,831	12.28	1437.5	0.27
23-Mar-11	Grassy Mountain	43,460	1.51	1439.5	54.01
24-Mar-11	Alcourt	9,000	14.00	1447	46.23
04-Apr-11	Blackwater	6,158,989	1.09	1435.5	94.21
18-Apr-11	Clarence Stream	426,955	6.57	1493	30.91
09-May-11	Lupin and Ulu	581,678	9.89	1502	14.47
12-Aug-11	Rothsay	133,053	7.00	1736	9.41
17-Aug-11	Die Hardie and Red Legs	139,945	2.54	1790	15.06
09-Dec-11	Souart	112,425	6.83	1709	18.35
12-Sep-11	Frasergold	1,839,544	0.52	1820	3.36
28-Mar-11	Monte Cristo and Sugarloaf	339,315	4.11	1417	70.97
22-Jun-11	Golden Ridge, Angel's Camp and Mineral hill	44,280	1.23	1552.5	85.08
22-Jun-11	Castle Black Rock	293,110	0.46	1552.5	19.99
26-Aug-11	Hillgrove	1,717,581	8.41	1788	24.78
17-Oct-11	Preview and Wedge Twin	297,060	8.35	1682	9.71
22-Nov-11	Mt Gibson	558,218	1.98	1699	12.54
22-Dec-11	Golden Crown and Faugh-a-Ballagh	33,450	3.22	1606.5	6.14
09-Jan-12	Fortnum	1,218,327	2.28	1615	29.62
10-Jan-12	Coogee	34,845	3.90	1637	27.00
26-Sep-11	Lemhi	1,213,500	1.29	1598	13.39
17-Oct-11	3T	193,004	6.37	1682	182.40
28-Sep-11	Mt Dittmer	311,280	49.93	1643	1.92
27-Sep-11	Coogee	34,845	3.90	1659	21.04
04-Aug-11	Mt Martin	335,025	2.19	1669.25	14.35
13-Oct-11	Boorara	83,618	1.36	1656	37.14

Date	Asset	Y (size)	X (grade)	Z (Gold price)	Magnitude (unit price US$/oz Au)
15-Dec-11	Colomac	759,306	1.78	1574	6.46
26-Jan-12	Pine Tree-Josephine	829,248	2.88	1727	6.26
05-Dec-11	Tunkillia	841,028	1.69	1744	13.49
08-Dec-11	Barlee	74,075	6.00	1715	70.59
05-Dec-11	Eureka	63,800	4.40	1744	63.40
25-Jan-12	Geko	145,189	1.30	1650	23.49
09-Feb-12	Vivien	154,507	8.30	1748	70.56
09-Feb-12	METS	52,298	10.30	1748	77.08
27-May-11	Mt Fisher	75,000	3.00	1533	61.46
13-Dec-11	Livengood Placer	230,000	1.00	1672.5	108.48
02-Mar-12	Gold Creek	24,113	1.50	1714	109.45
13-Mar-12	Mt Jewell	187,104	1.54	1697.5	41.38
29-Apr-11	Shining Tree	140,245	6.90	1540.25	275.96
22-Mar-12	Matagami	11,914	2.74	1635.5	500.17
24-Nov-09	Gold Dust	104,940	12.00	1163.2	10.90
26-Mar-12	Philips River - Kundip	957,349	3.33	1680.25	12.28
27-Mar-12	Fosterville	2,325,736	2.95	1692	43.78
10-Apr-12	Cove	231,300	20.23	1644	106.28
12-Apr-12	Malartic	68,000	5.80	1668.5	8.43
16-Apr-12	Castlemaine Goldfields Ltd	812,112	7.46	1653	53.44
27-Apr-12	Trelawney Mining and Exploratoin Inc	7,359,111	0.95	1653.5	69.50
15-May-12	Karratha Metals Ltd	35,789	12.23	1556.5	76.69
29-May-12	AU 81	60,000	1.42	1579.5	5.75
31-May-12	Keystone	209,242	11.52	1558	113.73
06-Jun-12	Cove	231,254	20.25	1635	111.01
25-May-12	Mill Canyon	69,000	28.52	1569.5	275.36
31-May-12	Paddington	6,602,744	1.72	1558	21.99
31-Mar-11	Blue Funnel	38,000	3.90	1439	32.38
19-Jun-12	Fontana	164,560	5.29	1625.5	167.17
26-Jun-12	Mt Henry	1,352,313	1.60	1576	23.33
23-May-12	Wilsons	326,243	6.97	1549	23.97

Table A-4.4. Certainty risk dataset

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
17-Sep-08	Rocky Dam	288,392	3.90	3.00	19
22-Sep-08	Charters Towers	288,392	3.90	3.00	20
22-Sep-08	Charters Towers	614,563	10.47	2.42	3
22-Sep-08	Sleeping Giant	13,889	2.70	3.00	11
9-Oct-07	Sleeping Giant	13,889	2.70	3.00	11
29-Sep-08	Frankfield	830,223	8.66	1.00	2
29-Sep-08	Frankfield	224,669	0.82	2.00	12

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
15-Oct-08	Duport	932,372	2.00	1.00	3
20-Oct-08	Spring Valley	469,771	2.21	2.43	7
23-Oct-07	Chester	72,873	2.34	2.00	5
27-Oct-08	Island	129,092	2.39	3.00	3
24-May-07	West Kalgoorlie	237,697	18.30	2.50	45
17-Nov-08	Bounty	782,707	2.37	2.18	2
20-Nov-08	Twin Hills	116,643	5.56	1.00	6
12-Dec-08	Yandan	116,643	5.56	0.99	5
2-Dec-02	Chariot	116,643	5.56	0.99	3
3-Jun-03	Riverina	251,129	7.30	2.00	30
3-Nov-03	Coyote	965,881	8.35	1.00	0
1-Mar-04	Burnakura	733,565	4.91	1.57	3
3-May-04	Burnakura	2,874,019	8.72	3.17	18
1-Oct-02	Paddys Flat	2,874,019	8.72	3.17	20
1-Oct-02	Lake Carey	61,980	11.90	2.50	36
1-Nov-02	Three Rivers	482,261	2.00	1.00	3
3-Feb-03	Mikado	598,968	2.30	1.00	3
3-Jun-03	Tunkillia	819,844	3.00	1.00	2
3-Jun-03	Tunkillia	482,261	2.00	1.00	5
3-Jun-03	Tunkillia	598,968	2.30	1.00	4
3-Jun-03	Tunkillia	819,844	3.00	1.00	3
3-Jun-03	Tunkillia	748,428	7.78	2.00	70
3-Jun-03	Tunkillia	748,428	7.78	2.00	78
3-Aug-05	Indee	748,428	7.78	2.00	52
1-Sep-03	Mt Korong	25,688	3.47	1.00	4
1-Sep-03	Mt Korong	25,688	3.47	1.00	13
1-Sep-03	Mt Korong	25,688	3.47	1.00	11
1-Sep-03	Karonie	455,887	2.29	3.00	1
1-Sep-03	Karonie	455,887	2.29	3.00	2
14-May-03	Enterprise and Penny West	656,975	2.14	2.60	6
1-Oct-03	Chalice and Indee	251,114	2.13	2.71	3
10-Oct-03	Indee project	494,260	1.93	2.65	9
1-Oct-03	Millrose project	170,000	7.35	2.84	103
2-Jan-04	Dingo Range project	578,231	4.41	2.92	20
1-Apr-04	Higginsville project	280,114	2.78	2.00	3
18-Jan-06	White Dam	2,652,437	1.00	4.70	15
13-Feb-06	Boddington	203,916	4.30	3.00	17
15-Feb-06	Woolgar	440,208	2.80	2.00	9
3-Mar-06	Menzies	203,916	4.30	3.00	40
12-Apr-06	Minjar	386,946	2.47	2.45	18
5-Jul-06	Penfold	221,503	1.94	2.47	0
20-Sep-04	Dreadnought	234,457	9.43	1.00	7
14-Jun-05	Coolgardie	234,457	9.43	1.00	7
9-Feb-07	Dargues Reef	708,763	1.00	2.22	1

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
16-Jun-03	Lapa	708,763	1.00	2.22	4
16-Jun-03	Lapa	93,559	3.00	2.00	4
21-Feb-07	Hollister Development Block	43,835	1.47	2.73	6
21-Feb-07	Duquesne Gold Mines Ltd	275,853	3.90	2.00	22
21-Apr-06	Comet -Webb's Patch	81,859	4.10	1.00	46
1-Jun-06	Eureka	41,539	3.40	2.00	127
1-Jun-06	British King	348,506	2.64	4.12	4
26-Feb-07	Mt Ida	877,072	2.20	3.00	4
13-Jan-04	Ravenswood	494,260	1.93	2.65	6
24-Feb-06	Lupin	475,831	0.93	1.00	4
11-May-06	Dogpay Lake	653,303	1.03	1.00	3
11-May-06	Dogpay Lake	839,134	1.13	1.00	2
11-May-06	Dogpay Lake	1,354,452	2.82	2.60	14
11-May-06	Dogpay Lake	122,199	7.84	3.50	9
11-May-06	Dogpay Lake	795,856	2.21	2.64	8
11-May-06	Dogpay Lake	257,166	1.09	2.84	16
15-Mar-07	Toms Gully	99,093	3.46	1.00	29
27-Feb-07	Eastmain	99,093	3.46	1.00	29
27-Feb-07	Eastmain	5,962,026	1.14	4.06	136
27-Feb-07	Eastmain	405,418	1.58	3.55	144
14-Feb-07	Meadowbank	224,092	8.68	3.00	24
23-Jan-07	Beaconsfield	172,012	2.55	2.78	5
18-Jan-07	Mount Morgan tails	170,851	2.50	2.80	5
2-Mar-07	Taurus	406,413	2.46	2.51	19
20-May-03	Jerritt Canyon	401,240	4.80	1.00	0
20-May-03	Jerritt Canyon	164,933	6.09	2.55	11
2-Mar-07	Buffalo Gulch, Friday/Petsite, Deadwood	19,290	15.00	1.00	36
2-Mar-07	Buffalo Gulch, Friday/Petsite, Deadwood	26,660	15.43	1.00	26
2-Mar-07	Buffalo Gulch, Friday/Petsite, Deadwood	30,865	16.00	1.00	22
2-Mar-07	Buffalo Gulch, Friday/Petsite, Deadwood	19,290	15.00	1.00	111
25-Aug-04	Buffalo Gulch	26,660	15.43	1.00	80
25-Aug-04	Buffalo Gulch	30,865	16.00	1.00	69
24-Aug-05	Buffalo Gulch	63,800	4.40	4.00	25
24-Aug-05	Buffalo Gulch	15,432	20.00	4.00	51
24-Aug-05	Buffalo Gulch	42,915	7.10	1.00	6
19-Jan-07	Engineer	261,659	2.12	2.85	11
19-Apr-06	Kasagiminnis Lake	291,789	1.78	3.02	6
12-May-03	McKinnon	30,598	1.10	1.00	12
4-Mar-02	Copperstone	30,598	1.10	1.00	46
27-Sep-05	Lac Pelletier	52,959	14.20	2.00	18
5-May-03	Aurbel	3,092,217	7.92	2.58	48
1-May-07	Croinor	2,222,362	4.15	2.82	26

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
10-Jan-07	Norseman	45,000	4.50	1.00	14
1-May-07	Chalice	137,477	0.97	3.40	24
19-Feb-07	Peak	21,863	34.00	1.00	50
24-Apr-02	La Ronge	423,342	15.47	3.28	29
15-Aug-06	Golden Heart	313,727	4.10	2.00	19
14-Jun-06	Golden Tag	313,727	4.10	2.00	27
14-Jul-04	Grew Creek	3,995,412	4.76	4.43	161
14-Jul-04	Grew Creek	1,368,151	7.71	3.84	155
2-Mar-07	Vinsale	936,296	44.65	2.00	105
2-Mar-07	Vinsale	298,657	6.03	2.00	187
16-Jan-07	Barry	111,219	24.02	3.10	30
24-Jan-06	Norlartic North	192,841	8.57	1.00	19
24-Jan-06	Norlartic North	272,534	10.64	2.91	14
14-Sep-05	Young-Davidson	342,973	11.85	1.00	11
6-Mar-03	Vault	720,000	1.00	2.00	7
6-Mar-03	Vault	708,763	1.00	2.22	2
6-Mar-03	Vault	708,763	1.00	2.22	3
16-Jun-03	Lapa	708,763	1.00	2.22	4
8-May-07	Dubenski	708,763	1.00	2.22	5
17-Jan-08	Mt Korong	1,028,280	1.95	1.00	5
3-Mar-06	Menzies	1,028,280	1.95	1.00	7
10-Jan-08	Kirkalocka	768,810	7.32	3.49	48
20-Dec-07	Peak Hill	607,470	1.53	2.82	10
20-Dec-07	Eucalyptus	289,955	6.31	3.01	14
14-Jan-08	Cripple Creek and Victor	78,531	5.31	2.00	76
29-Apr-05	Laverton	492,791	5.95	2.63	19
6-Aug-07	Riverina	952,178	3.60	2.46	9
9-Feb-07	Dargues Reef	287,042	6.20	2.00	21
8-Nov-07	Mt Magnet	72,192	6.32	1.00	67
2-Aug-07	Coolgardie	557,266	1.98	2.98	21
2-Aug-05	Mt Gibson	612,108	1.80	2.29	17
8-May-07	Mt Gibson	745,579	5.67	2.44	35
3-May-07	Gidgee	1,913,227	1.80	3.51	21
3-May-07	Youanmi	8,681	2.70	1.00	50
3-May-07	Aphrodite	196,451	3.73	2.84	20
20-Jun-07	Wiluna	23,909	6.39	3.15	16
24-Nov-06	Bird-in-Hand	549,826	9.89	2.54	21
31-Jul-07	South Kalgoorlie	236,887	3.27	2.61	4
14-Feb-08	Pajingo	132,783	7.00	2.00	7
17-Aug-07	Mt Monger, Moyagee	132,783	7.00	2.00	12
29-Oct-07	Stawel, Bendigo	54,891	13.88	5.95	129
17-Dec-07	White Dam	395,036	3.22	2.44	18
19-Feb-08	Mt Bundy	176,527	6.39	2.40	25
28-Feb-08	Lefroy	3,737,878	3.08	3.24	72

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
6-Mar-08	Redemption	2,726,705	3.25	2.72	23
17-Oct-07	Burnakura	220,538	2.79	2.75	56
22-Aug-07	Tuckabianna	1,848,680	0.81	3.31	33
3-Sep-07	Rothsay	328,779	1.12	2.93	32
3-Sep-07	Rothsay	987,671	2.40	3.00	10
16-Mar-05	Randalls	174,330	2.51	2.30	10
15-Jun-04	Bronzewing	139,084	2.10	3.00	42
28-Mar-08	White Dam	7,352,826	0.72	3.98	63
25-Mar-08	Comet	92,498	2.74	2.00	24
8-Nov-05	Davyhurst	485,685	7.50	2.80	47
4-Apr-08	Cracow	710,080	1.33	2.92	9
30-May-01	Kalgoorlie Southeast	2,255,675	10.79	3.37	145
28-Feb-01	Kalgoorlie Southeast	280,626	8.22	2.00	3
22-Dec-06	Tirigniaq	1,616,763	2.47	2.22	35
23-Jun-05	Lord Henry and Lord Nelson	165,207	3.18	1.00	1
14-Oct-04	Hodgkinson Basin	208,633	3.58	2.67	7
22-Mar-07	Wallbrook	329,770	1.13	2.66	54
10-Aug-07	Egerton	1,000,277	8.57	3.17	261
8-Apr-08	Minjar	406,900	2.46	2.40	25
15-Apr-08	Springfield	1,000,000	1.43	1.00	6
23-May-08	Celtic, Coogee, Redcastle and Euro	235,831	0.56	2.00	3
17-Jun-04	Raeside, Cardinia and Mertondale	235,831	0.56	2.00	12
29-May-08	Durack	231,386	2.15	3.12	9
29-May-08	Kalgoorlie West	42,632	2.33	2.65	13
29-May-08	Three Rivers	680,991	1.77	2.86	14
22-Oct-03	Burnakura	131,175	2.40	3.00	10
16-Apr-02	Constellation	2,571,417	0.93	2.00	12
10-Jun-08	Terra and LMS	341,693	1.69	2.00	5
12-Jun-08	White Well	487,000	0.91	2.45	18
12-Jun-08	White Well	83,592	1.30	1.00	12
12-Jun-08	White Well	112,528	1.00	1.00	9
19-Feb-08	Timmins West	112,528	0.70	1.00	9
23-Jun-08	Timmins West	2,255,675	10.79	4.05	178
28-Aug-06	Illipah	589,275	0.80	2.59	8
28-Aug-06	Illipah	3,576,277	7.84	2.57	117
5-Dec-07	Spanish Mountain	50,156	8.60	1.00	12
2-Jul-08	Quartz Mountain and Hope Butte	50,156	8.60	1.00	70
18-Mar-08	Santa Anna	212,032	7.24	2.53	37
14-Jul-08	Mealadine	338,954	4.33	2.55	3
16-Jul-08	Senore	43,534	23.19	3.22	38
16-Jul-08	Senore	105,652	14.06	2.42	33
22-Apr-08	Blue Hill Creek	1,200,000	2.43	2.00	5
22-Apr-08	Blue Hill Creek	325,800	0.34	2.00	16

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
10-Jun-08	Kilgore, Hai and Gold Bug	145,450	3.23	2.08	7
29-Jul-08	Caribou	10,465	9.30	1.00	429
1-Aug-08	Bounty	10,352,540	14.00	2.00	11
2-Jun-08	Hammond Reef	10,352,540	14.00	2.00	15
5-Aug-08	Damoti Lake	54,891	13.88	5.95	108
6-Aug-08	Bingo	564,246	6.50	2.00	4
29-Aug-08	North Laverton	564,246	6.50	2.00	16
19-Aug-08	Big Springs	315,676	12.11	2.58	41
28-Nov-08	Abo	899,710	0.61	2.00	60
28-Nov-08	Abo	671,307	9.23	3.72	44
18-Dec-08	Nixon Fork	212,032	7.24	2.53	44
23-Dec-08	Taurus	338,954	4.33	2.55	0
19-Dec-08	Frankfield	197,719	7.41	2.79	87
19-Dec-08	Frankfield	220,538	2.79	2.75	45
19-Dec-08	Frankfield	220,538	2.79	2.75	37
18-Dec-08	Abo	316,363	2.40	2.0	13
29-Nov-07	Abo	154,757	19.86	4.48	3
21-Jan-09	Garrison	220,538	2.79	2.75	39
21-Jan-09	Garrison	496,376	5.80	2.00	2
21-Jan-09	Garrison	496,376	5.80	2.00	8
21-Jan-09	Garrison	496,376	5.80	2.00	12
21-Jan-09	Garrison	1,041,684	1.00	2.00	2
21-Jan-09	Garrison	309,826	5.33	2.20	26
26-Jan-09	Detour Lake	309,826	5.33	2.20	43
27-Jan-09	Boddington	309,826	5.33	2.20	33
27-Jan-09	Boddington	2,238,871	2.19	1.17	4
26-Jan-09	Haile extension	2,238,871	2.19	1.17	6
31-Oct-02	Wallace South, Citroy Flagship, The Pinnacles, Weatherly Grid, City Girl and Brilliant-China Wall	2,238,871	2.19	1.17	5
3-Sep-02	Cargo	13,202,286	1.34	2.97	6
16-Apr-02	Constellation	85,313	1.30	1.00	0
24-Feb-09	Mt Morgans	23,135,539	0.92	5.50	131
24-Feb-09	Mt Morgans	23,135,539	0.92	5.50	144
26-Feb-09	Yundamindera	167,561	11.31	1.62	2
26-Feb-09	Yundamindera	167,561	11.31	1.62	5
26-Feb-09	Yundamindera	51,698	2.40	1.00	4
5-Feb-09	Mets	450,044	6.21	2.94	27
5-Feb-09	Mets	443,847	10.50	2.00	12
10-Feb-09	Commodore	46,794	1.32	1.00	15
11-Feb-09	Valentine Lake	2,792,934	3.50	4.04	47
17-Feb-09	Anglo-Rouyn	205,173	3.75	1.83	19

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
20-Feb-09	Williams and David Bell	205,173	3.75	1.83	24
27-Feb-09	Yellowjacket	85,480	1.38	1.0	17
27-Feb-09	Yellowjacket	47,397	2.35	1.00	30
4-Mar-09	Mesquite	30,846	3.05	1.00	46
10-Feb-09	Cadiscor Resources Inc	149,595	10.26	1.00	27
12-Mar-09	South Laverton	149,595	10.26	1.00	54
12-Mar-09	Georgetown	4,380,322	0.52	4.73	63
13-Mar-09	Jackson Minerals Ltd	358,952	2.13	2.7	4
30-Mar-09	Back River	44,456	1.89	2.0	5
30-Mar-09	Back River	96,342	20.91	2.11	11
30-Mar-09	Back River	330,717	2.09	3.18	31
2-Apr-09	Bronzewing	309,506	0.47	3.04	16
2-Apr-09	Bronzewing	2,353,113	10.50	2.51	6
31-Mar-09	Cadiscor Resources Inc	2,353,113	10.50	2.51	7
9-Apr-09	Golden Promise	2,353,113	10.50	2.51	9
9-Apr-09	Golden Promise	450,044	6.21	3	16
9-Apr-09	Musgrove Creek	882,200	2.49	2.8	8
14-Apr-09	Dioro Exploration NL	882,200	2.49	2.8	13
20-Apr-09	Mick Adam and Wadi	89,425	3.02	2.00	37
20-Apr-09	Mick Adam and Wadi	89,425	3.02	2.00	44
20-Apr-09	Mooseland	313,791	1.22	2.00	16
20-Apr-09	Mooseland	2,745,539	2.52	3.23	15
30-Apr-09	Pogo	4,142,063	2.54	2.86	10
11-May-09	Mineral Creek	226,012	1.31	2.2	1
6-May-09	Hog Range	226,012	1.31	2.2	7
19-May-09	Dohertys	787,716	13.37	1.00	20
10-Mar-09	Terrain Minerals Ltd	787,716	13.37	1.00	21
26-May-09	Box and Athona	3,938,702	15.34	4.75	157
26-May-09	Box and Athona	76,471	1.29	2.03	14
1-Jun-09	Elmtree	85,068	5.25	3.25	13
1-Jun-09	Elmtree	19,665	23.80	3.00	12
1-Jun-09	Elmtree	1,256,580	1.16	3.93	4
26-Mar-09	Castle-Black Rock	1,256,580	1.16	3.93	7
5-Jun-09	Scheelite Dome, Ogopogo and Willoughby	237,267	1.42	2.17	17
4-Jun-09	Silver Coin	237,267	1.42	2.17	39
8-Jun-09	Brewery Creek	237,267	1.42	2.17	20
10-Jun-09	Kookynie	2,818,592	1.99	2.43	7
11-Jun-09	Georgetown alluvial	143,232	1.35	1.00	5
3-Nov-08	Scorpio Mining Corp	287,405	1.45	2.51	25
15-Jun-09	Premier	424,240	2.34	1.7	4
26-Aug-08	Yarnell	42,500	0.50	1.00	50
16-Jun-09	Simkar - 1 g/t cut off	23,909	6.39	3.15	26
16-Jun-09	Simkar - 2 g/t cut off	131,604	0.80	1.0	13

Date	Asset	X (size)	Y (grade)	Z (confidence score)	Magnitude (unit price US$/oz Au)
16-Jun-09	Simkar - 3 g/t cut off	387,523	8.15	2.04	46
16-Jun-09	Simkar - 5 g/t cut off	143,419	3.01	2.00	57
12-Jun-09	Xplor Ltd	105,112	5.10	2.00	78
23-Jun-09	Davyhurst and Mt Ida	81,758	7.32	2.00	100
24-Jun-09	Kirkalocka	62,080	10.23	2.00	132
24-Jun-09	Lion Selection Ltd	1,566,259	2.53	2.98	27
25-Jun-09	Red Mountain	183,259	1.68	2.50	13
25-Jun-09	Red Mountain	2,288,236	1.51	3.29	48
26-Jun-09	Chester	683,930	5.78	3.12	15
29-Jun-09	Nixon Fork	683,930	5.78	3.12	16
1-Jul-09	Twin Hills	68,370	14.74	3.00	19
30-Jun-09	Monroe Lakes	154,757	19.86	4.48	23
6-Jul-09	Henty	165,273	8.67	4.50	10
6-Jul-09	Henty	198,179	7.43	2.79	7
6-Jul-09	Dioro Exploration NL	145,027	7.82	4.22	44
9-Jul-09	Shoal Lake	145,027	7.82	4.22	126
9-Jul-09	Shoal Lake	2,796,589	2.55	3.63	25
9-Jul-09	Shoal Lake	74,091	19.20	1.00	2
9-Jul-09	Sugarloaf	699,898	7.95	2.6	6
9-Jul-09	Sugarloaf	699,898	7.95	2.6	10
12-Jun-09	Windarra	699,898	7.95	2.6	26
6-Jul-09	Summit Lake	67,500	3.70	1.00	8
22-Jul-09	Kalgoorlie North	67,500	3.70	1.00	33
21-Jul-09	Prospect Valley	2,147,911	9.72	2.76	25
21-Jul-09	Prospect Valley	308,647	0.80	1.00	31
21-Jul-09	Prospect Valley	1,644,511	1.10	1.00	6
20-Jul-09	Klondex Mines Ltd	3,645,895	1.40	1.00	3
27-Jul-09	Souart	266,709	1.82	2.00	9
27-Jul-09	Souart	110,000	6.17	1.00	10
30-Jul-09	Dioro Exploration NL	110,000	6.17	1.00	19
31-Jul-09	Dingman	2,796,589	2.55	3.63	35
3-Aug-09	Ardeen	413,087	0.89	2.66	12
4-Aug-09	North Bullfrog	442,073	12.50	1.00	27
6-Aug-09	Crocodile Gold Inc	81,564	0.85	2.71	15
17-Apr-09	Crocodile Gold Inc	4,142,063	2.54	2.86	2
14-Aug-09	Lancefield and Beasely Creek	1,699,209	4.12	2.94	4
14-Aug-09	Lancefield and Beasely Creek	1,699,209	4.12	2.94	7

Table A-4.5. Country risk dataset

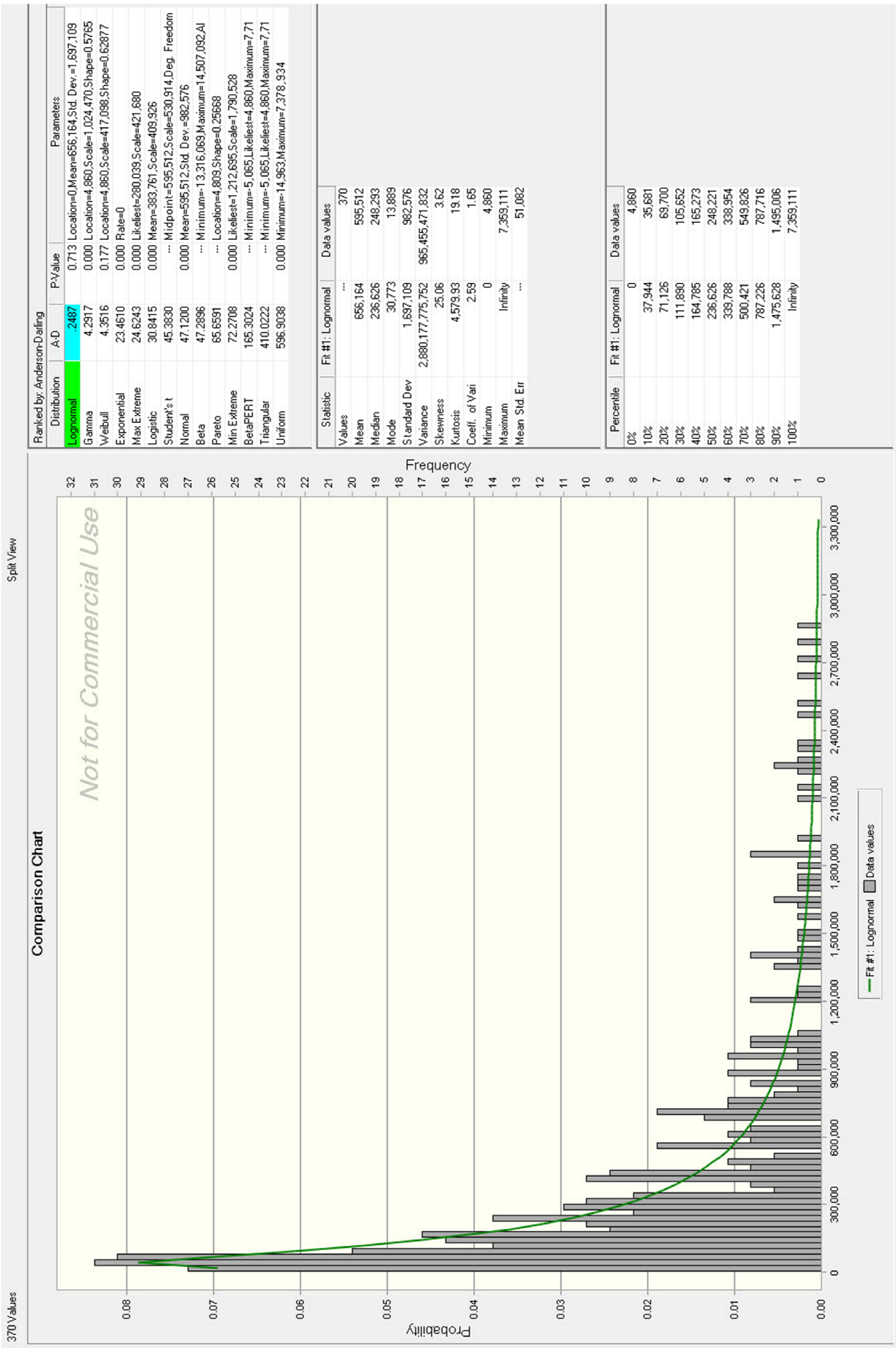
Date	Asset	X (size oz Au)	Y (grade g/t Au)	Z (country risk CFO)	Magnitude (US$/oz Au)	Country
03-Sep-08	Lobo and El Paso	66,830	6.28	0.55	202.6	Philippines
23-Sep-08	Archangel	386,926	0.80	0.55	13.7	Philippines
29-Sep-08	Frankfield	564,246	6.50	0.87	4.1	Canada
08-Oct-08	Dalabai	8,706	1.30	0.59	193.0	Kazakhstan
15-Oct-08	Duport	315,676	12.11	0.87	39.7	Canada
22-Oct-08	Mt Kare	1,210,480	3.81	0.48	33.7	Papua New Guinea
20-Oct-08	Spring Valley	899,710	0.61	0.95	45.2	United States
23-Oct-07	Chester	176,527	6.39	0.89	21.7	Canada
20-Nov-08	Aflease Gold Ltd	16,435,005	3.66	0.61	1.4	South Africa
12-Dec-08	Yandan	316,363	2.40	0.91	11.4	Australia
14-Jan-08	Miaozihe	576,704	10.25	0.63	19.5	China
13-Dec-07	Eastern Dragon	736,387	8.81	0.63	155.5	China
17-Jan-08	Mt Korong	92,498	2.74	0.85	19.1	Australia
20-Dec-07	Peak Hill	987,671	2.40	0.85	9.7	Australia
19-Feb-08	Mt Bundy	710,080	1.33	0.86	9.0	Australia
06-Mar-08	Redemption	1,616,763	2.47	0.85	35.1	Australia
03-Sep-07	Rothsay	132,783	7.00	0.85	7.1	Australia
28-Mar-08	White Dam	329,770	1.13	0.85	54.8	Australia
04-Apr-08	Cracow	1,000,277	8.57	0.87	264.3	Australia
14-Dec-07	Vatukoula	3,696,802	9.07	0.35	21.2	Fiji
28-Apr-08	Way Linngo	123,047	9.20	0.43	140.7	Indonesia
16-May-08	Boka	497,372	1.30	0.63	21.1	China
12-May-08	Cibaliung	555,152	11.38	0.43	88.4	Indonesia
29-May-08	Durack	42,632	2.33	0.85	10.9	Australia
25-Mar-08	Tabakoto and Segala	1,550,000	5.00	0.53	16.5	Mali
12-May-08	Avlayakan	464,682	11.27	0.54	26.3	Russian Federation
12-Jun-08	White Well	112,528	1.00	0.85	8.7	Australia
13-Jul-07	Furtei and Osilo	1,025,976	2.71	0.75	25.2	Italy
04-Oct-07	Quema	496,283	0.86	0.53	21.0	Panama
03-Mar-08	Papa Grande	2,432,457	0.86	0.15	10.1	Ecuador
27-Jun-08	Farabantourou and Sanso	59,881	2.50	0.53	5.5	Mali
02-Jul-08	Quartz Mountain and Hope Butte	589,275	0.80	0.70	6.7	United States
02-Jul-08	Pani	527,308	1.61	0.52	6.1	Indonesia
09-Jul-08	Tocantinzinho	2,102,811	1.25	0.71	66.2	Brazil
10-Jun-08	Kilgore, Hai and Gold Bug	487,000	0.91	0.79	15.4	United States
06-Aug-08	Bingo	105,652	14.06	0.95	35.3	Canada
20-Aug-08	Bombore	1,083,416	0.63	0.46	1.6	Burkina Faso
08-Dec-08	Paraiso	102,023	26.43	0.21	99.6	Ecuador
28-Nov-08	Abo	220,538	2.79	0.83	37.6	Canada
23-Dec-08	Taurus	1,041,684	1.00	0.83	2.0	Canada
23-Dec-08	Migori	1,167,072	1.10	0.52	6.1	Kenya
23-Dec-08	Dalradian	608,533	15.64	0.82	1.6	Ireland
19-Dec-08	Frankfield	496,376	5.80	0.87	1.6	Canada
29-Nov-07	Abo	220,538	2.79	0.79	46.4	Canada

Date	Asset	X (size oz Au)	Y (grade g/t Au)	Z (country risk CFO)	Magnitude (US$/oz Au)	Country
21-Jan-09	Garrison	309,826	5.33	0.87	25.2	Canada
27-Jan-09	Mestiza	1,474,932	2.07	0.30	2.1	Nicaragua
24-Feb-09	Mt Morgans	205,173	3.75	0.93	24.1	Australia
26-Feb-09	Yundamindera	47,397	2.35	0.93	27.5	Australia
11-Feb-09	Valentine Lake	443,847	10.50	0.91	11.9	Canada
20-Feb-09	Williams and David Bell	2,792,934	3.50	0.87	47.8	Canada
11-Feb-09	Stratagold Corp	3,306,869	0.81	0.88	2.6	Canada and Guyana
03-Feb-09	Sierra Minerals Inc	181,166	1.33	0.80	63.2	Mexico
03-Apr-09	Zara	1,041,282	6.31	0.33	59.9	Eritrea
09-Apr-09	Golden Promise	89,425	3.02	0.91	37.0	Canada
09-Apr-09	Musgrove Creek	313,791	1.22	0.83	14.4	United States
14-Apr-09	Dioro Exploration NL	2,745,539	2.52	0.93	15.6	Australia
17-Apr-09	Elle Valle/Carles	2,473,101	6.03	0.82	25.2	Spain
20-Apr-09	Mick Adam and Wadi	226,012	1.31	0.93	6.9	Australia
21-Apr-09	Sawayaerdun	1,524,377	1.12	0.66	5.5	China
20-Apr-09	Mooseland	787,716	13.37	0.79	18.0	Canada
12-May-09	Konongo	977,806	2.03	0.51	1.1	Ghana
19-May-09	Dohertys	19,665	23.80	0.93	11.7	Australia
10-Mar-09	Terrain Minerals Ltd	358,952	2.13	0.93	4.0	Australia
01-Jun-09	Elmtree	237,267	1.42	0.89	19.3	Canada
08-Jun-09	Brewery Creek	287,405	1.45	0.88	21.0	Canada
08-Jun-09	Marmato Mountain	2,779,900	1.14	0.63	8.8	Colombia
15-Jun-09	Altintepe and Inlice	842,532	1.47	0.66	11.1	Turkey
26-Aug-08	Yarnell	325,800	0.34	0.84	16.3	United States
16-Jun-09	Simkar - 2 g/t cut off	105,112	5.10	0.97	72.4	Canada
24-Jun-09	Kirkalocka	183,259	1.68	0.93	12.3	Australia
26-Jun-09	Chester	68,370	14.74	0.87	18.8	Canada
30-Jun-09	Monroe Lakes	165,273	8.67	0.88	10.0	Canada
06-Jul-09	Dioro Exploration NL	2,796,589	2.55	0.93	25.6	Australia
09-Jul-09	Shoal Lake	699,898	7.95	0.87	9.9	Canada
15-Jul-09	Kinbauri Gold Corp	2,927,612	4.44	0.82	29.2	Spain
22-Jul-09	Kalgoorlie North	266,709	1.82	0.93	8.8	Australia
21-Jul-09	Prospect Valley	1,644,511	1.10	0.83	5.2	Canada
24-Jul-09	Glencar Mining Plc	814,089	1.47	0.51	67.5	Mali, Ghana and Uganda
03-Aug-09	Ardeen	442,073	12.50	0.87	26.5	Canada
04-Aug-09	North Bullfrog	81,564	0.85	0.95	15.5	United States
05-Aug-09	Morelos	3,009,567	3.55	0.73	64.3	Mexico

Date	Asset	X (size oz Au)	Y (grade g/t Au)	Z (country risk CFO)	Magnitude (US$/oz Au)	Country
11-Aug-09	Kalana	1,142,119	6.33	0.51	17.4	Mali
03-Jul-09	Gateway Mining Ltd	463,865	1.66	0.91	15.2	Australia
19-Aug-09	Gold Mountain	2,721,564	0.89	0.66	2.0	China
17-Aug-09	Simkar	143,419	3.01	0.97	50.2	Canada
21-Aug-09	Chester	193,880	7.03	0.87	6.2	Canada
26-Aug-09	Sino Gold Ltd	8,345,612	2.18	0.66	313.2	China
01-Sep-09	Destiny	100,684	5.12	0.97	50.2	Canada
14-Sep-09	Garrison	2,238,871	2.19	0.87	3.8	Canada
16-Sep-09	Imwauna	725,733	12.54	0.48	15.0	Papua New Guinea
17-Sep-09	Maco	521,035	5.77	0.55	18.6	Philippines
18-Sep-09	Sawayaerdun	321,507	2.50	0.66	33.4	China
22-Sep-09	Zheng Guang	1,480,357	1.53	28.38	33.1	China
22-Sep-09	Cerro Quema	896,868	1.56	0.69	30.0	Panama
15-Sep-09	Auzuay 1	1,000,000	5.00	0.21	15.4	Ecuador
29-Sep-09	Goldboro	802,922	4.06	0.79	19.3	Canada
16-Oct-09	Sand Queens	180,134	8.61	0.93	40.8	Australia
27-Oct-09	Sindirgi and Tavsan	442,186	2.01	0.66	32.6	Turkey
28-Oct-09	Castle Gold Corp	1,792,635	0.52	0.69	53.9	Mexico and Guatemala
16-Jul-09	Moto Goldmines Ltd	22,523,078	3.17	0.33	30.9	Democratic Republic of the Congo
03-Nov-09	Little Stull Lake	248,365	10.30	0.88	5.7	Canada
04-Nov-09	Easter	198,697	2.03	0.95	14.4	United States
10-Nov-09	Zedex Minerals Ltd	3,579,656	2.59	0.55	15.7	Malaysia, Vietnam, Australia and the Philippines
30-Oct-09	Gaz	1,584,228	3.02	0.61	0.7	South Africa
16-Nov-09	Duparquet	3,508,556	3.64	0.97	52.0	Canada
18-Nov-09	REN	1,653,487	13.44	0.95	38.3	United States
18-Dec-09	West Tetyaevsky	419,786	3.27	0.59	43.8	Russian Federation
18-Dec-09	Malian	1,172,627	3.35	0.51	5.0	Mali
02-Nov-09	Kenieba, Keniaba East, Comifa and Boroya	324,404	3.92	0.51	15.1	Mali
29-Jul-08	Cochrane Hill and Caribou	212,032	7.24	0.79	37.3	Canada
29-Dec-09	Dioro Exploration NL	2,796,589	2.55	0.93	47.1	Australia
29-Dec-09	Awak Mas	2,192,060	1.10	0.52	2.4	Indonesia
31-Dec-09	Cerro Quema	896,868	1.56	0.69	27.9	Panama
20-Jan-10	Triton	600,000	15.00	0.87	2.2	Canada
28-Jan-10	Kremnica	1,548,860	1.41	0.78	1.6	Slovak Republic
05-Feb-10	Mt Korong, Mt Zephyr and Mt Goos	92,000	2.70	0.93	7.0	Australia
05-Feb-10	Eucalyptus and Malcolm	207,800	2.86	0.93	4.2	Australia
09-Feb-10	Clavos	147,470	6.83	0.87	35.3	Canada
07-Jan-10	Bullabulling	416,578	1.44	0.93	15.1	Australia
04-Mar-10	Terra	172,737	12.55	0.91	61.0	United States
08-Mar-10	Sugar Zone	283,502	9.75	0.87	33.1	Canada

Date	Asset	X (size oz Au)	Y (grade g/t Au)	Z (country risk CFO)	Magnitude (US$/oz Au)	Country
11-Mar-10	Underworld Resources Inc	1,412,323	2.96	0.88	90.4	Canada
15-Mar-10	Souart	110,000	6.17	0.87	70.7	Canada
22-Mar-10	Brett Resources Inc	8,090,508	0.87	0.95	44.7	Canada, United States and El Salvador
25-Mar-10	Orion	77,162	8.00	0.91	43.9	Canada
01-Apr-10	Comaplex Minerals Corp	5,039,050	7.35	0.85	141.3	Canada
07-Apr-10	Ingurubi	553,797	2.65	0.52	5.7	Tanzania
07-Apr-10	Golden Arrow	524,540	1.02	0.95	21.5	United States
28-Apr-10	Douay	152,073	8.16	0.97	70.4	Canada
30-Apr-10	Bluff	557,012	2.67	0.91	13.2	United States
04-May-10	Lihir Gold Ltd	52,348,038	2.21	0.76	158.9	Papua New Guinea, Côte d'Ivoire and Australia
07-May-10	Ondundu	490,026	3.39	0.67	26.9	Namibia
01-Jun-10	Wildrose	9,277	9.94	0.83	291.3	Canada
03-Jun-10	North Queensland Metals Ltd	1,396,049	4.01	0.91	26.3	Australia
03-Jun-10	Dufferin	42,747	13.12	0.79	220.8	Canada
14-Jun-10	Springfield	66,205	1.43	0.92	5.5	Australia
18-Jun-10	West Kalgoorlie	595,638	1.84	0.93	5.3	Australia
05-Jul-10	North Queensland Metals Ltd	1,395,877	4.01	0.91	50.4	Australia
06-Jul-10	Marban	970,953	2.16	0.97	34.8	Canada
09-Jul-10	North Queensland Metals Ltd	1,396,001	4.01	0.91	32.0	Australia
19-Jul-10	Croinor and Matchi-Manitou	289,955	6.31	0.97	41.1	Canada
10-Aug-10	Blackburn	238,131	1.12	0.93	2.7	Australia
26-Jul-10	Sergeevske	557,012	4.50	0.34	22.9	Ukraine
26-Aug-10	Shulea	723,911	12.51	0.48	14.7	Papua New Guinea
31-Aug-10	Golden Goose Resources Inc	1,741,939	7.24	0.87	6.8	Canada
10-Sep-10	Cerro Quema	896,868	1.56	0.69	27.8	Panama
08-Sep-10	Avoca Resources Ltd	6,626,198	2.40	0.98	135.8	Australia
15-Sep-10	Penny's Find	52,340	5.18	0.93	72.0	Australia
21-Sep-10	Sao Chico	1,000,000	15.00	0.71	5.5	Brazil
24-Sep-10	Rolling Rock Resources Corp	1,212,016	5.98	0.88	8.3	Canada
30-Sep-10	Shotgun	980,000	0.93	0.91	2.0	United States
04-May-10	Lihir Gold Ltd	52,348,038	2.21	0.76	158.9	Papua New Guinea, Côte d'Ivoire and Australia

Appendix 5. Size and grade distribution of gold deposit transactions



Distribution	A-D	P-Value	Parameters
Lognormal	.2487	0.713	Location=0,Mean=656,164,Std. Dev.=1,697,109
Gamma	4.2917	0.000	Location=4,860,Scale=1,024,470,Shape=0.5765
Weibull	4.3516	0.177	Location=4,860,Scale=417,098,Shape=0.62877
Exponential	23.4610	0.000	Rate=0
Max Extreme	24.6243	0.000	Likeliest=280,039,Scale=421,680
Logistic	30.8415	0.000	Mean=383,761,Scale=409,926
Student's t	45.3830	---	Midpoint=595,512,Scale=530,914,Deg. Freedom
Normal	47.1200	0.000	Mean=595,512,Std. Dev.=982,576
Beta	47.2896	---	Minimum=-13,316,069,Maximum=14,507,092,Al
Pareto	65.6591	---	Location=4,809,Shape=0.25668
Min Extreme	72.2708	0.000	Likeliest=1,212,695,Scale=1,790,528
BetaPERT	165.3024	---	Minimum=-5,065,Likeliest=4,860,Maximum=7,71
Triangular	410.0222	---	Minimum=-5,065,Likeliest=4,860,Maximum=7,71
Uniform	596.9038	0.000	Minimum=-14,963,Maximum=7,378,934

Statistic	Fit #1: Lognormal	Data values
Values	---	370
Mean	656,164	595,512
Median	236,626	248,293
Mode	30,773	13,889
Standard Dev	1,697,109	982,576
Variance	2,880,177,775,752	965,455,471,832
Skewness	25.06	3.62
Kurtosis	4,579.93	19.18
Coeff. of Vari	2.59	1.65
Minimum	0	4,860
Maximum	Infinity	7,359,111
Mean Std. Err	---	51,082

Percentile	Fit #1: Lognormal	Data values
0%	0	4,860
10%	37,944	35,681
20%	71,126	69,700
30%	111,890	105,652
40%	164,785	165,273
50%	236,626	248,221
60%	339,788	338,954
70%	500,421	549,826
80%	787,226	787,716
90%	1,475,628	1,495,006
100%	Infinity	7,359,111

Figure A-4.2. Size distribution

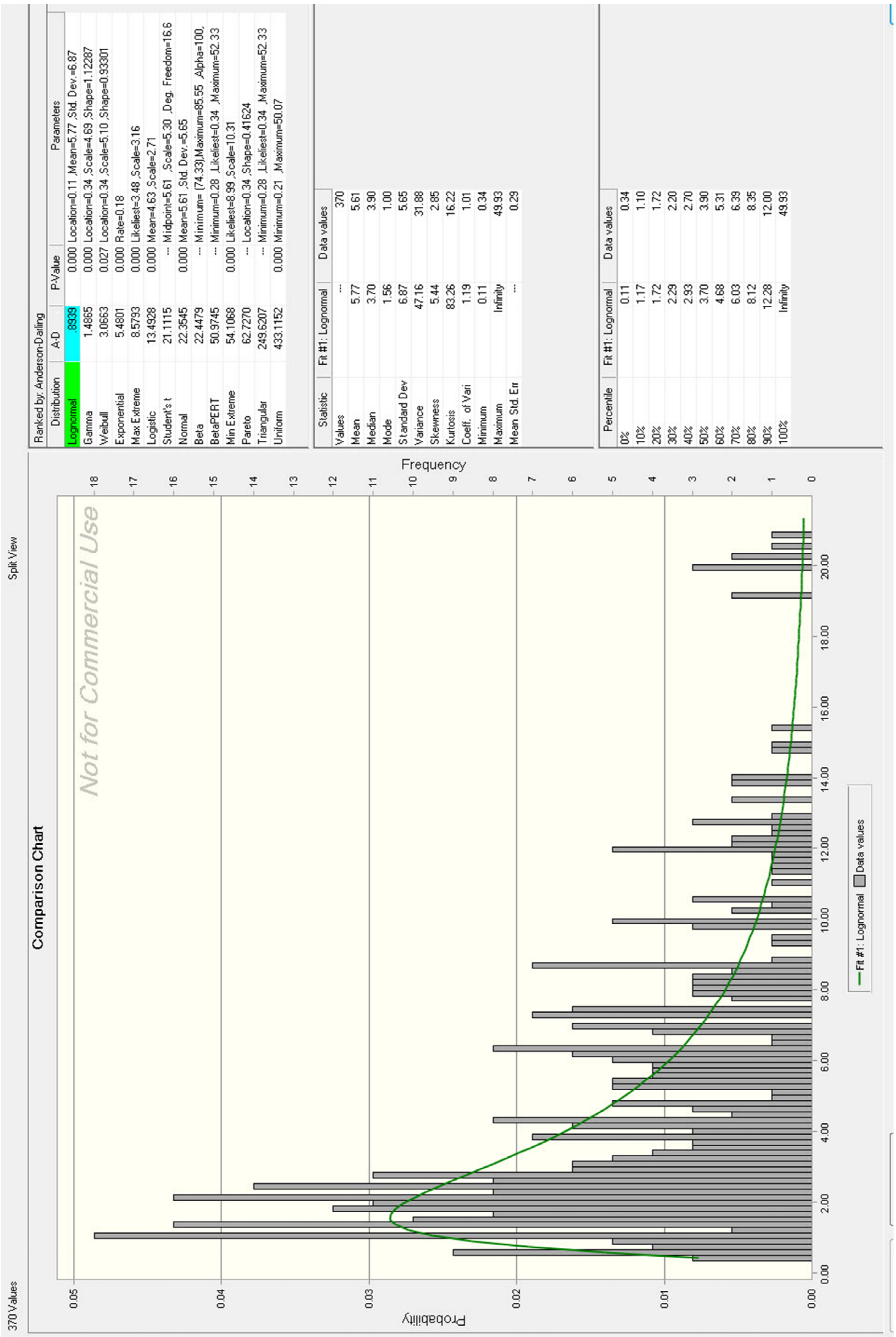
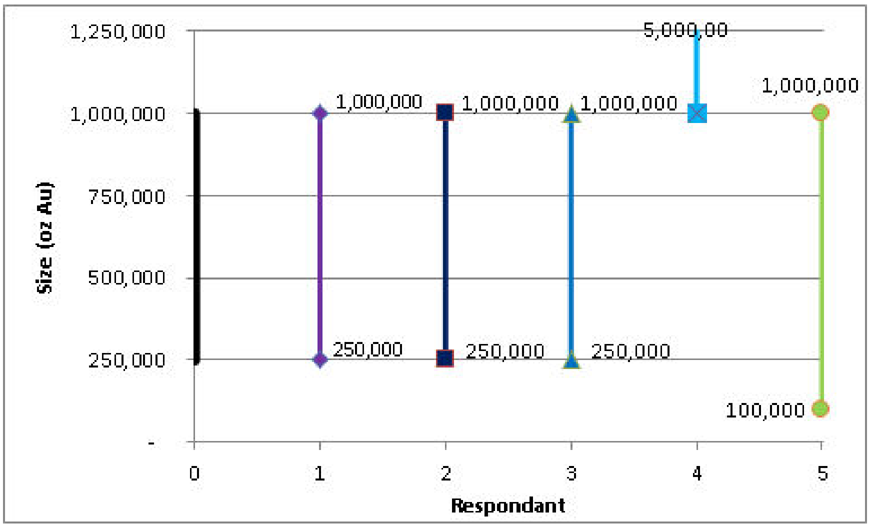


Figure A-4.3. Grade distribution

Appendix 6. Survey of perceptions of grade and size classifications

Respondent	Personal estimates				Comment
	Small (oz Au)	Large (oz Au)	Low (g/t Au	High (g/t Au)	
1	250,000	1,000,000	2	6	Emailed an unsolicited response at 9:40 am Friday 26 July 2013: "And here are my numbers (if that's what you're after): small gold deposits - anything below 0.25 Moz Au; large gold deposits - anything at or above 1 Moz Au; low grade - anything below 2 g/t Au; high-grade - anything at or greater 6 g/t Au (supporting U/G [underground] development). Those numbers come from a small company perspective. If I would work (sic) for a major I'd probably call anything less than 1 Moz Au small." The difference in grade was then discussed over a coffee, and the respondent had no strong aversion to the use of 3 g/t Au rather than 2 g/t Au.
2	250,000	1,000,000	2.8 (range 1.25 to 4.00)	5.8 (range 3 to 12)	Considered the moving size-grade distribution and OP [open-pit] vs UG [underground] considerations. When 55%:45% OP/UG distribution. OP small, low-grade is 2.5 g/t, small high-grade is 4 g/t, large low-grade is 1.25 g/t, large high-grade is 2.5 g/t Au. UG small, low-grade is 5 g/t Au, small, high-grade is12 g/t Au, large, low-grade is 3 g/t Au, large high-grade is 6 g/t Au. Using a 55%/45% near surface:deep ratio and applying this numbers, then averaging them, the 'generic' figures are 2.8 g/t and 5.8 g/t Au.
3	250,000	1,000,000	2. OP 6 UP (=2.97 eq)	6	Respondent differentiated the low-grades based on open-pit or underground. No upper limit placed on underground grade.
4	1,000,000	5,000,000	2 OP 5-7 U/G (=2.97 eq)	5-7	Grades were similar; however, the size view matches an international context rather than a domestic one. Based on the largest dataset, only 1.4% (5) of the transactions were greater than 5 Moz Au, making it statistically insignificant for a study into safe and mature mining jurisdictions.
5	100,000	1,000,000	3.00	12-15	Respondent confirmed that the assumption of 6 g/t Au is an acceptable hurdle if open-pit material is considered.
6					No response
7					No response
8					No response
9					Travelling o/s until late August 2013. Another survey participant was identified.
6 to 11	250,000	1,000,000	3.00	6.00	These persons were part of the original informal survey used in defining the boundaries in Bell et al. (2008).



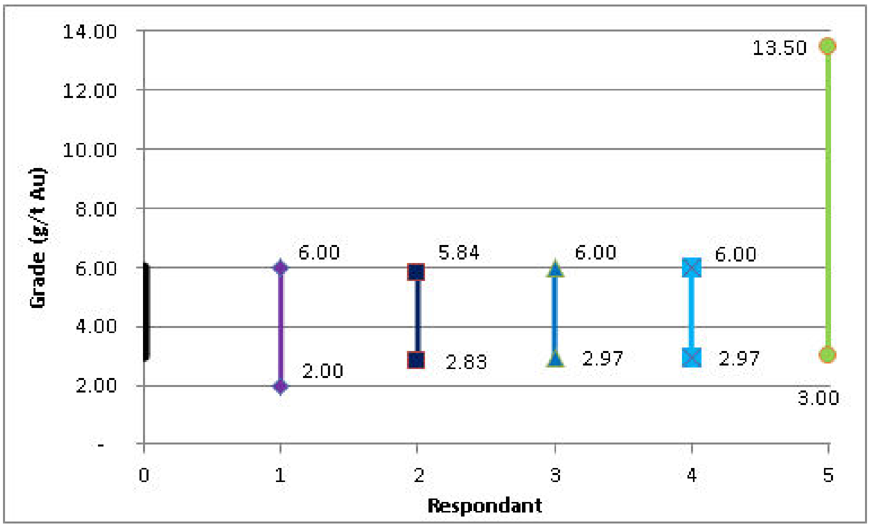


Figure A-5.1. Survey of perceptions of grade and size classifications

Appendix 7. Annual gold production rates

Statistic	Output
Median	114,198
Average	209,726
Max	854,056
Min	38,100
Q1	88,626
Q3	262,576

AISC Rank	Operation	Company	Mine Type	Grade (g/t Au)	Annualised gold production (pro-rata)
1	Ernest Henry	Evolution Mining Limited	UG	0.58	102,552
2	Cadia Valley	Newcrest Mining Limited	UG	1.2	854,056
3	Fosterville	Kirkland Lake Gold Limited	UG	25.6	362,472
4	Peak	Aurelia Metals Limited	UG	5.13	87,012
5	Hera	Aurelia Metals Limited	UG	3.66	54,984
6	Waihi	OceanaGold Corporation	UG	7.86	106,476
7	Mt Carlton	Evolution Mining Limited	OP	5.47	104,788
8	Gwalia	St Barbara Limited	UG	11.8	250,740
9	Duketon North	Regis Resources Limited	OP	1.02	109,548
10	Jundee	Northern Star Resources Limited	UG	4.6	306,408
11	Duketon South	Regis Resources Limited	OP	1.24	253,968
12	Cowal	Evolution Mining Limited	OP	1.22	245,040
13	Tomingley	Alkane Resources Limited	OP	2.29	62,536
14	Carosue Dam	Saracen Mineral Holdings Limited	UG	2.7	206,972
15	Tanami	Newmont Mining Corporation	UG	6.24	492,000
16	Thunderbox	Saracen Mineral Holdings Limited	OP	1.7	148,748
17	Tropicana	JV AngloGold/Independence	OP	2.2	500,400
18	Mungari	Evolution Mining Limited	OP/UG	2.89	140,480
19	Kalgoorlie	JV Newmont/Barrick	OP/UG	1.69	600,000
20	Boddington	Newmont Mining Corporation	OP	0.69	748,000
21	Edna May	Ramelius Resources Limited	OP	1.15	98,620
22	Mt Rawdon	Evolution Mining Limited	OP	1.2	118,848
23	Macraes	OceanaGold Corporation	OP/UG	1.23	199,892
24	Deflector	Doray Minerals Limited	UG	4.4	78,732
25	Cracow	Evolution Mining Limited	UG	5.17	89,164
26	Agnew Lawlers	Gold Fields Limited	UG	6.15	245,200
27	Granny Smith	Gold Fields Limited	UG	4.68	288,400
28	Kalgoorlie Operations	Northern Star Resources Limited	UG	4	306,096

29	Nullagine	Millennium Minerals Limited	OP	1.53	89,656
30	Mt Magnet Operations	Ramelius Resources Limited	OP/UG	1.74	107,092
31	St Ives	Gold Fields Limited	OP/UG	2.58	356,800
32	Beta Hunt	Royal Nickel Corporation	UG	3.93	100,512
33	Murchison	Westgold Resources Limited	OP/UG	2.6	101,192
34	Fortnum	Westgold Resources Limited	OP/UG	2.07	53,576
35	Mount Monger	Silver Lake Resources Limited	OP/UG	3.8	128,380
36	Plutonic	Superior Gold Inc	OP/UG	2	98,876
37	Matilda-Wiluna	Blackham Resources Limited	OP/UG	1.2	76,196
38	Cue	Westgold Resources Limited	OP/UG	1.6	50,228
39	Ravenswoo d	Resolute Mining Limited	OP/UG	0.99	73,624
40	Darlot	Red 5 Limited	UG	3.01	86,436
41	Nicolsons	Pantoro Limited	UG	5.75	38,100
42	Higginsville	Westgold Resources Limited	OP	1.51	39,156
43	Sunrise Dam	AngloGold Ashanti Limited	UG	1.87	244,000
44	Telfer	Newcrest Mining Limited	OP/UG	0.79	421,996

After Ulrich & Twigger (2018)

Appendix 8. Ownership risk sub-analysis

1.4. Non-staged transactions, pre- and post-June 2007

This section examines the difference between transactions where incremental equity is obtained, to those having a single-stage deal structure, pre- and post-June 2007. This was done because Brouthers and Divoka (2010) and Delios (2002) found that staging a transaction increases the ability to learn, and therefore increases option value (Habib and Mella-Barral 2007); shows a shift in market behaviour before and after June 2007; and Section 4.2.2.3 shows that staged transactions can significantly affect the payable premia. Consequently, Table A-8.1, Table A-8.2 and Table A-8.3 set out the market behaviour using data sub-sets pre- and post-June 2007 where the transactions only involved outright purchases.

Table A-8.1. Post-June 2007, non-staged prices relative to the pre-June 2007 equivalents

Ownership brackets		Relative price: entire dataset			Relative price: non-staged		
Absolute	100%	0.98	0.89	0.77	1.27	1.30	1.33
Overwhelming	100%-70%	1.25	1.14	1.01	1.11	1.02	0.90
Majority	70%-50%	1.95	1.76	1.54	0.75	0.69	0.60
Minority	<50%	1.08	1.79	1.43	0.67	0.65	0.63
Category		Inferior	All	Superior	Inferior	All	Superior

Table A-8.2. Ownership factors using pre-June 2007, non-staged transactions

Ownership brackets		Premia: entire dataset			Premia: non-staged		
Overwhelming	100%-70%	1.03	1.01	0.97	1.17	1.33	1.34
Majority	70%-50%	0.98	0.93	0.87	1.72	1.88	1.71
Minority	<50%	0.92	0.94	0.84	1.93	1.90	1.60
Category		Inferior	All	Superior	Inferior	All	Superior

Table A-8.3. Ownership factors using post-June 2007, non-staged transactions

Ownership brackets		Premia: entire dataset			Premia: non-staged		
Overwhelming	100%-70%	1.30	1.32	1.36	1.03	1.00	1.00
Majority	70%-50%	1.98	1.84	1.70	1.02	0.95	0.94
Minority	<50%	1.95	1.71	1.51	1.03	1.02	0.91
Category		Inferior	All	Superior	Inferior	All	Superior

The removal of the staged transactions had a significant impact on price patterns and how premia/discounts behave over the two time intervals as follows:

- **Prices of the non-staged, post-June 2007 subset** – the pattern appears to have reversed as partial, non-staged acquisitions incur substantial discounts (previously premia) with decreasing equity. This suggests that the option value in the post-June 2007 subset was substantially higher than in the preceding period, which is due to the macro-economic turbulence (volatility increases option value (Black and Scholes 1973)). As it conveys the right to learn without full commitment, staging appears to add option value, which is consistent with Brouthers and Dikova (2010) and Anand and Delios (2002). For absolute and overwhelming acquisitions, the optimal deal structure appears to be non-staged.

- **Premia of the non-staged, pre-June 2007 subset** – the premia payable increased markedly. This might be due to the readily available access to capital, making non-staged acquisitions more desirable.
- **Premia of the non-staged, post-June 2007 subset** – this time interval was characterised by difficulty in obtaining capital (Martel and Kravchuk 2012), which makes the acquiring parties more sensitive to strategic risk (Oh 2013). Removing staged transaction resulted in premia being nullified due to a loss of strategic benefit.

This analysis highlights that the availability of capital and the deal structure are linked when quantifying ownership premia under contrasting macro-economic conditions. It demonstrates optionality may attract premiums throughout the business cycle, but the magnitude may vary considerably depending on the time, circumstance and deal structure.

1.5. Cash and scrip transactions, pre and post-June 2007

A sub-analysis using cash and scrip only transactions was created for each time interval. This was done to test the hypothesis that cash is preferred by vendors (Capron and Shen 2007). For the pre-June 2007 dataset, the removal of exploration expenditure commitments increased the implied prices, showing a preference for inferior deposits (Table A-8.4). This confirmed the notion that where direct equity interest is to be retained, expenditure commitments are viewed favourably by the vendor, who will accept a lower price if there is an expectation of capital growth. For 100% equity acquisitions, the pre-June 2007 subset showed a stronger preference for superior deposits, suggesting that during that time and under those circumstances, the market was confident and prepared to pay a premium for outright ownership of the deposits.

Table A-8.4. Post-June 2007 cash and scrip factors relative to pre-June equivalents

Ownership brackets		Relative price: entire dataset			Relative price: cash and scrip		
Absolute	100%	0.98	0.89	0.77	1.05	0.92	0.75
Overwhelming	100%-70%	1.25	1.14	1.01	1.45	1.28	1.07
Majority	70%-50%	1.95	1.76	1.54	1.91	1.73	1.50
Minority	<50%	1.08	1.79	1.43	1.95	1.80	1.62
Category		Inferior	All	Superior	Inferior	All	Superior

The ownership premia of the cash and scrip subset for pre-June 2007 are shown in Table A-8.5. Inferior deposits maintained more or less the same price across the different equity stakes. However, the superior assets attracted slightly larger discounts. This behaviour in the smaller dataset is consistent with the observations in the total dataset.

Table A-8.5. Pre-June 2007 cash and scrip (only) ownership premia and discount factors relative to absolute acquisitions

Ownership brackets		Premia: entire dataset			Premia: non-staged		
Overwhelming	100%-70%	1.03	1.01	0.97	1.00	0.98	0.95
Majority	70%-50%	0.98	0.93	0.87	0.99	0.92	0.84
Minority	<50%	0.92	0.94	0.84	0.99	0.88	0.74
Category		Inferior	All	Superior	Inferior	All	Superior

The removal of the exploration expenditure commitments had negligible effect on the patterns in both the pre and post-June 2007 analyses. In this instance, there is no benefit from reducing the size of the dataset; therefore, it is more desirable to maintain a larger dataset that includes exploration expenditure commitments to maintain granularity.

1.6. Non-staged transactions differentiated by depth

The influence of staged option agreements on the implied price premia paid for deep and near-surface deposit premia are discussed in this section. The detemination of whether a deposit is near-surface is a result of either a disclosure effect, or the exercise of reasonable judgement that the mineralisation may conceptually be mined using open-pit mining methods. The sub-analysis in Table A-8.6 suggests that in broad terms, the price differences relative to the entire dataset were similar for near-surface deposits, but polarised in the deep deposit transactions. The influence of staged transactions on deep deposit prices is again a reflection of the risk and option value, with the associated ownership premia shown in Table A-8.7 and Table A-8.8.

Table A-8.6. Price factors of near-surface and deep deposits using non-staged transactions relative to the all transactions dataset

Ownership brackets		Relative price: near-surface			Relative price: deep		
Absolute	100%	1.02	1.03	1.00	0.76	1.00	1.02
Overwhelming	100%-70%	1.01	0.96	1.01	0.70	1.03	1.06
Majority	70%-50%	0.96	0.94	0.94	0.67	1.07	1.03
Minority	<50%	0.94	1.04	1.10	0.72	1.10	1.07
Category		Small	Medium	Large	Small	Medium	Large

Table A-8.7. Ownership factors of near-surface deposits using non-staged transactions

Ownership brackets		Premia: near-surface, entire dataset			Premia: near-surface, non-staged		
Overwhelming	100%-70%	1.11	1.29	1.09	1.10	1.19	1.10
Majority	70%-50%	1.21	1.50	1.15	1.14	1.37	1.20
Minority	<50%	1.08	1.27	1.04	0.99	1.26	1.13
Category		Small	Medium	Large	Small	Medium	Large

Table A-8.8. Ownership factors of deep deposits using non-staged transactions

Ownership brackets		Premia: deep, entire dataset			Premia: deep, non-staged		
Overwhelming	100%-70%	1.24	1.17	1.14	1.13	1.20	1.19
Majority	70%-50%	1.89	1.75	1.40	1.65	1.87	1.42
Minority	<50%	2.27	2.13	1.51	2.13	2.34	1.59
Category		Small	Medium	Large	Small	Medium	Large

From the analysis presented in the tables above, it would seem that:

- Near-surface deposit premia for staged and non-staged transactions are of a similar order of magnitude given that much smaller datasets were used in creating the block models. The pattern observation relating to the highest premia being payable for medium-sized deposits was uninterrupted.
- Deep deposits are more sensitive to staged transactions as the highest premia were no longer associated with small deposits, but rather medium-sized deposits. As deep deposits are riskier than near-surface equivalents, the option value associated with staged transactions affected their prices. By removing the staged transactions, optimal sales premia are achieved in the medium-sizes groupings as was the case for near-surface deposits.

This sub-analysis shows that underground deposits are more sensitive to the structure of the deal. Consequently, a Specialist must be cognisant of this price driver in their assessment of a partial equity project evaluation.

1.7. Cash and scrip differentiated by depth

The removal of the expenditure commitments resulted in the relative block prices shown in Table A-8.9 and the premia in Table A-8.10 and Table A-8.11. The removal of the exploration expenditure had the effect of generally increasing the price paid for both near surface and deep deposit (Table A-8.9)). However, there is minor impact on either the premia or patterns by eliminating exploration expenditure requirements (Table 23 and Table 24). If the qualities in Table 17, which concerns the main cash and scrip sub-analysis, are applied to the Table 23 and Table 24, the predicted premia are within a range of 10% to 20% of the actual modelled outcomes. However, as the data sub-sets underpinning Table 23 and Table 24 are around a third the size of the base-case dataset, it is not possible to make confident conclusions other than that the order of magnitude differences appear to be internally consistent between the models.

Table A-8.9. Price factors of near-surface and deep deposit using cash and scrip only transactions relative to the entire dataset equivalents

Ownership brackets		Relative price: near-surface			Relative price: underground		
Absolute	100%	1.04	1.10	1.08	1.00	1.14	1.02
Overwhelming	100%-70%	1.11	1.09	1.08	1.08	1.09	1.05
Majority	70%-50%	1.06	1.05	1.05	1.03	0.98	1.02
Minority	<50%	1.08	1.07	0.99	1.09	1.13	1.15
Category		Small	Medium	Large	Small	Medium	Large

Table A-8.10. Ownership factors of near-surface, cash and scrip transactions

Ownership brackets		Premia: near-surface, entire dataset			Premia: near-surface, cash and script		
Overwhelming	100%-70%	1.11	1.29	1.09	1.19	1.28	1.08
Majority	70%-50%	1.21	1.50	1.15	1.24	1.44	1.09
Minority	<50%	1.08	1.27	1.04	1.12	1.21	0.93
Category		Small	Medium	Large	Small	Medium	Large

Table A-8.11. Ownership factors of deep deposit, cash and scrip transactions

Ownership brackets		Premia: underground, entire dataset			Premia: underground, cash and script		
Overwhelming	100%-70%	1.24	1.17	1.14	1.35	1.12	1.18
Majority	70%-50%	1.89	1.75	1.40	1.95	1.51	1.40
Minority	<50%	2.27	2.13	1.51	2.46	2.11	1.70
Category		Small	Medium	Large	Small	Medium	Large

1.8. Yardstick adjusted

To account for gold price volatility between 11 September 2001 and 31 December 2009, the nominal implied transaction prices are Yardstick adjusted relative to the differential between the gold price prevailing at the time of transaction and the gold price on 31 December 2009. An analysis where the influence of the gold price is 100% correlated with the sale price is tested in this section. The block model of the gold price adjustments relative to the adjusted equivalents are shown in Table A-8.12.

Table A-8.12. Yardstick adjusted block model prices relative to the unadjusted equivalents

Grade (g/t Au)		Overwhelming (<100% - 70%)			Majority (<70% - 50%)			Minority (<50%)		
High	>6	1.42	1.46	1.44	1.39	1.39	1.29	1.31	1.44	1.43
Medium	3-6	1.46	1.52	1.41	1.32	1.54	1.32	1.26	1.52	1.42
Low	<3	1.39	1.51	1.45	1.31	1.50	1.41	1.26	1.38	1.36
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

A review of the outcome of the gold price adjustments shows that an across the board inflation in the range of 25% to 55% of the unadjusted prices results. In this instance, the overall premia patterns are not significantly affected; however, the previous block model suggests that gold price adjustments are less reliable than CPI adjustments, and therefore, no additional discussion is made.

1.9. Near-surface and deep deposits by grade

The ownership risk behaviour of premia and discounts by grade Figure A-8.1 is like that of the size behaviour, presented in Figure 27. The main difference relates to the presence of small discounts for near surface deposits and a poorer differentiation between the grade increments (crossing lines). However, the overall patterns are similar in that for near-surface deposits, where the market attributed the highest premia to transactions greater than 50%, whereas deep deposits attract higher premia with smaller equity stakes.

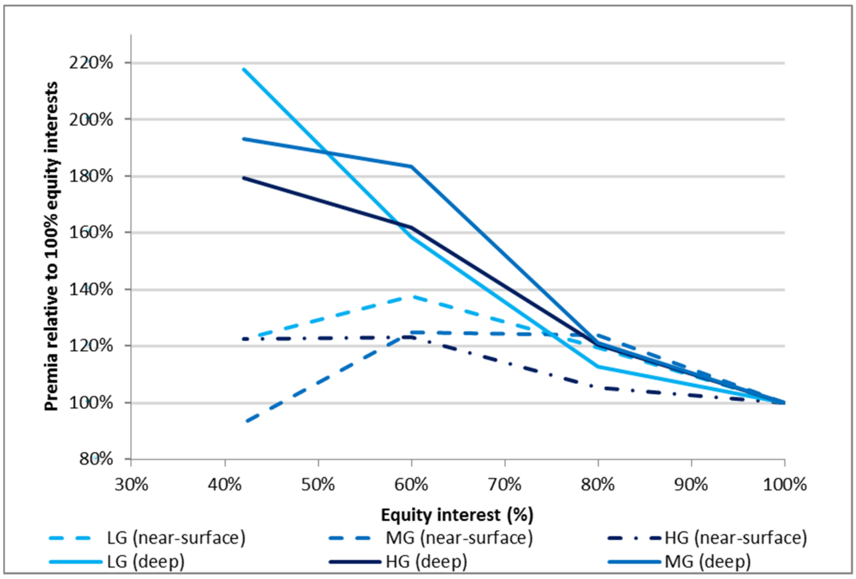


Figure A-8.1. Ownership premia for near surface and deep deposits

Appendix 9. Commodity price risk: linear sub-analysis

1.1. Linear analysis

As a first pass, this study uses gold price brackets in a linear two-dimensional analysis. This simple technique is useful as it:

- allows for big-picture trends to be easily identified
- is easily replicated without the need for sophisticated software and data analysis
- can be compared with the Yardstick method in a like-for-like (two-dimensional) testing manner.

1.1.1. All data points

A linear analysis of the full dataset suggests that while the unit price of a deposit does increase with increases in gold price, it does not do so in a fixed 1:1 price-price relationship. As Figure A-9.1 shows, the boxes defined by the Swanson mean (a method that provides a good approximation to the mean of skewed distributions (Hurst et al. 2000)) and medians show a positive skew in the dataset, except for the $500 to $600/oz gold price bracket, which is underpinned by a small dataset. The median prices fell consecutively within the $700 to$1,000/oz Au gold price range, with smaller declines between higher price brackets. The deposit price decrease in the $700 to $1,000/oz Au bracket is attributed to the initial securities market crash associated with the GFC as it occurred over the time span of 2008 and 2009. The reason for the price falls in other gold price ranges is not as easily identified. The elevated median acquisition price in the $1,500 to $1,600/oz Au bracket is influenced by spanning two distinct periods of time, from April to July 2011 and after May 2012. However, a review of the raw data shows that, in this bracket, there are 17 transactions, 4 of which involve operating mines and 5 transactions with unit values over $100/oz Au (two being mines and the other three being high- to very high-grade deposits). Consequently, this gold price bracket appears to reflect the dataset rather than a market behaviour.

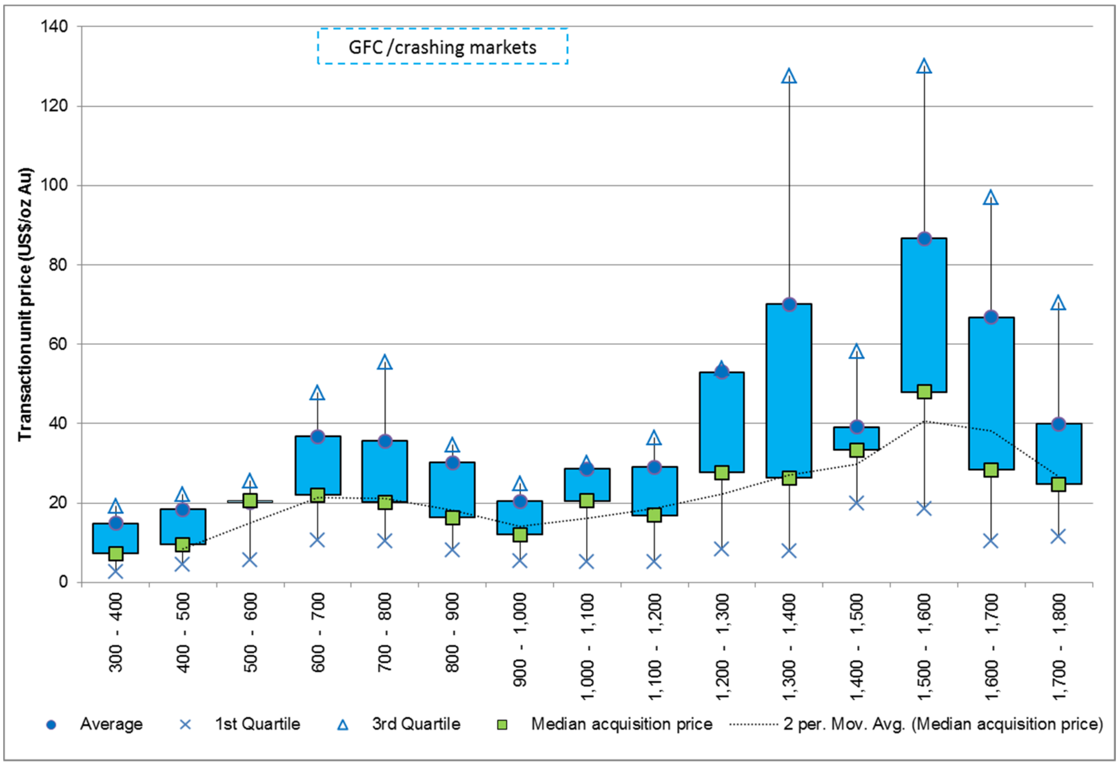


Figure A-9.1. Price-price trend of the entire dataset

1.1.2. Smoothed dataset

As a straightforward way to gauge the effect of very-high grade transactions and producing mines in the dataset, an analysis was undertaken that excluded operating mines and transactions with a unit price above $100/oz Au. While such an adjustment is akin to "cutting grades" before interpolating into a block model and reducing the amount of available data in this two-dimensional analysis, it is investigated because:

- it is otherwise difficult to account for the "nuggetty" data
- producing mines are likely to display the "certainty effect" outlined in Kahneman and Tversky (1979) and therefor realise higher prices
- the purpose of the two-dimensional analysis is to test the Yardstick method's premise that average/normal transactions will behave in a linear manner. Such unit prices are more than five times the median price; for testing the Yardstick method, these unit prices are excluded to reflect industry practice (Roscoe 2012), which is the subject of this analysis.

The effect of removing the operating mines and transactions with a unit price over $100/oz Au from the dataset resulted in 29 mines and 24 transactions being removed from the analysis (15% overall reduction in the population, "the smoothed dataset”). The price-bracket analysis shows that this smoothing caused the median prices to be lowered, as well as reducing the ranges between the quartiles (Figure A-9.2). The overall sinuous shape is retained, as is the downward trend for gold prices above $1,500/oz, although there are slight shifts in the locations of the peaks and troughs. The sinuous price response suggests that aside from the gold price in the market and technical aspects (e.g. size, grade, maturity), other price drivers do take effect over time.

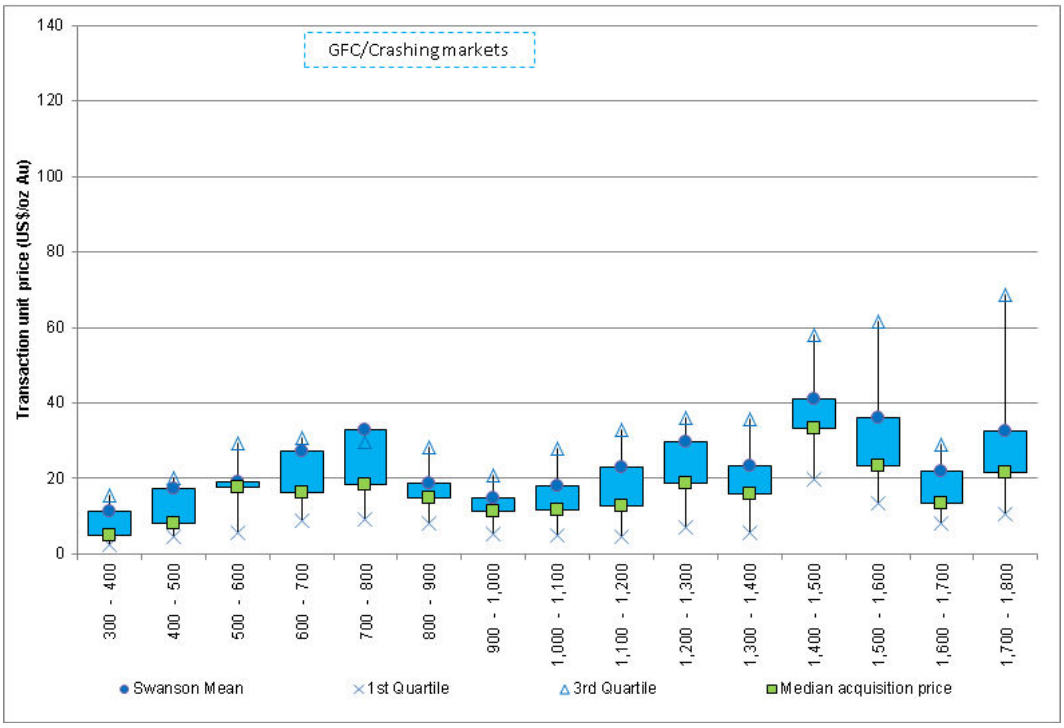


Figure A-9.2. Price-price trend of the smoothed dataset

1.1.3. Yardstick percentiles

To test the Yardstick method (which assumes a 1:1 gold deposit price:gold metal price relationship), the transactions within the smoothed dataset are presented as percentages of the prevailing gold price at the time of announcement (Figure A-9.3). This representation shows that Yardsticks respond similarly to the $/oz measures but have a negative slope over the long term as opposed to the positive slope associated with the long-term trend in acquisition price.

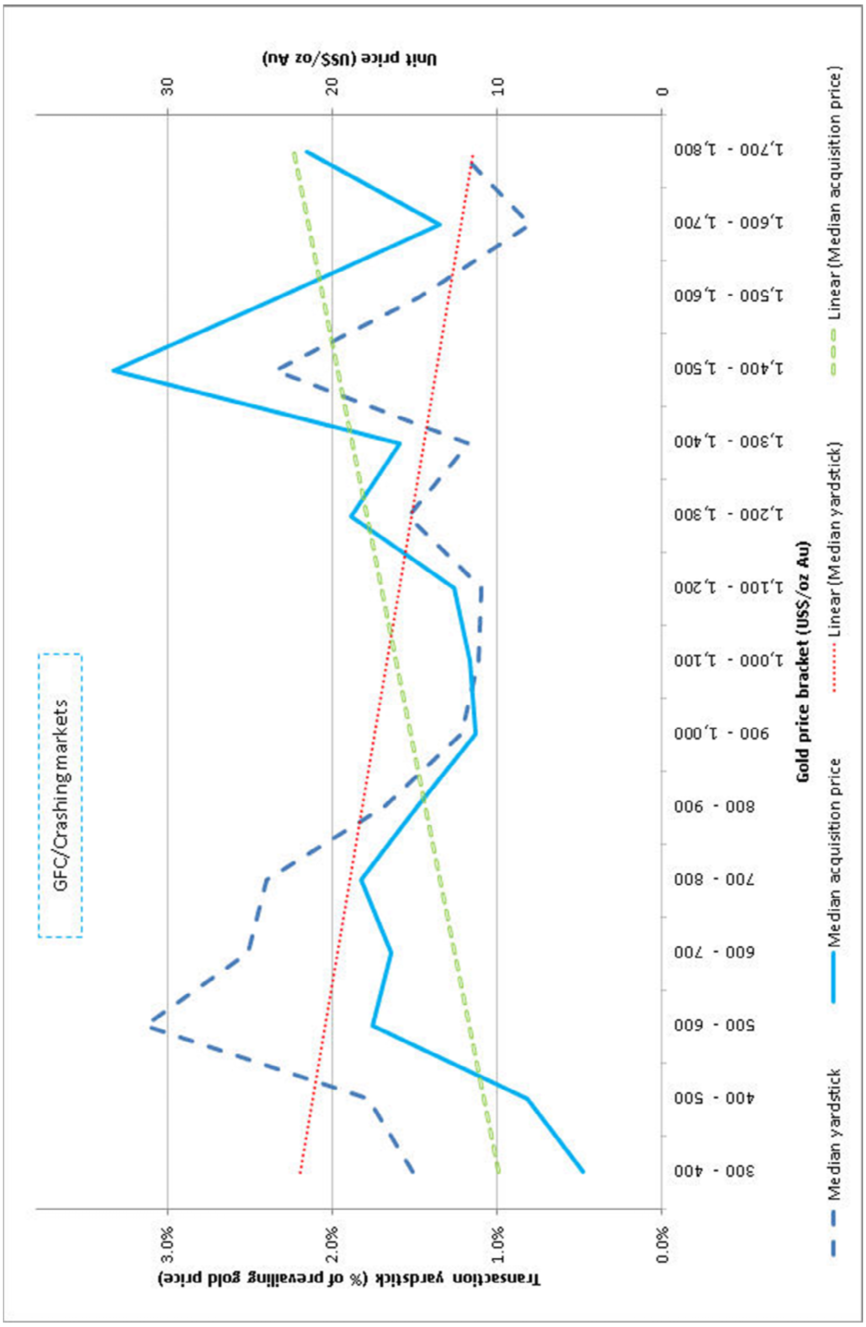


Figure A-9.3. Price-price trend of the smoothed dataset using Yardstick measures

1.1.4. Time-series

An alternative method of interrogating the dataset is to plot it as a time-series, as this allows for the rate of the gold price appreciation to be taken into account (Figure A-9 4). Treating the data in this way results in the subset increments used to derive the median values being different to those of the previous analyses. The distinct feature of this time-series is that it shows how both the unit prices and the Yardstick values underwent a “resetting” in 2008 (i.e. at the time of the crash associated with the GFC). This representation of the data is less connected to the gold price in the market because the X-axis is based on a time dimension, but shows how the unadjusted unit prices do appear to follow the gold price trend, although the rates of growth differ. This is a critical point, as the differing growth rates result in the Yardstick trend being less obviously related to the prevailing gold price in the market. Visually, the case for using $/oz Au unit prices is much more appealing than Yardstick percentiles.

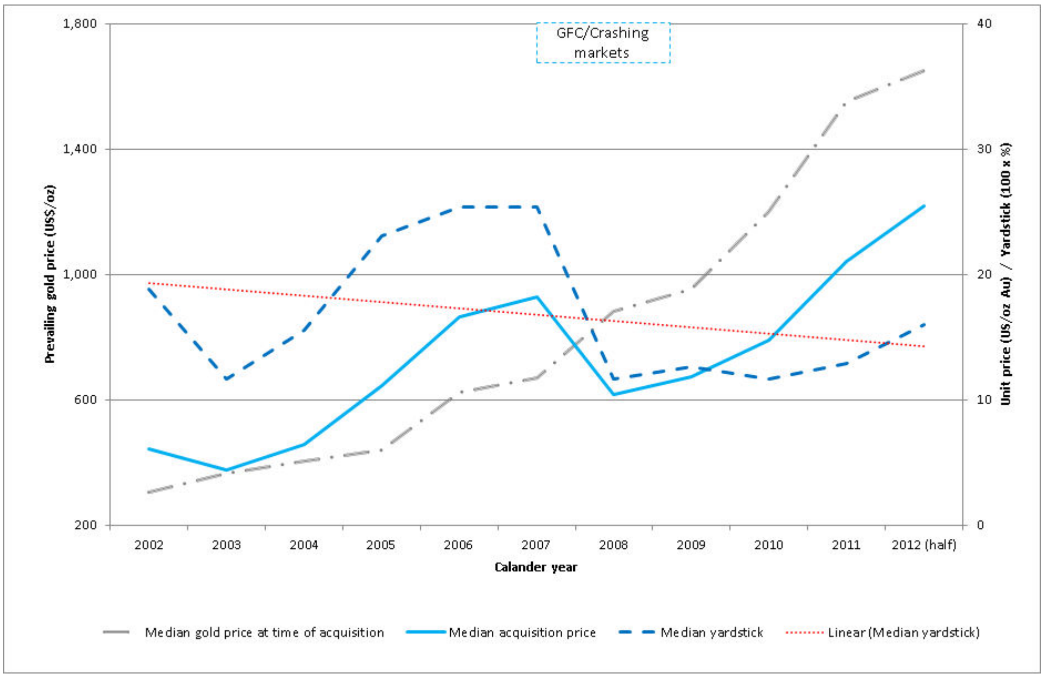


Figure A-9 4. Time-series distribution of the smoothed price-price dataset

1.1.5. Discussion on the validity of the Yardstick method

The two-dimensional analysis of actual gold deposit transactions suggests that the assumption inherent in the Yardstick method that deposits transact at a set proportion of the gold price, is erroneous. This is based on the following observations:

- **The sinuous shapes in Figure A-9.1 and Figure A-9.2 show that the price-price relationship is not consistently positive.** While it is possible to attribute some of the falling trends to crashing securities markets, the upper price brackets also displayed a falling unit price. This suggests that the association of gold with fear of an impending deterioration in general economic conditions negatively impacts the price of a deposit, even though the gold price is positively impacted. As it stands, the Yardstick method does not account for such sinuous price behaviour, which is of significance for industry given that transaction datasets up to three years old are often considered valid as a reference (or in the case of Spicer (2009), six years).

- **Long-term Yardsticks are less consistent than the unadjusted unit prices**: Yardsticks are supposed to negate gold price distortions such as the sinuous transaction price response noted above. Therefore, they should yield a more consistent, linear/flat trendline than the raw unit values. However, the squared correlation co-efficient (r^2) of the Yardstick in Figure A-9.3 is lower than that of the unadjusted transaction values (0.26 vs. 0.34). This implies that the Yardstick method adds to distortions and inconsistencies in the interpretation.
- **The Yardsticks over the long term seem to have a negative correlation with the price of gold**: As the assumption is that the transacted price will always be at a fixed proportion to the metal price, the Yardsticks should produce relatively flat lines on a time-series or price-series graph. Instead, the price-price pattern relationship appears to have an insignificant slope (-0.013 correlation vs 0.25 for the $/oz Au units) thereby challenging the notion of a fixed, positive, proportional price-price relationship which underpins the Yardstick method.
- **It is volatile**: By applying a gold price adjustment to transaction data, the resulting dataset should be less volatile than the unadjusted equivalent. Using the logarithmic cashflow returns technique (Mun 2002), the Yardsticks have similar volatilities to the unit prices (Table A-9.1). Consequently, the Yardstick method is ineffective in significantly reducing dataset volatility.

Table A-9.1. Volatility determination of the time-series brackets

Year ended	Comparable		Yardstick	
	Median price ($/oz Au)	Ln (t1/t0)	% oz Au $	Ln (t1/t0)
2002	6.1		18	
2003	4.4	-0.3264	12	-0.4814
2004	6.5	0.3901	16	0.2912
2005	11.2	0.5453	23	0.3918
2006	16.6	0.3999	25	0.0980
2007	18.2	0.0910	25	-0.0004
2008	10.4	-0.5593	12	-0.7751
2009	11.8	0.1265	13	0.0757
2010	14.8	0.2223	12	-0.0808
2011	21.0	0.3539	13	0.1007
2012 (half)	27.0	0.1917	16	0.2475
Volatility		33%		34%

The main problem with the Yardstick method is that it is more difficult to make predictions/projections compared to conventional ($/oz) unit pricing.

Interpretational difficulty heightens the risk of human error and compounds the risk and fundamental problems associated with the Yardstick method. In the absence of significant benefit, the loss of data integrity and additional risk of interpretative error makes the Yardstick method inferior to the unadjusted comparable transactions and joint venture-term methods.

Appendix 10. Commodity price risk: block model sub-analysis

1.1. Outright acquisition commodity price risk block models

As the research into ownership premia and discounts demonstrated that there are significant behavioural and price impacts conveyed by partial ownership, a block model was generated whereby only 100% acquisitions were included. This resulted in 260 transactions (down from 370) being used to populate a block model, which is free from partial ownership distortions. The result of this model is presented in Table A-10.1, with the results of all 370 data points (previously presented as Table 26) shown in subscript.

Table A-10.1. Metal price block model using only 100% equity transactions

Grade (g/t Au)		Low-medium metal price comparison (<$700 vs $700-1,000 oz brackets)			Medium-high metal price comparison ($700-1,000 vs >1,000 oz brackets)			Low-high metal price comparison (<$700-1,000 vs >1,000 oz brackets)		
High	>6	1.05	0.90	1.02	2.24	1.88	0.96	2.36	1.70	0.98
		1.23	1.37	1.50	1.82	1.23	0.76	2.24	1.69	1.15
Medium	3-6	1.02	1.15	1.25	3.18	1.82	0.85	3.24	2.11	1.06
		1.47	1.44	1.38	2.38	1.41	0.97	3.50	2.02	1.33
Low	<3	1.20	1.62	1.64	2.87	1.36	0.86	3.44	2.20	1.42
		1.29	1.25	1.63	2.88	1.57	1.56	3.73	1.95	2.49
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

By removing partial ownership transactions from the dataset, it appears that the block model unit prices are roughly similar in the low price environment, with half the blocks showing small falls, and the other half showing small gains. They are also mostly lower in the medium and high price environments, sometimes substantially. This suggests that the risk sharing benefits and lower capital requirements of partial transactions are rewarded in these environments where the market appears to be more risk averse. This was also observed in the research into ownership premia in Section 0.

In the low to medium price shift environment shown in Figure A-10.1, the transactions appreciated by a factor of 1.21 against a metal growth of 1.65 (originally 1.39 and 1.97). There is an increasing factor with size (e.g. 1.09<1.23<1.30). This observation is stronger than in the original 'all in' block model where the size procession is 1.33 to 1.35 to 1.49. This suggests that aspects of the market are more orderly when only 100% equity transactions are included in the analysis, despite the reduced data-point support. There is a discount factor of 0.9 for medium, high-grade deposits. It is assumed that this is an artefact of using a smaller dataset, whereby discreet blocks are more variable, although the overall trends are clearer (refer to the preceding point). There is a strong negative relationship with grade, with low-grade deposits appreciating more than the higher-grade equivalents. This differentiation was not observed when all the available transactions were used. It is possible that the market is clearer due to removing the distortions associated with partial interests, although this cannot be categorically stated because of the 30% reduction in the number of data points.

Figure A-10.1. Size based price appreciation factors using 100% equity transactions

In the low to high price shift environment shown in Figure A-10.2, the transactions appreciated by a factor of 2.05 whereas the metal price grew by a factor of 2.36. The improved 'price tracking' incurred in the high-price environment was also observed in the original Table 26. The negative relationship with size becomes even more pronounced than when all the available transactions are used to populate the block model. The grade-based differentiation remains relatively consistent with the low-medium price environment.

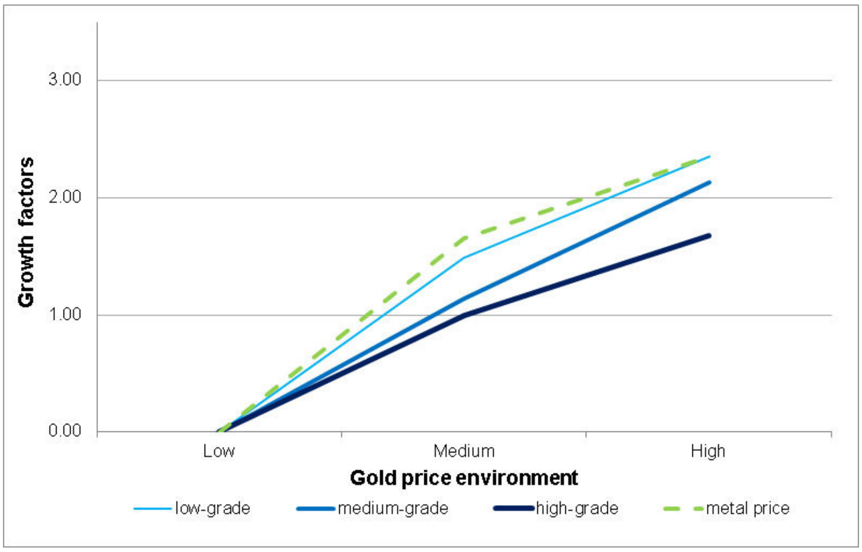


Figure A-10.2. Grade based price appreciation factors using 100% equity transactions

The analysis of the 100% equity transaction block model suggests that while unit prices are affected, the overall trends are like those generated using all the available transactions. On a discrete block basis, there is increased aberration due to a lower number of data points. However, the overall effect of removing partial interests seems to be that the behavioural differences:

- between small, medium and large deposits become more marked
- based on grade appear to be more orderly than when partial transactions are included in the block model.

Appendix 11. Certainty risk – sub-analyses

1.1. Yardstick adjusted certainty risk block models

The 'Yardstick method' typically entails expressing the unitised sales price as a percentage of the prevailing commodity price (e.g. gold price/$/oz Au = %). This method of expressing a sales price is an attempt to factor in changes in commodity prices and is reliant on the assumption that there is a linear, 1:1 relationship. For example, it assumes that a 10% rise in the price of gold will translate to a 10% rise in what a gold deposit will sell for.

To account for gold price changes between 11 September 2001 and 15 August 2009, the transaction prices are corrected relative to the differential between the gold price prevailing at the time of the transaction and that on 15 August 2009 (Table A-11.1). Inflation of the price of a mineral asset based on the relevant commodity price implies that project prices are a linear function of the prevailing metal price. This of course is not the case for a variety of reasons. Substantial changes in commodity prices would influence the very size of reserves, hence the optimal design and throughput of a mine. Even if the change in price were not sufficiently large to justify changes in production rates, fixed and variable operational costs, as a proportion of revenue and margins, would not be constant and would not lead to a linear relationship. Conversely, for deposits not already in production, the long lead times to actual production may reduce the influence of spot commodity prices. However, such Yardstick adjustments are routinely accepted and used by Specialists, and consequently, a relevant analysis has been included in this research.

Table A-11.1. Yardstick adjusted block confidence block prices confidence

Grade (g/t Au)		Low-confidence index <2.5 (Sherman Kent 0.4 – 0.67) ($)			Medium-confidence index 2.5-3.5 (Sherman Kent 0.67 – 0.80) ($)			High-confidence index >3.5 (Sherman Kent 0.80 – 0.98) ($)		
High	>6	78	57	43	44	70	74	59	64	147
Medium	3-6	93	21	23	45	37	45	49	59	134
Low	<3	34	18	14	26	34	34	37	52	90
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

A comparison of the gold-price-inflated block model prices with those presented in the preceding section shows that the block prices are higher in the approximate. In general terms, the overall relationships among the blocks do not change significantly compared to those observed in Table 33 and Table 34. However, there are more aberrations in Table A-11.1 For example, small, medium-grade deposits in the low, and to a lesser degree, medium-confidence domains, are more expensive than their higher grade-size equivalents.

Given that the inter-block relationships within Table A-11.1 are generally less robust than those in Table 33, it is suggested that the current industry practice of 1:1 ratio Yardstick adjustments are an oversimplification of the relationship between the price of a deposit and the prevailing gold price. A metal price adjusted unit-price using a percentage of the gold price prevailing at the time of the transaction may significantly over-price assets during periods of high-gold prices (e.g. 15 August 2009) or alternatively, under-state the price of assets during depressed gold price periods.

1.2. Pre- and post-June 2007 certainty risk block models

Given the time range within the dataset, two sub-analyses were undertaken to test the influence of higher gold prices pre- and post-June 2007 (Table A-10.2). Prior to June 2007, the market was generally buoyant, capital was easy to obtain, and gold had not experienced any substantial sharp and sustained price movements. Post-June 2007 represents a period when new floats on the Australian Stock Exchange ceased trading at significant premia to their listing prices, access to capital was severely constrained, and may represent a period during which gold was viewed as a more desirable commodity and store of wealth.

To test the influence of different market conditions, the CPI-only method was used to re-generate a new block model using 124 (41% of the dataset) transactions that occurred before June 2007; and second block model using 176 (59%) transactions that occurred after June 2007. During both intervals of time, the near-surface/deep ratio was approximately constant at 60:40.

Table A-10.2. Post-June 2007 block price factor relative to the pre-June equivalents

Grade (g/t Au)		Low-confidence index <2.5 (Sherman Kent 0.40 – 0.67)			Medium-confidence index 2.5-3.5 (Sherman Kent 0.67 – 0.80)			High-confidence index >3.5 (Sherman Kent 0.80 – 0.98)		
High	>6	2.44	0.47	0.68	0.91	2.12	2.30	1.54	1.20	1.30
Medium	3-6	1.46	0.81	1.50	0.89	0.92	1.21	1.90	0.81	0.67
Low	<3	1.00	2.83	2.00	1.06	0.49	0.60	1.00	0.47	0.60
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

The absolute prices and the relational results in Table A-10.2 suggest that:

- The inter-block relationships remain the same, albeit with magnitude differences to those observed using the entire dataset presented in Table 33. The observation that price generally increases with grade and size remains; that small, low-grade deposits with low-confidence trade at premia to their larger equivalents; and increased confidence for small deposits erodes price.
- Small, low-grade deposits appear to be relatively unaffected by changing equity market conditions, irrespective of the confidence category. The relative resilience of small, low-grade deposits is due to the larger pool of market participants seeking such assets.
- In medium and high-confidence domains, medium and large low-grade deposits attracted a substantial discount in the order of 50% to 60% of the pre-June 2007 prices. The aversion to low-grade deposits is due to the market making a connection between low-grade and low-margins; or the need for higher capital expenditure in a capital-constrained market. For high-grade deposits the inverse may also be true.
- In low-confidence domains, the market again seems to behave in a distinct way compared to the higher-confidence domains. In the low-confidence domain, the market appears to apply a discount to deposits of medium to large size and medium to high-grade relative to pre-June 2007 prices. This counter-intuitive result reflects low-confidence deposits being held by small to medium-capitalisation companies with little or no income, and highly constrained in their capacity to raise capital. Due to the limited capital available, the smaller vendors may have been compelled to accept cheaper prices or raise sufficient capital to increase the confidence in their deposit.
- The newer market dynamic had an apparently strong preference for deposits that are either low-grade or small (although their absolute prices remain less than the larger or higher grade comparable). This relative price improvement for small or low-grade assets in the post-June 2007 dataset may be due to many small companies seeking these assets for upgrading their status from early-stage explorers, or switching commodities (e.g. uranium, phosphate or iron explorers wanting to re-badge themselves as gold developers/miners). Perceived exploration potential may also be a factor in explaining the relative performance of small and low-grade deposits.

Whilst there are differences between the two models covering the two intervals of time, the overall trends within the models are reasonably similar given the smaller sub-sets of data used and the complex interaction of exploration potential and market appetite. On this basis, the use of a dataset encompassing all phases of a single market cycle is justified if a rule-of-thumb is sought.

1.3. Near-surface and deep deposit certainty risk block models

To account for the cost and risk differences between near-surface and deep deposits, two sub-models were generated, with the price differential factors (deep ÷ near surface) shown in Table A-11.3. The first model uses only near-surface deposits which made up 57% of the total dataset; and the second model uses transactions involving deep deposits. The two data subsets are broadly comparable, with the near-surface dataset having a median of 0.71 and a median of 0.27 Moz Au; and the deep dataset having a mode of 0.75 and a median of 0.40 Moz Au. Unsurprisingly, the largest transaction in the near-surface data subset is approximately twice the size of the largest deep transaction on a metal equivalent basis; however, the near-surface subset also contains numerous small deposits. As a consequence of size-grade combinations in the near-surface subset, the overall statistical profile for the two subsets is broadly similar (excluding the range in total metal content). The level of project development was also similar for both datasets.

Table A-11.3. Unit prices of deep deposit relative to the near-surface equivalents

Grade (g/t Au)		Low-confidence index <2.5 (Sherman Kent 0.40 – 0.67)			Medium-confidence index 2.5-3.5 (Sherman Kent 0.67 – 0.80)			High-confidence index >3.5 (Sherman Kent 0.67 – 0.80)		
High	>6	2.03	2.77	4.11	1.19	2.95	1.85	2.30	1.52	1.31
Medium	3-6	2.69	1.73	2.33	1.59	1.44	1.32	2.67	1.26	0.77
Low	<3	2.29	1.08	1.42	1.81	0.54	0.73	1.57	0.71	0.39
Size (Moz Au)		<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00	<0.25	0.25-1.00	>1.00
		Small	Medium	Large	Small	Medium	Large	Small	Medium	Large

The observations about the difference between near-surface and deep deposits include:

- In most cases, underground deposits traded at higher prices than those nearer to the surface. In the first instance, this would appear to be a counter-intuitive outcome as open-pit projects typically have more attractive capital and operating costs than those possibly amenable to underground mining methods. While hard to explain, the market could be adding a premium due to the cost and difficulty in defining Reserves and Resources at considerable depths below surface and thereby leaving upside exploration potential

- The highest increase in price relative to the near-surface equivalents is generally associated with low-confidence estimates. Again, this observation is explained by lower confidence deposits being perceived as having higher exploration potential than their higher confidence comparable.
- Medium and large, low-grade underground deposits attract heavy discounts (~40% to ~70% of relative price). This is likely to reflect the higher-grades required to offset higher production costs, with 3 g/t Au generally considered as being sub-economic unless amenable to open-pit mining techniques. It appears the exploration potential of low-confidence deep deposits partially offsets the influence of higher discounts due to higher production cost.
- The absolute block price patterns for near-surface and deep deposits remained the same for those observed in the entire dataset of Table 33. Small, low-confidence deposits had higher unit prices than the larger deposits for both open-pit and underground deposits. Small deposits decrease in price with higher confidence. Price generally increases with higher grades or sizes.

Appendix 12. Cross-commodity price analyses

1.1. Background

1.1.1. Introduction

This section examines the price difference between gold deposits and base-metal (copper, lead, zinc, nickel) deposits. Wampler and Ayler (1998) identified that multiple commodities in a deposit may materially affect its price. Bartrop (2010) identified that premiums are payable for gold mining companies. Twite (2002) attributes gold premiums to optionality, but does not make a direct comparison with base-metal deposits.

No formal literature was identified that directly addressed the price difference between gold and base-metal deposits. Industry practitioners appear to attribute gold premiums in the order of 1.3 to 2.0 times the underlying net asset value (NAV) (Lonergan 2006; Fredricksen 2012; Andrawes and Myers 2013), whereas base-metal companies may trade at less than a factor of 1.3 (McKibben and Egana 2012). This apparent "gold-premium" above the base-metal equivalents is attributed by Lonergan (2006) to factors including relatively low mining and metallurgical risk, a homogenous product sold into a sophisticated market that minimises realisation risk, and actively traded futures and forward markets.

Given the observations in gold securities, it is reasonable to expect that some sort of gold-premium should also be observable in mineral asset transactions. However, the market for gold deposits is much less liquid and less well researched than securities in general, and it is not always appropriate to apply the observations from one to the other, as demonstrated by the research into ownership premia (refer to section 0). Consequently, there is merit in testing whether the gold premium exists at an asset level.

As determined by a review of Alexander Research's database, gold deposits appear to be geologically more widespread, with a market that is more liquid and less diverse than their base-metal equivalents. Therefore, gold deposits are easier to research and conclusions have a greater certainty than the more individual base-metal studies. Lilford and Minnitt (2002) state that it is possible to use gold equivalent calculations in platinum group element deposits on the basis that they reflect operating and profit margins; however, no empirical evidence was cited. Before gold analogies are applied to base-metal transactions, it is important that the cross-commodity analogies be supported by empirical evidence.

To compare deposit transactions involving different metal types, it is possible to describe them using a common term such as the transaction price per ounce of gold equivalents. This allows for *in situ* comparisons; however, this methodology is flawed as it does not consider the differences in recoverable, payable metal and cost structures. To account for these value differences, it is possible to make payable metal adjustments when calculating the unit prices. As there is no consistent linkage between value and price, it is important that in any cross-commodity price analysis observations are made in both unadjusted and value-adjusted models.

The size and grade of a deposit must be considered as they affect the related capital, risk-exposure and profit margins. To account for size and grade variances, as well as recognising the noise associated with real data, it is important that models be generated that at a minimum, consider these two dimensions (e.g. it is incorrect to analyse based on a generic ounce of gold, as discussed in section 4.3).

1.1.2. Assets vs securities

While the premium associated with gold mining companies is generally acknowledged (Bartrop 2010; Twite 2002), it is uncertain if it holds true for the price of the underlying mineral assets, as real asset prices are poorly researched compared to those of securities. Despite significantly different ownership structures and associated benefits, the highly liquid securities market presumably provides insight into the future direction of gold deposit prices. However, security prices are often subject to high levels of speculation (Sornette 2000) and display behaviours that are different to those of asset prices (Garabade and Silber 1976; Adams 1997; Sorenson 2000; Zan et al. 2012). The price behaviour in reaction to a changing variable is distinctly different between securities and real assets, as observed in partial ownership premia and discounts (section 0). Simply put, if the securitisation process did not “unlock value” then the assets would never be floated into a publicly listed company. On the basis that the price of securities reflects a different ownership and benefit structure, it is uncertain what the magnitude of the gold premium is at a real asset level, and therefore warrants research. However, before a gold premium study can be undertaken, it is important to understand the technical differences between gold and base-metal deposits that may affect value and price.

1.1.3. Technical differences

A comparison between gold deposits and base-metal deposits can only be made if excessive technical and cost differences do not exist. For this to hold true, some points that need to be considered are:

- **Mineralisation** – there is a great diversity of mineralisation styles in both gold and base-metal deposits. In most cases, this is unlikely to have a significant impact on a comparison between the gold and base-metal deposit markets, as value is largely driven by quantity and quality (e.g. orogenic gold is not typically differentiated from epithermal gold in the valuation-pricing process). As base-metal deposits tend to be polymetallic, they may have a higher option value due to the ability to optimise the target commodity under changing macro-economic conditions (Li and Knight 2009). While some polymetallic gold deposits (e.g. gold-copper porphyries) may exhibit this quality, an assumption is made that if gold accounts for more than 75% of the metal equivalent value, then this flexibility option is minimal as the non-gold stream is viewed as a by-product. Where gold accounts for less than 75% of the implied value the deposits may depend on the secondary mineralisation as co-products, that is, where the economic viability of a mine is dependent on these minerals. Alternatively, the 75% threshold represents a point in which the distribution of the population curve in Figure A-12.1 flattens out, thereby representing a shift in the natural distribution of the deposit types. This distribution is based on the dataset that underpins this study and is discussed in more detail in Section 1.2.

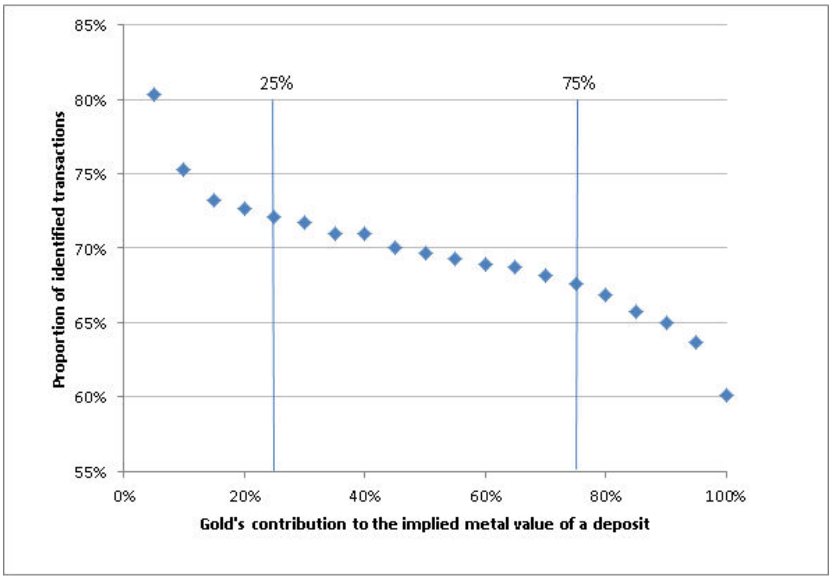


Figure A-12.1. Deposit distribution based gold's contribution to the in situ vale

- **Mining** – in most of the gold and base-metal deposits, the mineralisation is likely to be amenable to conventional and interchangeable mining equipment, as the market for equipment is primarily differentiated according to scale (Farooki 2012). Given similar size and grade attributes for deposits, it is assumed that there is no significant capital or operating differences in the mining process, with the possible exception being that of the costs to transport material, which is based on location. Conversely, analogies may not be made with bulk commodities such as iron or coal as they typically require substantially more upfront capital investments, and have mine lives significantly longer than most gold or base-metal operations.

- **Processing** – the processing infrastructure used by various base-metal mines is largely interchangeable (Martin et al. 1976). The main item of capital expenditure is usually the ball-mill, a front-end piece of equipment used to pulverise the ore, which is not contingent on the commodity. After crushing, gold ore will typically go through a cyanidation and leaching tank (van Deventer et al. 2004), whereas a base-metal ore are often treated through a series of floatation cells (Guang-Yi et al. 2011). Alternatively, the gold or base metal ores that are amenable to heap leaching that requires limited crushing (Subrahmanyam and Forssberg 1989). In the majority of cases, there is not a major difference in the capital expenditure required for gold and base metal deposits. In situations where deposits are likely to have a significant difference due to the processing type they must be excluded (e.g. nickel laterites, which account for 59.5% of global nickel resource (Mudd and Jowitt 2014)).

- **Saleable product** – gold deposits typically produce a highly refined product (doré), which may return between 99.8% and 99.95% of the metal value (Cotton 1993), which is in turn sold into sophisticated and liquid terminal markets (Lonergan 2006). In comparison, base-metal mines, unless fully downstream integrated, will produce intermediate products, such as a concentrate, which is sold to a third party or an offsite smelter. The sale of concentrate incurs costs and penalties (Lewis et al. 1993) that result in order of magnitude net smelter returns for:
    - copper in the range of: 70-80% (Wilson and Chanroux 1993a)
    - nickel: 65%-75% (Cunningham 1993)
    - lead: 45%-65% (Wilson and Chanroux 1993b)
    - zinc: 40%-60% (Wilson and Chanroux 1993c).

Where offsite processing, smelting and refining is required (as is often the case with base-metal deposits), the full payment is staged and delayed, thereby putting additional strains on cash flows, value and presumably the price of a mining operation.

- **Consumption** – gold demand is perceived as a safe investment in unfavourable economic conditions (Reboredo 2013; Baur 2011) and is not readily priced in terms of supply and consumption (Govett and Govett 1982; Capie et al. 2005; Starr and Tran 2008) and is priced largely on the sentiment of financial markets (Batten et al. 2010). In comparison, base-metals are used in industrial/commercial applications with metal prices that are primarily dictated by the mining supply and industrial demand relationship (Evans and Lewis 2002).
- **Metal price** – while quoting in equivalent terms is useful for communication purposes, it must be remembered that the underlying commodities have different price volatilities. Such volatility can add real option value to a deposit (Guj and Chandra 2012; Guj et al. 2012; Samis et al. 2012; Goodfellow et al. 2012); however, its effect on deposit prices is less certain. For the study period, it was calculated that the annualised volatilities using the logarithmic cash flow returns approach (Mun 2002) were as follows: gold: 22%; silver: 42%; lead: 46%; zinc: 39%; copper: 35%; and nickel: 43%.
- **Price profiles** – the price appreciation path of deposits, as they mature from discovery, varies from commodity to commodity. This results in the classification of “convex” and “concave” minerals as described in Trench and Packey (2012) and illustrated in Figure A-12.2. There are numerous reasons for this, but in general it represents technical risk, financial risk, and market familiarity with the commodity. Consequently, the comparison with gold deposit transactions should only be made using convex minerals, and should exclude those that are:
  - heavily reliant on metals such as molybdenum, a common co- or by-product in copper-gold porphyry deposits (IMOA 2013)
  - metallurgically difficult deposit types, such as lateritic nickel, that are not amenable to atmospheric leaching, as distinct from the relatively easy to process nickel sulphide deposits (McDonald and Whittington 2008).

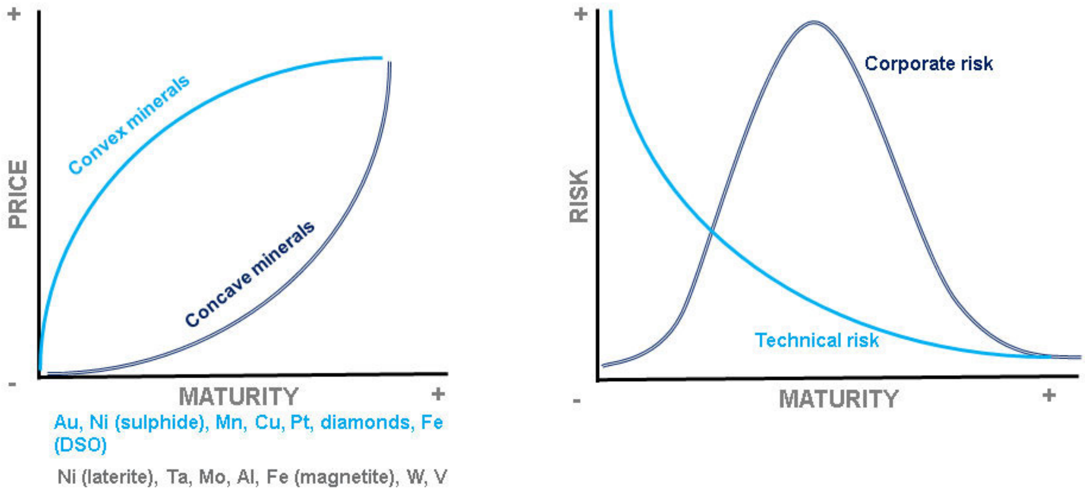


Figure A-12.2. Price and risk growth profiles

(after Trench and Packey, 2012)

Clearly, gold had the lowest volatility in this group. Furthermore, base-metals prices are considered to follow a mean-reverting geometric Brownian motion, whereas gold prices follow a non-reverting random walk (Shafiee and Topal 2009). This relative stability and non-cyclicity plays into its perceived role as a store of wealth, and hence, in differentiating the deposit prices.

Once there is an understanding of the technical differences between gold and base-metal deposits, attempts can be made to minimise their influences in the methodology used to gauge the gold-premium.

Existing quantum

The magnitude of gold-premiums is largely measured through the analysis of security prices. A review of security prices in Bartrop (2010) shows that, relative to diversified miners, gold securities over the calendar years 2009 and 2010 had consistent premiums of 1.6 for both earnings and cashflow per share. However, relative to base-metal companies, the earning-per-share ranged from a factor of 0.4 to 1.2 while the cashflow per share multiples were 1.0 to 1.1 per share. Other sources suggest that the security related premia are in the order of 1.3 to 2.0 times a gold company's NAV (Lonergan 2006; Fitzgerald 2012; Twite 2002; Andrawes and Myers 2013), but base-metal deposits may only achieve a factor of up to 1.3. In Bartrop (2010), a four-year cash flow comparison of 19 different corporations found that the 6 gold corporations traded at earnings multiples that were 1.06 times higher than base metal miners, and 1.58 times higher than diversified miners. However, it is noted that the size of the premium, particularly compared to the base-metal miners, is variable year on year. The difference can be broadly attributed to a range of aspects including operational flexibility (Twite 2002), lower risk, more sophisticated markets (Lonergan 2006), and single commodity leverage (Bartrop 2010).

1.2. Dataset

1.2.1. Study period

The research into the gold-premium spans from July 2005 through to July 2012. In this instance, the study period did not extend back to September 2001 due to the paucity of available base-metal transactions prior to July 2005. The study period represented somewhat different fortunes for base-metals when compared to gold and silver. Between July 2005 and July 2008, base-metal prices underwent significant appreciation as part of a period during which “metal prices surged to levels never before seen” (Humphreys 2010), even in real terms. After recovery from the price declines that occurred in mid to late 2008, most base-metal prices traded in ranges well below the previous peaks (Figure A-12.3).

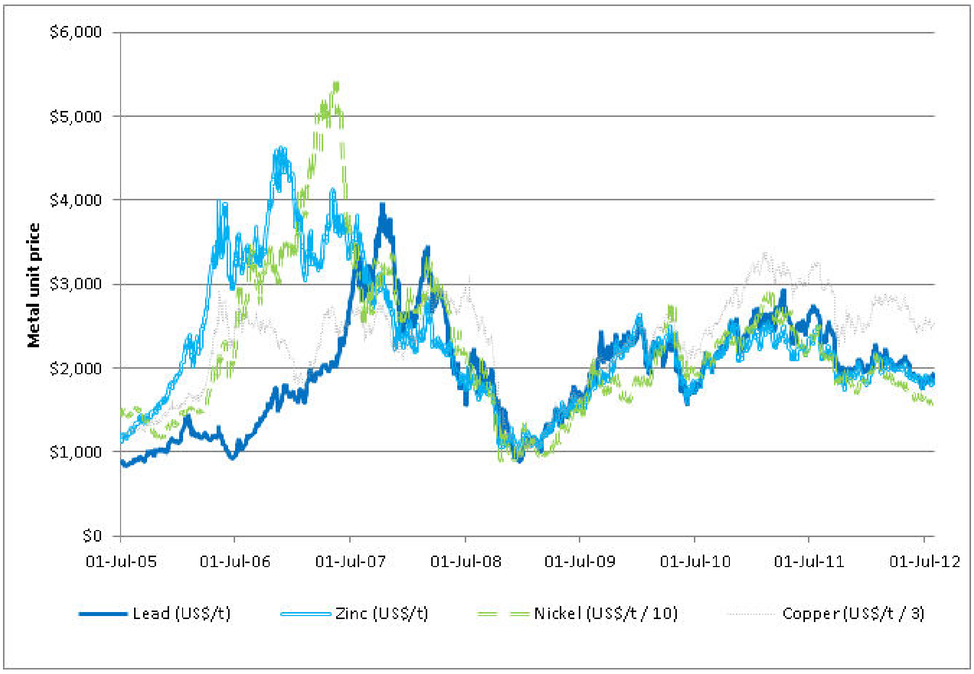


Figure A-12.3. Lead, zinc, copper and nickel spot prices

To categorise the deposit types, the following metal contributions were used:

- **100% to 75% gold** (361 transactions) – such projects are gold ‘plays’ and the market attributes prices accordingly. Any other metals produced are considered by-products.

- **<25% gold** (173 transactions) – such deposits are likely to be considered by the market to be pure base-metal '*plays*', as gold is likely to be recovered as a by-product or co-product. In the original conceptualisation of this thesis a 25%-75% gold contribution had been considered; however, there were only 24 transactions that satisfied this criterion. The analysis discussed in the following sections included up to 75% gold transactions, but changing the threshold had negligible effect on the patterns observed. Therefore, to attain the clearest distinction between gold and base metals, the 25%-75% gold contribution transactions were excluded in the following analysis.

Unlike previous applications in this thesis, this section involves deposits of different commodity types. While the initial intent was to cast the Z-dimension as the proportion of the *in-situ* metal made up by gold, it is important to establish whether it is valid to mix such datasets in a single block model. A pair T-test was run on deposits with a gold contribution ≥75% and those with a contribution <75%. From this analysis, there is less than a 1% chance that the two domains were from the same population. On this basis, it was deemed to be inappropriate to mix base-metal deposit transactions with gold deposit transactions. As a result, the two datasets were treated separately. This made using the Z-axis to represent the percentage gold contribution no longer a valid concept. Consequently, the analysis had to be undertaken in a two-dimensional manner (i.e. planar surfaces rather than three-dimensional space). However, the application of geostatistical analysis in two dimensions may have some advantages over its application in three dimensions due to the ability to avoid any bias related to information in the third dimension, which for varying reasons, may distort the reliability of the estimation process (Bertoli et al. 2003). The two-dimensional geostatistical analysis showed that the transformed nugget-effect is around 20% for the ≥75% gold contribution analysis and 30% for the <75% analysis. Furthermore, the geostatistical relationships defined by the semi-variograms within the datasets was found to differ, as shown in Figure A-12.4 and Figure A-12.5.

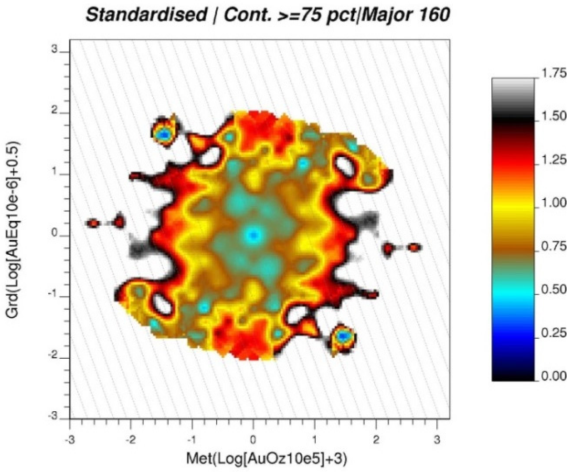


Figure A-12.4. Semi-variogram of transactions where gold was attributed ≥75% of the value

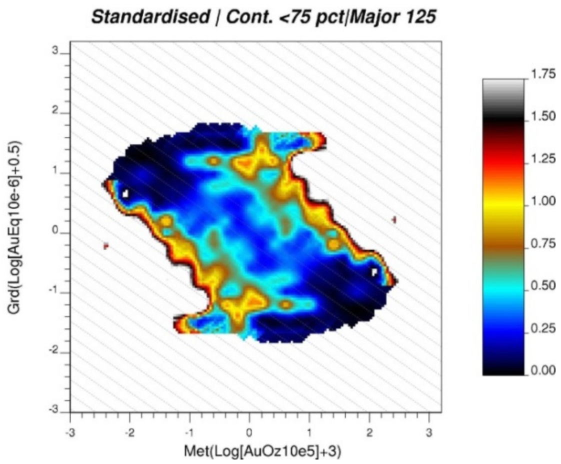


Figure A-12.5. Semi-variogram of deposits where gold was attributed <75% of the value

When the results of the semi-variograms of Figure A-13.10and Figure A-13.11 were used to populate the two-dimensional models, statistical problems were encountered. Compressing the datasets into a single plane resulted in many data points (size-grade) being located very close together. An artefact of using the ordinary-kriging method to interpolate within the model is that it is not very good at handling a large number of closely spaced data points (Bohling 2005), as it assumes that there is no spatial bias (Pyrcz and Deutsch 2003). However, compressing the data points onto a two-dimensional surface results in a strong clustering effect and generated outcomes that did not honour the underlying datasets. Consequently, a simpler, locally weighted scatterplot smoothing (LOESS) method was used as it is less affected by a large number of very closely spaced data points., LOESS is a form of regression (Cleveland 1979; Cleveland and Devlin 1988) that unlike ordinary kriging, does not make assumptions about dataset distributions in its production of surface plots. Instead, the LOESS declustering process involves applying a grid to the LOESS surface that smooths out the data surface (SAS/STAT 1999). The resulting LOESS maps are shown in Figure A-12.6 and Figure A-12.7 (note that the colour scales are not the same in each figure).

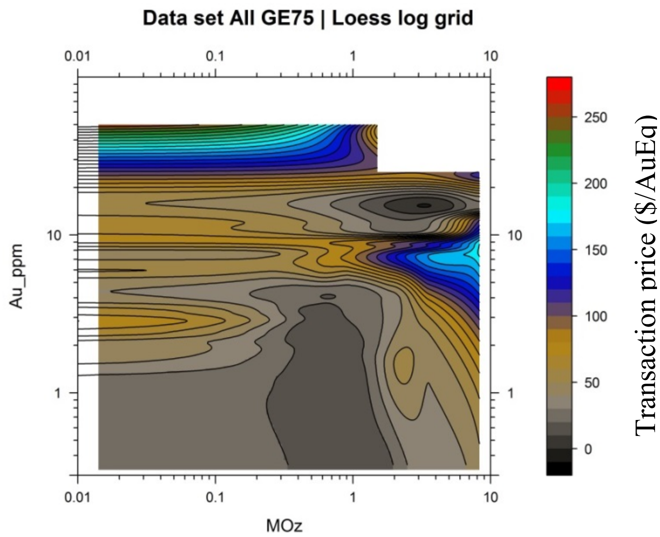


Figure A-12.6. LOESS map of deposit transactions where gold was attributed ≥75% of the in-ground value

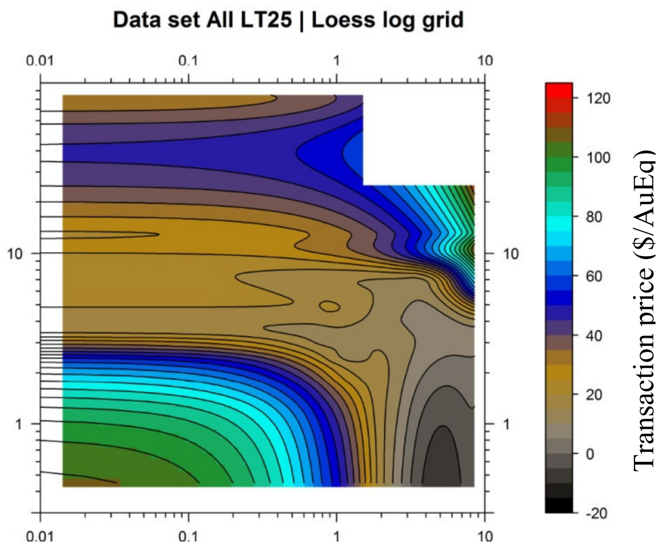


Figure A-12.7. LOESS map of deposit transactions where gold was attributed less than 25% of the in-ground value

1.3. Gold-premium models

1.3.1. Base-case

In forming a base-line for comparative analysis, models were generated where there were no adjustments made for technical differences between gold and base-metals projects. This means that all metals were weighted according to their prevailing metal prices when undertaking a metal equivalent calculation. The figures detailed in Table A-12.1 represent the Swanson means (Hurst et al. 2000), medians and LOESS estimates for those transactions considered to be gold plays. This allows for an analysis of the performance of the LOESS method in honouring the underlying dataset.

Table A-12.1. The unit prices of the gold dominant models using all transactions

Grade (g/t AuEq)	Size (Moz AuEq) LOESS ($)			Swanson Mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	102	90	60	84	61	94	33	23	25
Medium (3-6)	40	37	86	38	21	110	28	16	49
Low (<3)	28	24	51	25	15	38	16	10	16

Each of the LOESS, Swanson mean, and median models in Table A-12.1 demonstrate the “small deposit effect”, whereby deposits under 250,000 AuEq commanded a higher unit price than their medium-sized counterparts. One unusual feature is that the large, medium-grade deposits appear to be more expensive than their higher-grade counterparts for all three models. After interrogating the raw data, this appears to be an artefact of the data and is not considered to reflect market behaviour. In Table A-12.1, both the LOESS and Swanson mean tend to estimate prices higher than those implied by the medians, reflecting a positive skew in the underlying datasets. This is because the declustering is done by effectively projecting a grid onto the raw LOESS surface, and then applying an average to the nodes of the grid. As the LOESS method attempts to create a smoothed surface across all the size-grade combinations, it leads to compromises between price prediction and trend surface generation. Overall, the LOESS models shown in Table A-12.1 are harder to rationalise. For example, the high-grade medium size deposits were cheaper than the larger grade-equivalent ($90 vs $60), something that is difficult to ascribe to market behaviour. Furthermore, the LOESS estimate predicted a very high unit price for small, high-grade deposits ($120), which does not compare favourably to the Swanson mean, and median estimates of $84 and $33 respectively.

In contrast to the above, Table A-12.2 contains the LOESS, Swanson mean, and median estimates for the transactions where gold accounted for less than 25% of the implied value. The prices predicted by the LOESS and Swanson mean are of a higher order of magnitude to that of the medians, reflecting a highly skewed dataset. The seemingly important small deposit effect is disrupted, with only the Swanson mean predicting a consistently higher unit price. Furthermore, all three models strongly predict that medium sized, low- to medium-grade deposits are much more expensive than their larger grade-equivalent (e.g. $46-$6, $18-$15). The loss of prominence of the small deposit effect and the size related price declines imply that:

- the small-deposit effect is something that may only be attributable to the gold market. This is unlikely given the effects of market liquidity (smaller deposits have more potential buyers) and option theory (exploration upside).
- the size-grade domains that worked well for the gold deposit market cannot be directly transferred to the base-metal market
- the underlying dataset contains much more noise (less efficient market).

Table A-12.2. The base-metal dominant models using all transactions

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS ($)			Swanson mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	38	42	63	30	23	50	8	5	6
Medium (3-6)	20	18	15	16	15	12	7	9	5
Low (<3)	70	46	6	135	20	18	12	10	5

When comparing the price estimates of the gold and base-metal transactions (Table A-10.3), it appears that the Swanson mean is most consistent in predicting increasing premia in response to an increase in grade (ignoring large, high-grade). However, none of the models predict consistent patterns in response to increasing the size of the deposits involved in the transaction. Irrespective of the irregularities that may reflect a noisy dataset, the base-metal transactions appear to trade at significant discounts to their gold equivalents. The gold-premium appears to be in the order of 2.1 (LOESS and Swanson Mean) to 3.9 (median model) times the base-metal equivalent.

Table A-12.3. The gold-premiums using all transactions

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS			Swanson Mean			Medians		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	2.7	2.1	0.9	2.8	2.7	1.9	3.9	5.0	4.2
Medium (3-6)	2.0	2.1	5.8	2.4	1.4	9.5	4.2	1.7	9.8
Low (<3)	0.4	0.5	8.9	0.2	0.74	2.1	1.4	1.1	2.9

1.3.2. Optimistic payable metals adjustments

When all other aspects are kept equal, base-metal deposits tend to have lower mine-gate revenues than gold deposits due to additional processing and transport requirements. Therefore, a separate analysis was undertaken where adjustments were made to the amount of contained metal. Making such an adjustment attempts to account for the specific revenue streams of different commodities (i.e. the payable metal differences). While it is impossible to make such adjustments with certainty due to the paucity of publicly available information, the ranges presented in Wilson and Chanroux (1993a, 1993b, 1993c) and Cunningham (1993) are adequate as an order of magnitude. In recognition of the increased competition in the smelting and refining industry since 1993, the optimistic upper limits of these ranges are used such that **copper: 80%**, **nickel: 75%**, **lead: 65%** and **zinc: 60%.** For example, a copper deposit with a gold price equivalent content of 1 Moz would have a factor of 0.8 applied to it to reflect the differences in the payable metal.

The effect of making such metal adjustments is that the grade and contained metal decrease while the unit prices increase, thereby affecting the distribution of the dataset. Therefore, the reader needs to be cognisant that the results of this model are not directly comparable with the unadjusted models in the preceding section due to differences in spatial distribution. The adjustment also allowed for three additional transactions to be included in the dataset which otherwise did not meet the requirement of being less than 9.0 Moz Au. Making such value-based adjustments may distort market behaviours, as many acquisitions are likely to be based on headline gold-equivalent figures due to insufficient information regarding metallurgy, toll rates, and economics. On the other hand, gold recoveries are generally comparatively high (>90%), minimising this discrepancy. Keeping this in mind, the simplified results of the payable metal adjusted models are shown in Table A-12.4. The gold dominant models are not shown, as the adjustment has minor impact on the figures and no impact on the trends.

Table A-12.4. The base-metal dominant models using optimistic payable metal adjustments

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS estimates ($)			Swanson Mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	56	64	112	9	79	93	9	7	77
Medium (3-6)	23	21	37	35	37	17	17	7	7
Low (<3)	63	36	10	91	19	13	14	15	4

A review of Table A-12.4 suggests that compared to the unadjusted figures shown in Table A-12.2, the payable metal adjustment results in the raw unit prices increasing by a factor of approximately 1.5 for all three models; however, the distribution of the changes was erratic. The inconsistencies associated with the anticipated small deposit effect are not resolved by making optimistic payable metal adjustments. This is because different weights need to be applied, or because the market does not make such adjustments when using metal equivalent unit prices (as seems to be the case in the gold deposit market).

When comparing gold premiums of the optimistic metal adjusted models, it appears that there are still many inconsistencies between the LOESS, Swanson mean, and median models. None of these three models appeared to outperform the others in terms of the predicted premiums/discounts (ignoring the unit price estimates) (Table A-12.5). The LOESS and median models estimated global premia of 1.7 and 2.5 respectively; however, the Swanson mean suggests that no premium is payable.

Table A-12.5. The gold-premiums using optimistic payable metal adjustments

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS			Swanson Mean			Medians		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	1.8	1.4	0.6	9.2	0.7	1.0	3.8	3.0	0.3
Medium (3-6)	1.7	1.7	2.3	1.1	0.6	6.5	1.7	2.5	6.6
Low (<3)	0.4	0.7	5.1	0.3	0.8	3.0	1.2	0.7	3.8

1.3.3. Other sub-analysis

Three additional sub-analyses were undertaken on the gold premium dataset (Appendix 9). The block models involved examining the post-June 2007 transactions in isolation, accounting for changes in the metal prices by making Yardstick style adjustments, and making pessimistic payable metal adjustments. The former two observations are consistent with previous investigations, and the latter did not yield an improvement over the optimistic metal adjustment.

1.3.4. Post-June 2007

As the gold price began to appreciate at an accelerated rate after June 2007 (see Figure 21), an analysis was undertaken that only considers transactions that occurred after this time. The unit price estimates in Table A-12.6 suggest that:

- the small deposit effect remains in effect, thereby honouring the observations made in the block model investigations
- relative to the models using all the available transaction the unit prices are similar, although there is localised variation
- all other relationships appear to be similar, suggesting that the reduced data density did not affect the model integrity.

Table A-12.6. Unit prices of the gold dominant models, post June 2007 transactions

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS estimates ($)			Swanson mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	116	103	52	90	69	68	39	21	24
Medium (3-6)	41	38	80	42	21	116	30	16	49
Low (<3)	29	26	50	26	16	43	16	12	18

In comparison, the post-June 2007 base-metal transactions shown in Table A-12.7 show that while the unit price predictions of the Swanson mean, and median models are often quite different, similar price behaviours are observable between the models. However, the LOESS model is highly erratic and shares relatively little behavioural commonality with the Swanson mean, and median models. It appears that that LOESS method suffers from the reduction in data density, with predictions of negative prices for high-grade deposits (clearly a nonsensical result). This is a function of the LOESS and kriging methods producing a surface plot that extrapolates trends into areas that are sparsely populated. Consequently, it appears that the LOESS model is highly sensitive to data density, potentially making is unusable for base-metal market analysis.

Table A-12.7. The base-metal dominant models using post June 2007 transactions

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS estimates ($)			Swanson mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	-2	4	63	23	23	70	12	4	58
Medium (3-6)	19	20	15	11	20	12	7	10	6
Low (<3)	74	46	6	136	20	18	12	10	5

The gold-premia implied by the post-June 2007 dataset (Table A-12.8) shows that there was no improvement in defining consistent gold-premium patterns. Overall, the Swanson mean predicts a gold-premium of 2.4 (up from 2.1) and the median model a premium of 2.8 (down from 3.9 using all the available transactions), implying that there was no obvious and consistent shift in how gold-premiums were attributed before and after June 2007.

Table A-12.8. The gold-premiums using post June 2007 transactions

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS estimates			Swanson mean			Median		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	-72.9	28.6	0.8	3.9	2.9	1.0	2.8	5.4	0.4
Medium (3-6)	2.1	1.9	5.3	3.8	1.1	10.0	4.6	1.6	8.5
Low (<3)	0.4	0.6	8.8	0.2	0.8	2.4	1.4	1.3	3.3

1.3.5. Pessimistic payable metals adjustments

A separate model was run using the lower limits of **copper: 70%**, **nickel: 65%**, **lead: 45%** and **zinc: 40%**, which are also based on Wilson and Chanroux (1993a, 1993b, 1993c) and Cunningham (1993). This is done as there is merit in making harsher adjustments to reflect that the receipt of payment for mined metal can be much later than that for gold deposit (several months versus days scenario). The result of making these pessimistic payable metal adjustments is show in Table A-12.2, from which the overall unit price increased by a factor of 2.1. Compared to the optimistic adjustments in the preceding section, the pessimistic payable metal adjustments appear to be inferior in producing sensible unit price patterns, as it appears to largely exacerbate the low-high range of prices without improving the observable patterns.

Table A-12.2. Base-metal dominant models with pessimistic metal adjustments

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS ($)			Swanson mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	99	110	170	13	160	107	13	11	86
Medium (3-6)	33	34	63	34	48	31	9	22	9
Low (<3)	60	33	14	48	19	22	15	13	5

When more pessimistic payable metal adjustments are made, the apparent gold-premia (Table A-12.9) are eroded to nothing for both the LOESS and Swanson mean models, neither of which have much explainable consistency. The median model fared better in that a small-deposit effect was observed, and the median sized deposits incurred discounts relative to the larger deposits (ignoring the large, high-grade discount as the underlying data is anomalous). Given that the unit price predictions are more volatile (Table A-12.2) it is interpreted that the observable small-deposit effect in the pessimistically adjusted gold price premia is incidental rather than actual.

Table A-12.9. The gold-premiums using pessimistic payable metal adjustments

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS			Swanson Mean			Medians		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	1.0	0.8	0.4	6.4	0.3	0.9	2.6	2.1	0.3
Medium (3-6)	1.2	1.2	1.3	1.1	0.4	3.3	3.1	0.8	5.3
Low (<3)	0.5	0.7	3.7	0.5	0.8	1.7	1.1	0.8	3.3

1.3.6. Yardstick adjusted

In previous studies into country risk, mineral estimate confidence, and ownership, there were models that made metal price adjustments to the sales prices. This metal price-based adjustment uses the same principles as the Yardstick method, and attempts to account for differences in the prevailing commodity price over the study period. However, this is a less reliable means of measuring a unit value (Section 4.3).

For consistency with other applications in this thesis, new models were generated that used commodity-price-adjusted sales prices (Table A-11. 3), from which it was noted that relative to the unadjusted models, the LOESS and Swanson mean unit price dropped by a factor of 0.97 while the median model's unit prices increase by a factor of 1.15. This Yardstick adjustment reduced the prominence of the small-deposit effect in the Swanson mean for the small, high-grade deposits (to $29-$29 compared to an unadjusted $30-$23); but improved if for the median model's small, medium grade prediction of $11-$9/oz AuEq (previously $7-$9). No significant improvement by making Yardstick adjustments is consistent with the other Yardstick type investigations made elsewhere in this thesis.

Table A-11. 3. The base-metal dominant models using Yardstick adjustments

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS estimates ($)			Swanson mean ($)			Medians ($)		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	35	38	55	29	29	38	18	4	5
Medium (3-6)	21	18	13	17	18	10	11	9	5
Low (<3)	73	48	6	123	19	18	10	9	7

Comparing the Yardstick adjusted gold and base-metal models results in very large premia being generated (Table A-11.4), namely 3.1 for the LOESS, 3.2 for the Swanson mean and 3.6 for the median model. However, these premia are erratic and are not viewed as being particularly informative.

Table A-11.4. The gold-premiums using Yardstick adjustments

Grade (g/t AuEq)	Size (Moz AuEq)								
	LOESS estimates			Swanson mean			Median		
	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)	Small (<0.25)	Medium (0.25-1.00)	Large (>1.00)
High (>6)	3.7	3.2	1.9	4.0	4.4	4.4	3.6	8.0	8.4
Medium (3-6)	2.7	3.1	10.8	3.2	1.9	19.8	3.7	3.2	16.5
Low (<3)	0.6	0.8	13.3	0.3	1.4	3.1	2.6	2.2	3.4

1.4. Discussion

The research into the gold premium at an asset level suggests that the natural grouping of gold and base-metal deposits appears to be polarised, with only 4% of the transactions falling within the co-product (25%-75% Au contribution) classification. This has negative implications on using the gold content as a measure for the third dimension in a block model analysis, making a two-dimensional approach more appropriate.

Using a two-dimensional approach, it seems that unlike the market for gold deposits, the base-metals market appears to be erratic in terms of its size-grade relationships. This is due to a less liquid, inefficient market; greater technical variance amongst polymetallic deposits; or there being multiple sub-markets for each base-metal type (e.g. the copper deposit market behaving differently from the nickel deposit market). This latter point is supported by the research by Singer (2013) (note: this was published after this application was undertaken) who also concluded that different commodity-type deposits cannot be compared in a like-for-like manner.

The base-metal deposits did not readily display recognisable or consistent market patterns. This is due to the low data density (148 transactions) resulting in the prediction of negative weights when analysing sub-samples of the dataset. The size-effect appears to be weakly represented in the base-metal data; however, its vagueness is due to different size-grade combinations being applicable to small, medium and large sizes, and low, medium and high grades. Alternatively, the grouping of multiple metal types may not be appropriate, or the markets are inefficient in differentiating complex project qualities.

Irrespective of whether value adjustments are made to reflect payable metal, gold deposits still seem to attract a premium over their base-metal equivalents. The order of magnitude of this premium seems to be around two to three times that of their base-metal equivalents, which is higher than those ascribed to securities (factor of 1.5). Presumably, this has to do with the security-based premia being largely based on NAVs and securities, rather than *in situ* deposits. Given that the gold deposit market is much easier to study, is less technically diverse, and appears to be reasonably rational, it is a much easier medium to use for researching market dynamics. As the gold deposit market appears to be more efficient than the base-metals equivalents, a speculative conclusion is that its patterns (but not size-grade combinations) may tentatively be used in identifying market opportunities in the latter.

Appendix 13. Exploration price analysis

1.1. Background

1.1.1. Introduction

Determining the price of a mineral exploration project is an imperfect process, in part due to inadequate information, but also due to the common application of questionable methodologies. When dealing with exploration projects where a potentially economically viable deposit is yet to be identified, the pricing methodologies used are largely reliant upon subjective opinion. Such methods generally rely upon previous or anticipated future expenditure (the cost approach, Section 2.3.2) and a comparison with the sales prices of projects with similar characteristics (the market approach, Section 2.3.3). Each method uses actual world price drivers, adjusted by ad-hoc market or “industry experience” factors intended to lessen any shortcomings. This research challenges the validity of these ad-hoc adjustments based on both logic and empirical evidence. In addition, the research shows how multivariate analysis and ANNs can be used to create empirical models that help create more robust price estimates.

1.1.2. Price drivers

The price of an exploration project is influenced by a myriad of factors, each of which has a different impact under various times and circumstances. Obviously, the principal price driver is, or should be the potential of a project to yield positive cash flows from future mining activities. However, there is insufficient information available for early-stage exploration projects upon which a cash flow model is constructed. Aside from broader supply-demand and other market condition considerations, price estimates are made based on technical qualities such as jurisdictional location (Section 2.2). Reflecting this uncertainty, Specialists often ascribe confidence intervals in the order of ±35% around a preferred estimate Table A-2.2 in Appendix 2.

1.1.3. Quantifying exploration potential

While it is possible to identify the key “ingredients” required to form a mineral deposit using the mineral systems based technique (McCuaig et al. 2010), the way exploration potential is attributed in most cases highly subjective, with the opinions of different experts sometimes being polarised. For example, some geologists prefer nearology over the notion that “you won’t find the next Mount Isa next to Mount Isa” (Groves 2012).

As it is difficult to assign weights to individual exploration projects when many transactions are considered, into which the Specialist has no great insight, the Kilburn method is often used as a starting point for ranking/pricing the projects. The relative ease at which the Kilburn descriptive terms can be applied makes it suited to market classification (refer to Table A-3.1). However, the weights used in that table are seemingly arbitrary, static, and have not evolved significantly over the last two decades. Furthermore, the linear relationships implied by the Kilburn method and the logic that connects them is not always valid. While the price drivers seem reasonable, the validity of the Kilburn method in predicting price is debateable, and therefore, worthy of empirical research.

1.2. Dataset

1.2.1. Time-frame

In collating a dataset for research into exploration project price, transactions were collected from the period between January 2006 to November 2010. While ideally a dataset going back to 11 September 2001 would have been used, no exploration data was identified that met these needs. Consequently, all those that were available were used. The age discrepancy with the other applications is not material as:

- there are sufficient transactions during this time frame to give it statistical significance
- unlike gold deposits, the market for early-stage exploration projects is much more cyclical and affected by changes in supply (i.e. new tenements pegged purely to meet demand).

1.2.2. Qualities

To derive a dataset for this study, the database was filtered to the extent that it included only transactions that were in Canada and Australia, as they are similar in maturity, and exist in stable mining countries where the minerals are owned by the government. Transactions from within the United States of America were not used, as there are significant differences in the regulatory systems of each state, as well as an emphasis on the private ownership of mineral rights (Ellis 2001; Lawrence 2000; Eggert 1989). Within this subset, the transactions were filtered to only include those where gold mineralisation was being targeted; which did not contain estimates of potential size and grade of a deposit; and involved the maximum allowable equity stake (i.e. increments in staged acquisitions were disregarded). The filters resulted in a study dataset of 997 transactions with the following qualities:

- **Country** – 348 Australian and 649 Canadian transactions.
- **Monetary quantum** – Total transacted value of AUD2,071 M cash equivalent, of which the Australian transactions accounted for AUD830 M.
- **Equity** – 501 (111 Australian, 390 Canadian) transactions involved 100% equity stakes, 119 transactions between 100% and 75%, 316 transactions between 75% and 50%; and 62 transactions less than 50% equity.
- **Multi-commodity prospectivity** – 125 transactions, or 13% of the dataset, concerned transactions where there may have been an equal or secondary target commodity type.
- **Consideration** – cash made up 23%, scrip 30% and exploration expenditure commitments 47% of the total implied price. Out of the 292 transactions that included royalty terms, 275 of them occurred in Canada.
- **Age** – 297 transactions occurred between 1 January and 5 November 2010, 389 in 2009, 178 in 2008, 94 in 2007, and 39 in 2006.

As this research uses multivariate analysis and ANN, it is possible to incorporate much more information than is the case with the block model method. To account for the more heterogeneous nature of the broader markets, additional price drivers were collected, which included:

- information on the states/provinces where the projects are located
- prevailing gold price based on Kitco (2012) securities markets as measured by the Standards and Poor's (S&P) 500 Index (Yahoo 2012a)
- gold specific securities markets as measured by the S&P Global Gold Index (Yahoo 2013)
- cash rate targets based on Australian and Canadian government data (RBA 2013; BoC 2013)
- likely mineralisation style, such as epithermal or lode gold
- project-specific price drivers as described by the Kilburn method
- mineral commodity targets other than gold considered relevant to the project
- proportion of cash and shares

- expenditure commitments that make up part of the consideration stated in the transaction announcements.

The influences of macro-economic conditions are also included in the expanded information. The ability to raise venture capital is a crucial element to any sustainable exploration programme (Nikkonen 2013; Popov and Roosenboom 2013; Cairns et al. 2010). Access to venture capital is influenced by commodity-specific sentiment as well as risk appetite, which for gold can be divergent forces due to gold being viewed as a haven during turbulent times when decreased risk appetite makes obtaining venture capital difficult (Goodman 1956; Solt and Swanson 1981). To give additional detail about the general direction of the markets, a manually determined market direction based on the rises and falls of the S&P 500 Index was used. To determine the appropriate direction, a review of the S&P 500 Index and the spot gold price was undertaken (Figure A-13.1). The review suggested that:

- Between September 2006 and June 2007, the gold price appreciated in a steady manner, with the S&P Index generally rising. During this time, IPOs for all commodities were numerous and venture capital readily available. This period is considered a “steady” market.
- From June 2007 to October 2008, the gold price began to appreciate rapidly and the S&P 500 Index began to decline. This period was also marked by a substantial reduction in IPO listing premiums on the Australian Stock Exchange. For this study, this period is considered as a “risk-averse” market.
- Between October 2008 and March 2009, the gold price dipped and the S&P 500 index rapidly declined. No exploration or mining corporation IPOs were issued on the ASX, and companies slashed all non-essential expenditures, including exploration programmes. This period is considered a “crashing” market.
- After March 2009, the gold price recovered its losses and began a steady appreciation, while the S&P index began regaining price, although remaining below its January 2006 level. From this point onwards, IPOs began to re-emerge and raising capital became possible and prevalent. This is viewed as a “recovering” market.

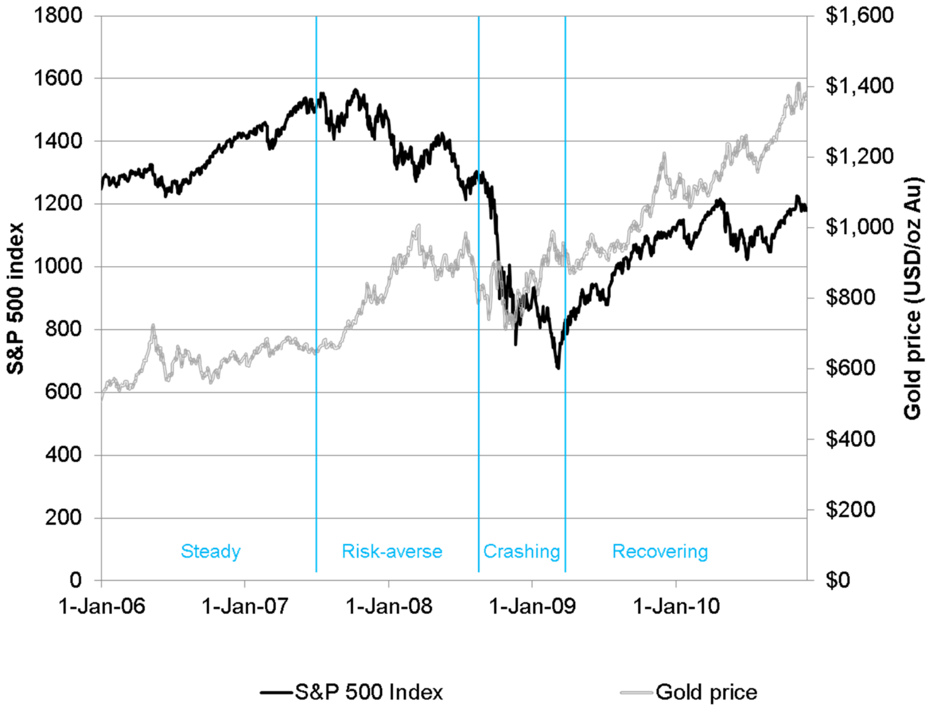


Figure A-13.1. The spot gold price, S&P500 Index and manually defined epochs

1.2.3. Australian vs Canadian

The Canadian and Australian transactions datasets were markedly different (Figure A-13.2). Using the entire dataset, the tenement size distribution of the Australian transactions is such that half were under 210 km^2 and 90% were under 1,580 km^2. Interestingly, the project areas used by Kreuzer et al. (2007) begin to ascend rapidly around the 80 km^2 mark, and meets the “all data” distribution in Figure A-13.2 at around 400 km^2 (a steep gradient signifying population density). The 80 km^2 size increment anecdotally correspond with the industry’s perception of the size band in which the Kilburn method is reliable. Furthermore, 49% of both the IPO projects in Kreuzer et al. (2007) and acquisitions were in Western Australia, suggesting that the two independently sourced and derived datasets are representative, even if there are different motivations driving both (e.g. singular, small tenements may not provide enough exploration trials in an IPO portfolio). In comparison to the Australian dataset, half of the Canadian transactions were under 23 km^2 and 90% were under 160 km^2. It is assumed that the prevalence of small project transactions in Canada is a result of the flow-through share scheme and a “prospector” culture rather than prospectivity, infrastructure or other drivers. Both the Canadian and Australian datasets showed that partial acquisition terms become more favoured over outright acquisitions as the size of the deposit increases.

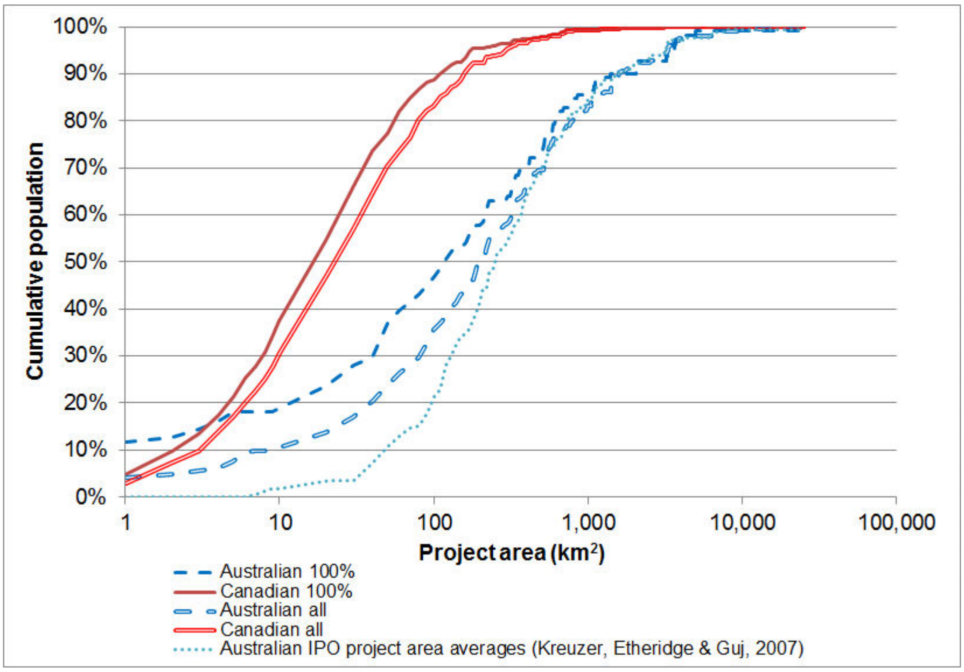


Figure A-13.2. Exploration project size frequency chart

To demonstrate the price distribution of the dataset, Figure A-13.3 and Figure A-13.4 show the sales price relative to the project area. Using all equity transactions, the Australian study dataset had a median implied sales price of AUD6,131/km^2 and an average price of AUD150,415/km^2; where the Canadian subset had a median of CAD33,782/km^2 (or AUD37,267 using spot exchange rates) and an average of CAD179,054/km^2 (AUD197,744/km^2). These figures show that the market influence of size is a very important price driver, as the trendlines are broadly similar in orientation, yet due to the median size differences, the sales prices the price prediction for a particular size area are substantially different. Furthermore, the squared correlation co-efficient (R^2) of the Canadian dataset is much lower than that of the Australian equivalent. Possible reasons for the reduced correlations in the Canadian dataset include:

- the large number of very small corporations conducting transactions, reducing market efficiency due to limited in-house skills and experience
- many transactions have net smelter returns with a common term of 2%, which could be reduced to 1% for CAD1.00 M, irrespective of size or quality. The prevalence of somewhat static net smelter return terms in the consideration mix distort the cash-equivalent terms due to the price of the NSR being highly subjective.

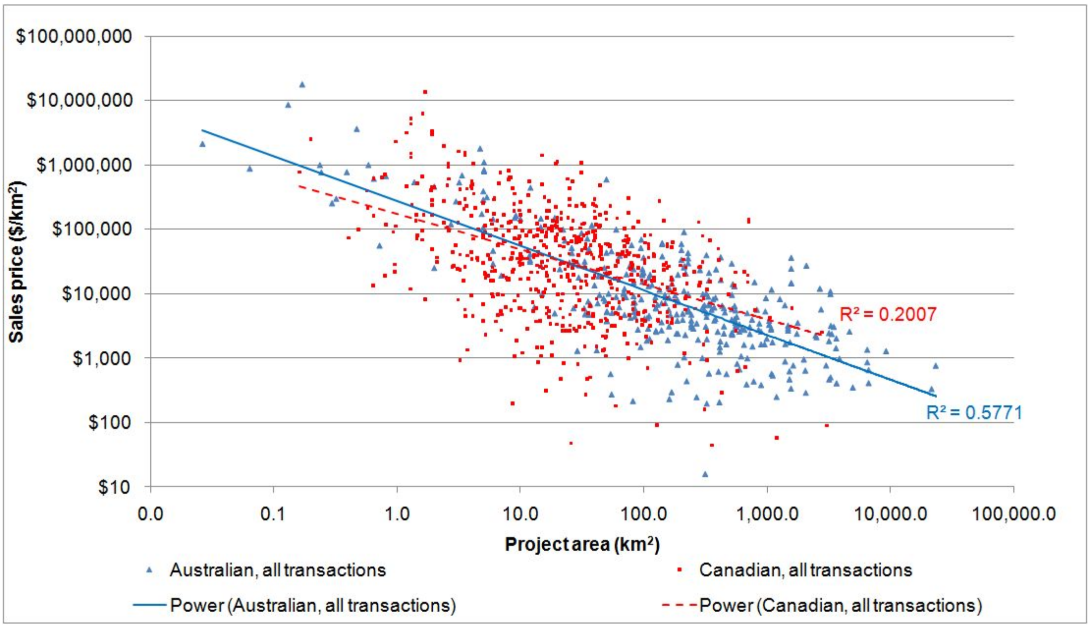


Figure A-13.3.All transaction with partial sales grossed up to 100%

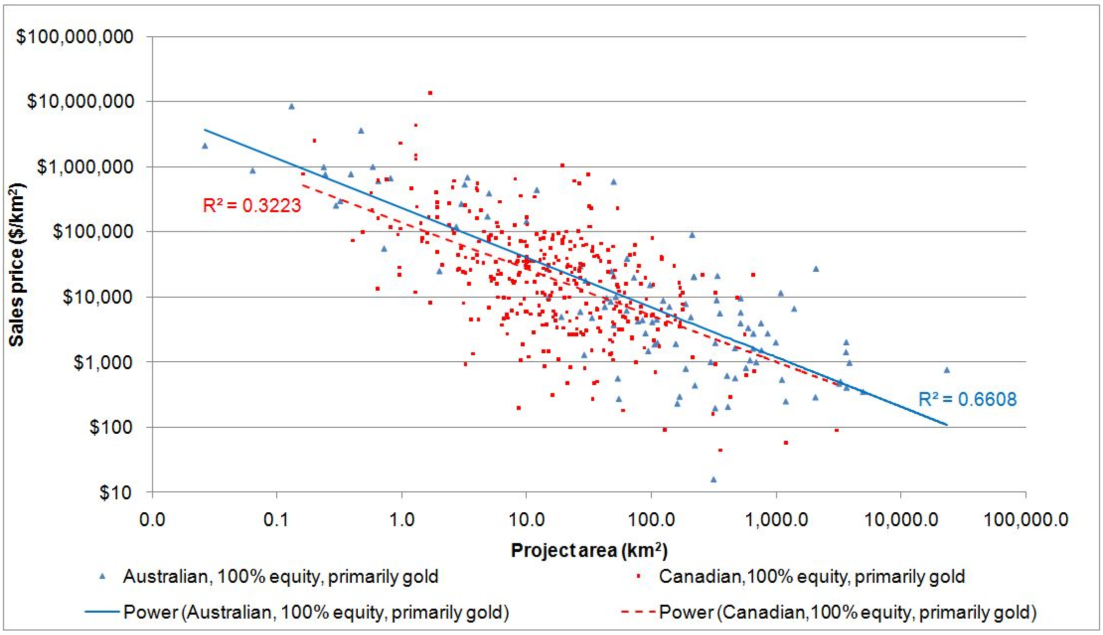


Figure A-13.4. 100% equity exploration transactions where they are primarily prospective for gold

1.3. Techniques considered

1.3.1. Kilburn base holding cost modification

To be able to interrogate the dataset for the appropriate weights for a Kilburn-style system, a standardised base holding cost (BHC) was initially used in calculating the Kilburn predicted prices. Each state, territory and province has its own unique government-mandated rent and expenditure commitments to keep the underlying tenements of a project in good standing. These costs are often subject to sliding scale cost increases over time, with the tenements having finite usable lives during which area reductions are required. Consequently, the ability to know the maturity and costs associated with the tenement package for each project cannot be quantified easily in the public domain. To mitigate the effect of foreign-exchange differences, each transaction was analysed using the local currency. As the Australian and Canadian transactions are considered separately in the following analyses, the influence of exchange rate differences is minimal.

The Kilburn predicted sales prices for each of the recorded transactions using industry standard weights and a $500 BHC are shown in Figure A-13.5 (the BHC can be changed with no effect on the distribution pattern). When this figure is compared to the actual sales (Figure A-13.4) the Kilburn method does not adequately reflect the strong increase in price that appears with increasing size; and within a comparatively narrow unit price range. To counter this effect, practitioners often apply the Kilburn method to smaller parcels, such as individual tenement holdings; however, such a level of detail is rarely available in the public domain. In addition, it is questionable whether this methodology reflects the acquisition psychology as parties to a transaction usually consider a project area in the whole, rather than each of the individual tenements (a top-down versus bottom-up argument). Consequently, the common industry Kilburn weights are ineffective at a project level and need to consider the market behaviour in respect to size. Unfortunately, this does limit the ability to test whether the current Kilburn weights are reflective of real world transactions. Therefore, at a tenement level, the Kilburn pricing method can neither be empirically proved or disproved, leaving it to be challenged at a project level.

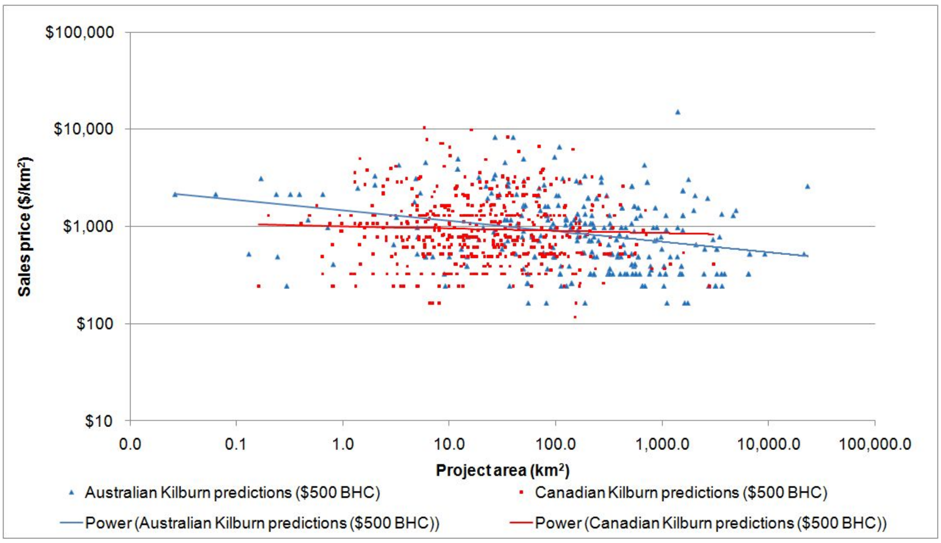


Figure A-13.5. All exploration transactions with Kilburn predicted prices

To overcome the size deficiency in the Kilburn method an additional price driver needs to be incorporated into the technique. This could potentially be addressed by adding an additional column to Table A-3.1, however, given the uncertainty concerning the actual holding costs for each tenement in a project, an alternate to the BHC as a base unit was sought.

Kilburn with Yardstick base

A less commonly used market method is the Yardstick approach, which attempts to use the prevailing commodity price as a starting point for all price determinations of a deposit. The method typically entails expressing the unitised sales price (e.g. $/oz Au) as a percentage of the prevailing commodity price. Proponents of the Yardstick method believe that it is a better reflection of market dynamics, which are assumed to be reflected entirely by the commodity price. In application to deposits, commodity prices appear to be an inferior basis upon which a project price can be estimated. As discussed in Section4.3, the problem with using a commodity price as a starting point is that it may have a long-term negative correlation with the project price, is more difficult to interpret, and fails to reduce dataset volatility.

Despite the misgivings about the Yardstick method, when the commodity price is used as a starting block (akin to the BHC) it allows for size to be incorporated into the equation. For example, if the spot gold price were divided by the project area in square kilometres and multiplied by Kilburn weights, the unit price would decrease with size.

To determine if such an exploration Yardstick does have some potential, the entire dataset was treated in such a manner using the industry applied Kilburn weights (re-presented in Table A-13. 1. Common qualitative descriptions used in the Kilburn method). To give the experimental results some comparability with the actual sales prices, the Kilburn-Yardstick hybrid was multiplied by a factor of 500. The results of this theoretical experiment are shown in Figure A-13.6. The lope of the simple Kilburn-Yardstick hybrid is clearly too steep to be representative of the market and requires further adjustment to bring it in line. Consequently, the Kilburn-Yardstick hybrid method was not explored any further.

Table A-13. 1. Common qualitative descriptions used in the Kilburn method

Relative location	Maturity	Prospectivity	Success
No workings	No workings	Generally unfavourable lithology	Extensive previous exploration with poor results
Minor or weak anomalies	Minor workings	Generally unfavourable lithology with structures	No targets outlined
Several anomalies	Several workings	Generally favourable lithology (10%-20%)	Geophysical or geochemical targets
Abundant or strong anomalies	Abundant workings	Alluvium covered, generally favourable lithology (50%)	anomalous drillhole intersections
Significant deposits	Significant mine	Generally favourable lithology (50%)	Intersections of potential economic interest
Major deposit	Major mine	Generally favourable lithology (70%)	
World class deposit	World class mine	Generally favourable lithology	
		Generally favourable lithology with structures	
		Generally favourable lithology with structures along strike of a major mine	

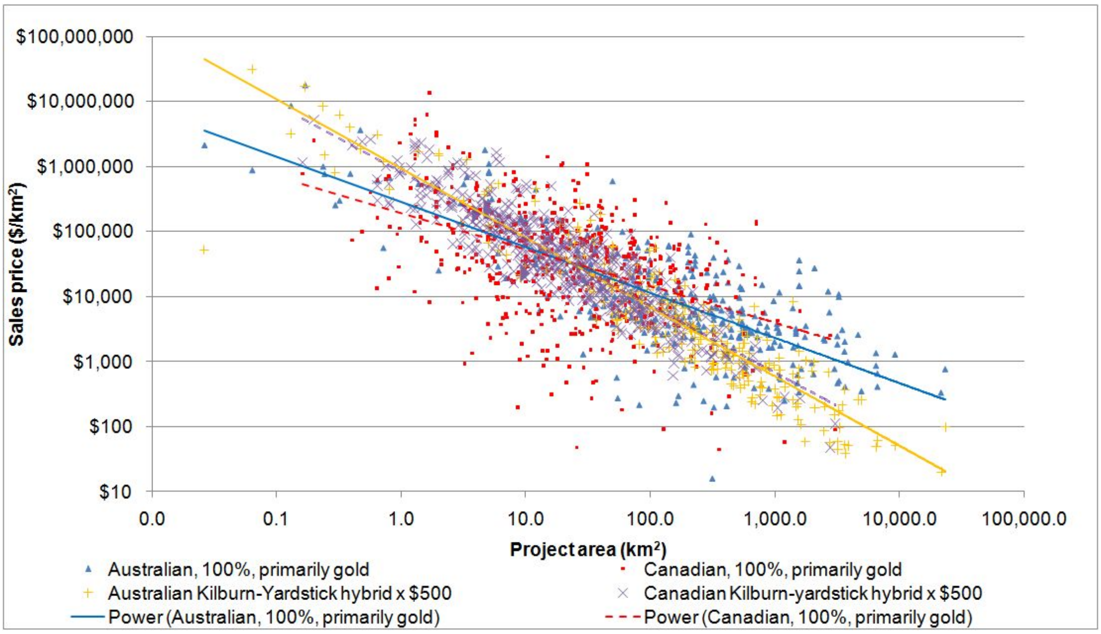


Figure A-13.6. Experimental Kilburn-hybrid multiplied by 500

1.3.2. Kilburn with a trendline base

To account for the market influence in relation to size, the trendlines from the raw data were used to determine a reference point for each transaction to which the Kilburn multiplier was then applied (Figure A-13.7 and Figure A-13.8). This simple adjustment visually appears to be a more realistic representation of the actual sales prices. However, the Australian predictions have a median error (predicted vs actual) of -23% and an average error of 209% compared to actual sales. Similarly, the Canadian predictions having a median error of -47% and an average error of 328% compared to the actual sales. Clearly, the Kilburn-style weights require adjusting.

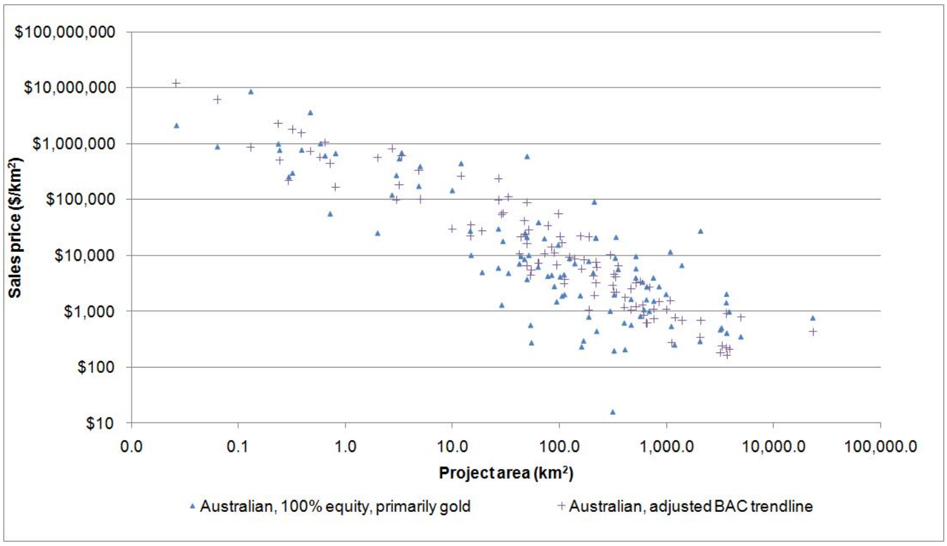


Figure A-13.7. Australian 100% equity transaction with size modified Kilburn predicted prices

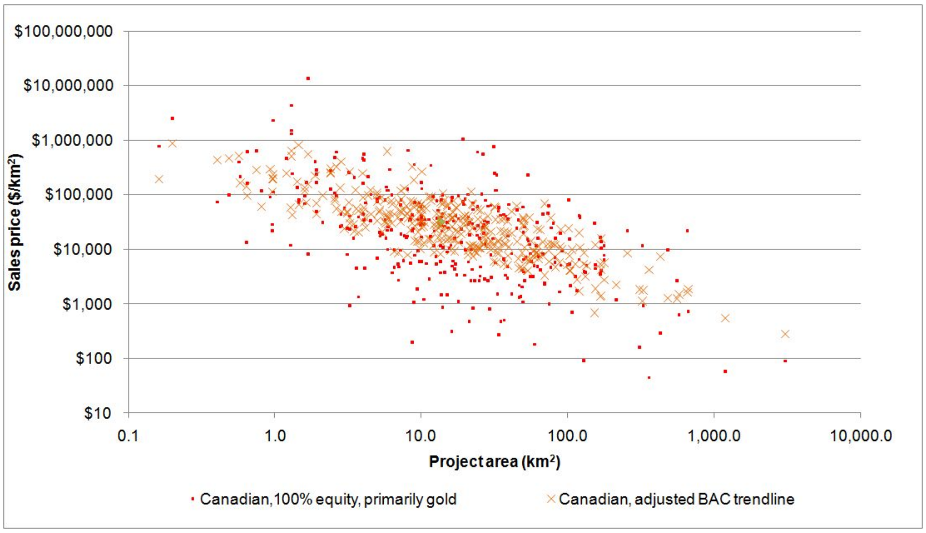


Figure A-13.8. Canadian 100% equity transaction with size modified Kilburn predicted prices

The use of a trendline deviates from the Kilburn method where a BHC is used; however, the trendline method is more suited to this analysis as it:

- removes ambiguity relating to the types, maturity and costs of the tenements within a project area

- provides a stable platform upon which the weights of the Kilburn descriptions can be experimentally adjusted (in effect the BHC is replaced by a market based Base Acquisition Cost (BAC), and
- is drawn directly from real world price patterns.

By establishing a dataset of actual sales prices and Kilburn-predicted prices using the BAC, an analysis was undertaken using the Microsoft Excel™. The 'Solver' function was used to estimate the weights by making incremental experimental adjustments to maximise the correlation. The Solver function uses a trial and error method to approximate best solutions by changing multiple inputs simultaneously. Despite various permutations, no useable outcomes were achieved. This suggests that the relationships between the remaining price drivers are too complex to be elucidated with such a simple technique. Consequently, it was determined that a more vigorous multidimensional critique was required using multivariate analysis.

1.4. Techniques used

1.4.1. Linear trendline analysis

A simple trendline analysis is used to form a generalised appreciation of the exploration market characteristics. This method is easy to replicate and is important in establishing a reference point against which other techniques can be gauged. The axes used for establishing the trendline are area (km^2) and price ($\$/km^2$). The area was chosen instead of other variables because in the Australian market, it is clearly the main price driver, as evidenced by an r^2 of 0.5771. It is speculated that size is not the main price driver *per se*, rather it reflects the clustering of smaller tenement holding in areas that are in higher market demand.

1.4.2. Multivariate analysis

While a trendline analysis is useful, it is restricted to considering one variable at any given time. Consequently, there is a need to be able to recognise more than one variable in estimating price. This is done using multivariate analysis, in this case the least square regression method, which uses different equations for each of the input variables, and sets about reducing the sum of the r^2 residuals to arrive at the best fit (Abdi 2003a, 2003b). The variables that are appropriate to this study are described in Section 1.2.2.

1.4.3. Artificial neural networks

Given the diversity of price drivers and the potential for non-linear relationships, ANNs are a suitable technique in characterising the exploration market. This is because ANNs can model a variety of classification problems such as in speech, character and signal recognition and they have also been used for predictive modelling of mineral prospectivity (Brown et al. 2000; Porwal et al. 2003; Nykanen 2008). The following characteristics of ANNs may make them suitable for price analysis of exploration projects:

- ANNs can approximate any relationship between the dependent variable and predictor variables in a given system however complex that relationship might be, provided that a relationship exists.
- ANNs can capture the non-linear response of the dependent variable to the predictor variables in different combinations. The price of the dependent variable is controlled by a single predictor variable in one instance or by a combination of predictor variables in other instances. Similarly, the same predictor variables could contribute differently in different instances.
- The correlations between variables do not affect the outputs of ANNs. This is particularly important for the present analysis as most of Kilburn price drivers are correlated in one way or another. For example, if a project area is close to a working mine, there is a high probability that it contains prospective geology, albeit the geology thought not to be prospective being heavily discounted by the explorer. Such correlations can confound simple linear additive or multiplicative models.

ANNs imitate human cognition in deriving knowledge by learning from training data and using it for generalisation beyond the training data. Their architecture comprises many interconnected computational neural units that map each input sample to its output price. The mapping is controlled by inter-neuron connection strengths known as synaptic weights, which are dynamically modified until each input feature vector is mapped correctly to its known output price. Synaptic weights are therefore repositories of knowledge, which are used by ANNs for generalization to unseen data (Livingstone et al. 1997). The key requirement of ANN modelling is the availability of adequate numbers of representative training samples because an ANN acquires all knowledge about the system from the training samples. Given the access to the Alexander Research database, which is the most robust project price database identified, ANN modelling of exploration project prices was undertaken to build on from the finding of the multivariate analysis.

1.4.4. Models

Linear trendline analysis

As this research topic uses multivariate analysis and ANN, the use of simplistic trendline analysis based on size is important to providing a reference point for the reader. This is because it allows the reader to observe the quantitative differences between each of the techniques. Furthermore, the correlation co-efficient between size and price in the Australian dataset of 0.5771 suggests that size is the primary price driver thereby making it a suitable reference point.

As a cross-check, 4 Australian and 14 Canadian outliers were manually identified and removed from the dataset. This had the effect of modifying the:

- Australian r^2 up from 0.5771 to 0.6116
- Canadian r^2 down from 0.2007 to 0.1976.

While it is preferable to keep all data points in a block model analysis that considers inherent variability, for linear analysis the outliers have the potential to distort the results for the overall market (Roscoe 2012).

For consistency with the multivariate and ANN analysis, linear size-price trendlines were produced using 75% of the data points randomly sampled from the population. The predictive power of the trendlines was then tested on the unseen 25% of the dataset, as shown in Table A-13.2 and Figure A-13.9. The Australian and Canadian datasets both tracked each other reasonably well, although there is greater confidence in the Australian estimates. Based on the size of the tenements alone, an Australian trendline will predict a price that is within ±40% (~consistent with industry confidence range) of the correct number 28% of the time. If size, by proxy, accounts for 61% of the underlying price, this simple method is used as a first-pass, low-confidence, order of magnitude estimate. However, the Canadian dataset predicts into a ±40% accuracy bracket 20% of the time, but with the area of tenements accounting for 20% of the price driver. Consequently, it does little to inspire confidence.

Table A-13.2. Trendline predictive confidence brackets

Item		Results (%)									
Accuracy bracket		0-10	0-20	0-30	0-40	0-50	0-60	0-70	0-80	0-90	0-100
Confidence	Australian	7	14	19	28	35	40	46	56	69	72
	Canadian	5	9	14	20	24	35	42	51	59	66
	Combined	4	12	17	21	30	34	43	55	65	72

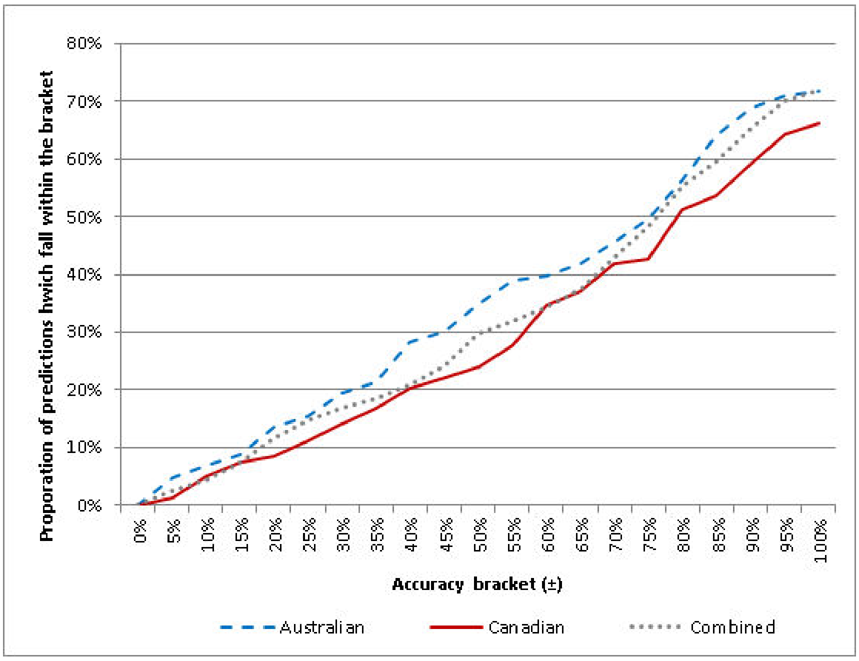


Figure A-13.9.Trendline predictive confidence brackets

1.4.5. Least squares regression analysis

To consider more than one variable in determining the price of an exploration project, the LSR technique was used. The dataset contained many descriptive qualities that were converted into binary fields to be interrogated. This resulted in 95 variables being used in the LSR analysis. The Gretl open-source software (Gretl 2013) was used to analyse of the Australian, Canadian and combined datasets which were cast into a natural log-log transformed space.

A first pass, real-space LSR was ineffective in achieving additional price prediction confidence. However, when the dataset had a natural log transform applied to both the price and area, the results improved markedly. For the:

- Australian dataset the r^2 increased from 0.6116 to 0.7297 and identified 9 significant price drivers

- Canadian dataset the r^2 jumped from 0.1973 to 0.6331 and identified 4 significant price drivers.

Aside from project area, the price drivers that are common to both datasets/jurisdictions are whether exploration expenditure is included in the consideration and the equity interest obtained in a project. These price drivers were of course expected. Other drivers, that were either less important or not common to both datasets include:

- currency exchange rates
- the inclusion of a net smelter return in the transaction terms, and
- the state or territory the project is located in (particularly in Australia).

The use of the natural log transform places greater emphasis on localised variance around the point of interest. This appears to explain much of the improvement in the Canadian r^2 figures. The observation of these distributions are common in economics, such as 97% to 99% of household income distributing log-normally (Clementi and Gallegati 2005).

It appears that the effect LSR can estimate within the industry common confidence interval of ±40% and achieve a correct result 33% of the time in Australia, and 39% of the time in Canada (Table A-13.3 and Figure A-13.10). While suited to potential use as an order-of-magnitude price estimating method, that considers 73% of the Australian and 63% of the Canadian price drivers, the fact that LSR considers a wide range of variables challenges the empirical validity of many industry confidence bands (previously shown in Table A-2.2).

Table A-13.3. LSR predictive confidence brackets

Item		Results (%)									
Accuracy bracket		0-10	0-20	0-30	0-40	0-50	0-60	0-70	0-80	0-90	0-100
Confidence	Australian	10	18	25	33	42	48	58	66	74	77
	Canadian	10	21	29	39	48	55	64	71	76	79
	Combined	10	20	27	37	46	53	61	69	75	78

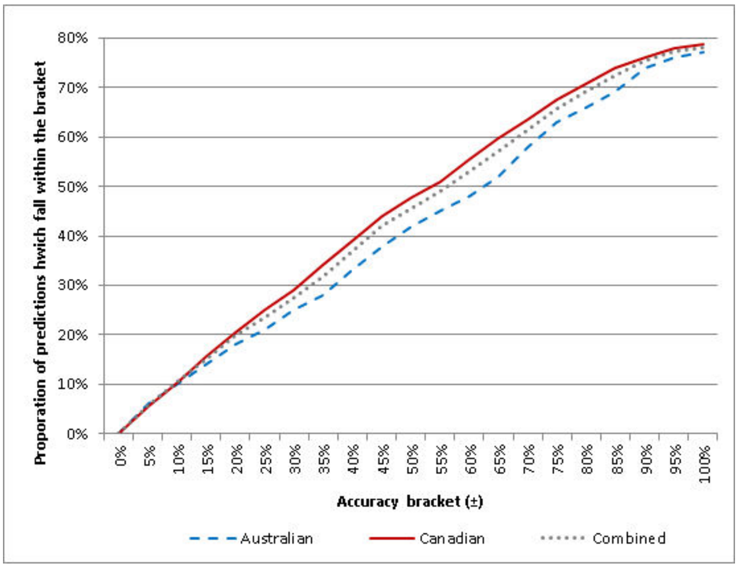


Figure A-13.10. LSR predictive confidence brackets

Artificial neural networks

For this research, an ANN was constructed with 95 input variables, two hidden layers and an output layer. As for the trendline and multivariate analyses, 75% of the data was used to train the networks with the remaining population being used to test its predictive accuracy. The resulting differences between the training and test outcomes are marked. The ANN performed very well in predicting prices within the training the dataset, but very poorly when attempting to predict the prices of the unseen test dataset, as shown below:

- Australian results had a training r^2 of 0.981 but on the unseen dataset the predicted output r^2 was only 0.028
- Canadian results had a training r^2 of 0.984 but an output r^2 of 0.203.

It appears that the ANNs tend to overfit to the training dataset. This overfitting negatively affected the ability to estimate within industry common confidence intervals (Table A-13.4 and Figure A-13.11). For the Australian dataset, the ANN outperformed the LSR in the ±20% to ±65% confidence brackets. However, for the Canadian dataset the ANN performed poorly against the LSR across all confidence brackets, and in some instances, was only as good as a simple trendline estimate.

Table A-13.4. ANN predictive confidence brackets

Item		Results (%)									
Accuracy bracket		0-10	0-20	0-30	0-40	0-50	0-60	0-70	0-80	0-90	0-100
Confidence	Australian	8	21	30	38	46	51	56	62	64	74
	Canadian	8	12	20	23	30	35	41	51	59	70
	Combined	5	14	23	27	32	36	43	52	61	70

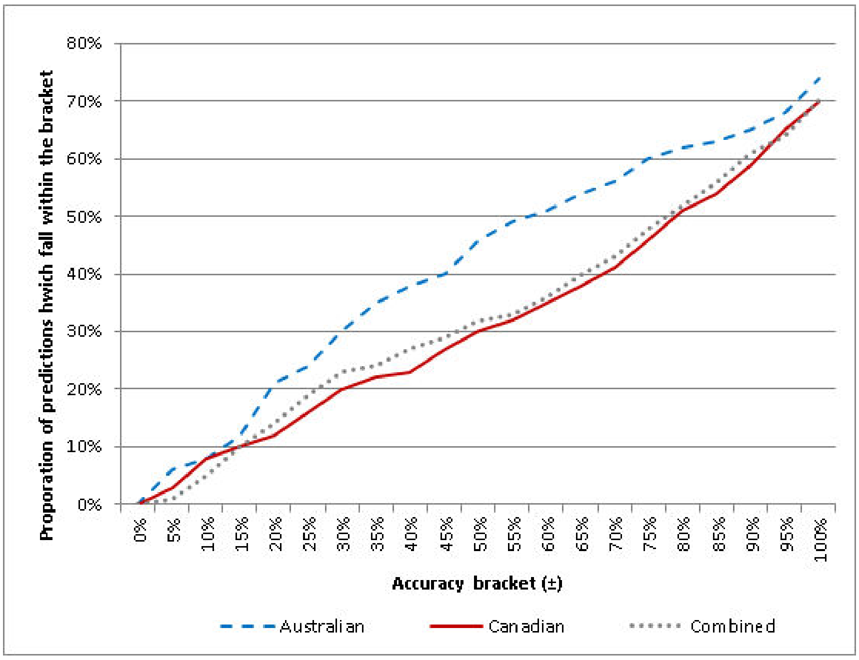


Figure A-13.11. ANN predictive confidence brackets

1.5. Discussion

This research into pricing exploration projects and the underlying price drivers resulted in the observation that project size appears to be the primary negative driver for unit prices in early-stage exploration projects. It is hypothesised that this reflects the increased holding costs of large areas being quite onerous, and therefore, the number of market participants who can afford to meet these obligations reduces with tenement size (less demand result in lower prices per km^2). Conversely, small tenements are affordable to a larger pool of market participants who will compete and drive up the unitised resale price. As a result, size does matter (Muller and Lorenzen 2012). As smaller areas have higher resale unit prices, projects located in desirable locations, such as in established mineral camps, tend to be broken up and marketed into smaller tenement parcels as time progresses. Consequently, if an incoming party wants to acquire an entire mineral belt they are unable to do so due to dispersed ownership and high acquisition costs (remembering that amalgamating various tenements into a single project area may then decrease the unit price due to decreased demand). Furthermore, the corporate objectives of small tenement holders are likely to be more modest than those of larger corporations, and as such the value-in-use is higher to them (e.g. a $0.5 M deposit has a high value-in-use to a family-owned private entity than a tier-one international miner).

The Australian and Canadian markets are markedly different, not just in size distribution, but in how price is attributed. In Australia, size appears to account for much of the price; however, in Canada it is much less influential. This suggests that the prevalence of small Canadian corporations materially affects market attributes.

The use of the natural log-log transformed LSR technique resulted in a marginal improvement in the Australian, but significant improvement in the Canadian correlation co-efficient. The reasons for this may include:

- Larger Australian corporations are more concerned with value. That is, the larger the project the closer the price is to the inherent value, and as Australian projects are generally larger than their Canadian counterparts, this translates through to the price behaviour.
- Canadian corporations are sensitive to a variety of other price drivers that are less connected to the probability of mineral discovery (e.g. financial markets, commodity prices, etc.). This implies a difference, not necessarily a superiority, in market sophistication.

The ANN technique provides some improvement over LSR in predicting into various accuracy brackets in the Australian dataset (Figure A-13.12 and Figure A-13.13), however, it performed very poorly for the Canadian dataset, showing limited improvement over the use of the trendline. This suggests that the learning processes underpinning the ANNs may overfit to the price drivers in the Canadian dataset (i.e. the theoretical results extrapolate poorly onto the unseen data). Consequently, the LSR is better at picking out and extrapolating the trend generated by the Canadian price drivers. However, ANNs may yield some improvement over the LSR technique in predicting the Australian market, suggesting that the Australian market is more orderly in its price attribution than the Canadian market.

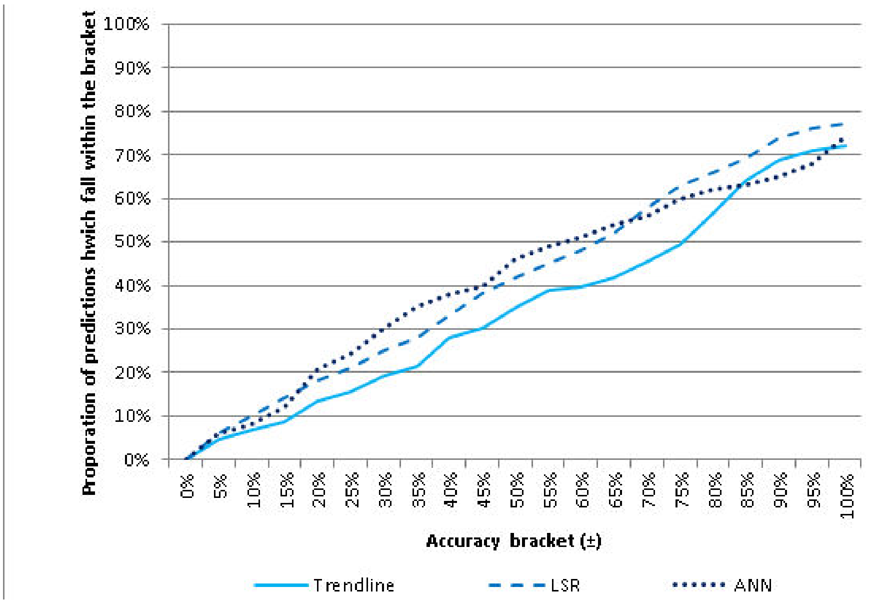


Figure A-13.12. Australian confidence brackets for the trendline, LSR and ANN techniques

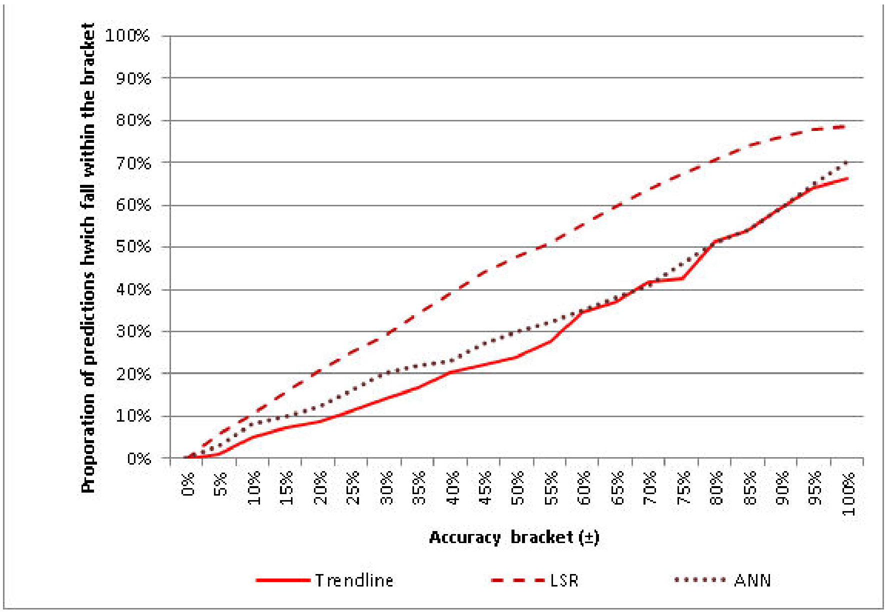


Figure A-13.13. Canadian confidence brackets for the trendline, LSR and ANN techniques

Based on the observations outlined above, it does not appear to be possible make direct price analogies between the Australian and Canadian exploration markets. The most likely reason is the structural differences in the industries, with the substantial number of small Canadian corporations influencing market behaviour. It is speculated that despite increased market liquidity, the Canadian market is more sensitive to macro-economic conditions. However, this negatively affects market efficiency (e.g. too many corporations in the business of wheeling and dealing rather than exploring). Furthermore, the LSR technique is the most suited to determining a possible order of magnitude for the price, as it is consistent across jurisdictions, is simpler, more transparent, and through the log-log transformation, achieves much of the improvement potentially captured by the ANN.

For the industry confidence interval of ±45% around a preferred price, there is no empirical evidence to validate the somewhat subjective ranges used in Table A-2.2. The best outcome was using the LSR technique on the Canadian dataset, which estimated within the ±45% confidence bracket 48% of the time. While there are likely to be project-specific details that are not modelled in this research that account for these '*flip of a coin*' odds, it cannot be discounted that industry practitioners are overconfident in their understanding and prediction within a variable market. In part, this is due to the certainty implied by heuristic methods like Kilburn and MEE. This research challenges their validity as:

- Size is shown to be the key price driver in the Australian market, yet the methods do not take this into account in a direct manner, leaving it open to interpretational variance (e.g. it is suitably vague to allow any number to be generated).
- The LSR technique determined that none of the Kilburn descriptive terms is strongly significant in attributing price. For the Australian dataset, only the proportion of the project that was prospective had any significance. It is important to note that there is likely to be a correlation between the size of a project, and the proportion which remains prospective for hosting gold mineralisation. For the Canadian dataset, only the presence of historical workings had an influence on price, albeit weak.
- The ANN performed very poorly in the Canadian market and the LSR determined fewer significant price drivers, suggesting that this market is more erratic in attributing price. Given that the Kilburn method is of Canadian origin, and the rigidity of the Kilburn weights (although there is subjective flexibility), these results raise concerns over the way it was conceived.

Based on the empirical evidence presented in this research, the Kilburn method, and other simplistic methods such as MEE, is likely to be invalid. While new methods are always being devised, at the time of writing, the most defendable methods were the EV and Replacement methods, which may help form an opinion of value. This information can then be used to calibrate where a project may reside in a market-based range of values, the order of magnitude of which is supported by the LSR technique.