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Using Option Pricing Theory to Value Development Land

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In this paper we explore the use of option pricing theory to value development land for individual housing units. Such land is generally purchased vacant with the intention of building on it at some point in the future. This can be treated as a "real option" capable of being valued using several methods previously used in the valuation of securities and with limited application towards property assets. Our results confirm that option pricing models appear to have the greatest potential for valuing development land for which immediate development is not optimal. The traditional valuation methods (such as a residual valuation or discounted cash flow) cannot adequately reflect the 'hope value' of a site which has a very low or negative current development value. Overall, the option pricing models examined in this study also predicted development plot transaction prices more accurately than a traditional estimate of residual value. For development plots with an apparent negative residual value, the option pricing models examined in this study predicted considerably lower transaction prices than those actually observed. This may suggest that vendors have a reservation price, below which they will not sell, or it may suggest that prospective purchasers are willing to pay a significant premium that cannot be explained either by current market value or option value. There is evidence of significant variation in the accuracy of option pricing models within an urban area. To an extent, this is surprising because option pricing models already make allowance for intra-urban variation in house prices. However, construction costs, the cost of borrowing, rental yields and the volatility of returns are assumed to be set at the market, rather than neighbourhood, level and this may not actually be the case in practice. The predictive performance of option pricing models does not appear to be constant over the economic cycle. The option pricing models tested in this study tended to under-predict development plot transaction prices significantly in a period of strong property market growth. This may suggest that expectations play a more important role in determining the option value of development land than currently thought to be the case.

1. Introduction

This paper examines the potential for using option pricing models as a method for the valuation of land with development potential. It draws on recent advances in real estate applications of option pricing theory, and carries out a series of empirical tests using residential house sale and land sale data for Perth, Western Australia for the period 1995-2008. Australian data are chosen for the empirical tests primarily because the structure of the new-build housing sector offers considerable potential from the perspective of this research. In the UK, the great majority of new housing completions are carried out by firms of private house builders. Typically, housing developers purchase sites suitable for the construction of more than one dwelling. A given development site therefore gives rise to a multiple of new house sales. This greatly complicates the task of empirically testing any method designed to value the development site. In Australia, by contrast, the majority of new housing completions are procured privately, on an individual basis, and on individual plots of land suitable for the construction of a single dwelling. Although there is a market for individual housing development plots in some local markets in the UK, the relative scarcity and inavailability of data undermine their research potential.

This paper is organised as follows. Section 2 introduces option pricing methods in real estate and discusses the rationale for their application. Section 3 briefly outlines several types of option pricing model with real estate applications while section 4 formally introduces the aims and objectives of this study in addition to the study area, data and methods. Sections 5 and 6 present the results of the empirical analysis designed to test the option pricing models in the context of a database of observed housing and land prices in Perth, Western Australia.

2. The use of option pricing models in real estate

During the past thirty years, significant advances have been made in the theory of option pricing. More recently, option pricing models have been adapted for the purpose of valuing 'real options' and, more specifically, for permitting analysis of real estate valuation and investment problems.

Option pricing problems in a real estate context are a subset of real options. These are distinct from 'land options', which are often used in the development land acquisition process. Land options are used by developers to secure control of sites that do not have immediate development prospects. Hence, they mitigate the need for substantial advance cash outlay (see Leishman et al, 2000). The pricing of land options is well documented, and this project is not directly concerned with these. Instead, the focus is on the concept of 'real options'.

Real option pricing theory is developed from models designed to value options to buy and sell ordinary shares (call and put options). These financial options are contracts that allow their owner to buy or sell ordinary shares in the future at a previously agreed price. Call options give the owner the right to purchase shares at a given price (the exercise price) on or before a given date while put options give the owner the right to sell. Since the exercise price is determined when the option is purchased, the value of an exercisable call option is simply equal to the difference between the market share price and the exercise price.

Real options can be thought of as implicit options since they follow on as consequences of investment decisions. For example, a development site is an option to build at some point in the future and owning the site can be likened to owning a call option with an infinite life. The exercise price is equivalent to the price paid for the site at the time of its acquisition while the market price is a function of (unknown) future housing prices, interest rates and construction costs. The site may well have a present market value derived from the expected profitability of developing it immediately but it also has an option value because the developer can choose to postpone development until some point in the future. These are the arguments of Titman (1985), one of the earliest real estate relevant discussions of real options. The study explains the existence of land which, although suitable for development and situated in high density urban areas, remains vacant. This situation can occur when the option value of a site exceeds its value assuming immediate development.

There has been a number of recent studies concerned with real estate applications of real option theory. This strand of the literature is inspired by the fact that some real estate rights bestow the owner with potentially valuable 'option-like' assets. Lucius (2001) sets out a broad categorisation of real options with a real estate focus including the option to: abandon, shut down, contract, expand, defer or invest in stages. In part, this builds on a strand of literature concerned with the pricing of natural resources using a real options approach (see Brennan and Schwartz, 1985; Paddock et al, 1988; Morck et al, 1989).

The owner of a site with development potential may choose to construct a revenue-bearing building at some later date rather than develop it immediately. In order to acquire the building and its associated rental income stream, the land owner will incur development costs. These can be likened to the exercise price of a financial call option while the development site can be likened to the option contract. Thus, a compelling argument in the real option literature is that a development site can be thought of as an option (owning a plot is like owning the option to have a building on it at some point in the future). This gives rise to the argument that the plot could be valued using an option pricing model derived from financial option models.

Titman (1985), Williams (1991, 1993) and Grenadier (1996) demonstrate that the price of an option to develop (i.e. the price of development land) can be found by solving a partial differential option valuation equation derived from the Black and Scholes financial option valuation equation (Black and Scholes, 1973). Williams (1991) demonstrates that the present value of an option to own developed property is a function of development revenues and costs, time and the riskless rate of interest. As with Titman (1985), Williams (1991) shows that the effect of increasing uncertainty is to increase the present value of an option. Just as the option pricing equation predicts a higher option price for stocks with greater volatility, ceteris paribus, the price of a site with development potential increases as the volatility of development revenues over costs increases.

Other real estate applications of option pricing theory have examined the pricing of leases with option-like features (Grenadier, 1995; Ward and French, 1997; Ward et al, 1998; McAllister, 2001). For example, Ward and French (1997) demonstrate that the premium for a lease with an upwards only rent review clause rather than an upwards/downwards rent review clause can be calculated using this method. Option pricing theory has also been used very effectively to evaluate the impacts of public policies on real estate market outcomes. For example, Geltner et al (1996) predict that the availability of alternative uses, even if contemporaneously similarly priced, increases the option value of land and delays development. More recently, Ho et al (2009) have applied binomial and Samuelson-McKean (Samuelson, 1965) option pricing models to evaluate the effects and value of housing upgrade public subsidies in Singapore.

3. Common forms of option pricing model in real estate

3.1 Binomial models

In one of the earliest, and often cited, examples of option pricing theory application to real estate, Titman (1985) demonstrated that higher levels of uncertainty are associated with higher option values. His work set out to provide an explanation for the failure for sites with development potential to become developed. The model follows a binomial approach. Land owners seek to maximise the value of their land by selecting from a range of development possibilities such that the residual value, the positive remainder after construction costs are deducted from capital values, is maximised. The residual value is defined as follows:

$$\max \Pi(p_0) = p_0 q - C(q)$$

subject to:

$$\frac{\partial C}{\partial q} > 0$$

$$\frac{\partial^2 C}{\partial q^2} > 0$$

where,

q number of building units

C construction costs, a function of the number of building units

p_0 current market price per building unit

Given the constraints above, the optinmal building size occurs at $\delta C \div \delta q = p_0$, or the equality of marginal revenues and marginal costs. Given this condition for optimal development density, the focus moves to the land owner's decision concerning choice of use and development timing. Land owners are assumed to face a choice between developing now, or deferring development for one year. Current and future construction costs, and current capital values, are known – only capital values at the deferred development date remain unknown. This defines the present value of vacant urban land as follows:

$$V = \Pi(p_h)s_h + \Pi(p_l)s_l$$

where,

$\pi(p_h)$ the profit arising from deferred development and a 'high' market price outcome

$\pi(p_l)$ the profit arising from deferred development and a 'low' market price outcome

s_h state price or opportunity cost of deferring development followed by sale of buildings at the 'high' market price outcome

s_l state price or opportunity cost of deferring development followed by sale of buildings at the 'high' market price outcome

Titman (1985) therefore represents an example of the binomial option pricing approach applied to real estate. These methods work on the principle that an option can be priced by setting up an 'option equivalent' investment strategy with identical risk and return properties. Using the principle of arbitrage, the value of option and option equivalent are equal.

Despite the rigidity of the assumptions necessary to employ the binomial approach in real estate research, the method has some intuitive appeal. For example at the grant of a new 10 year commercial lease, with rent review at the end of the fifth year, uncertainty concerns future market rents at a specific future time. The value of an 'upwards only' rent review clause, vis-a-vis upwards or downwards rent review terms, can be calculated using the binomial method provided that the two future possible rent levels are known (Leishman, 2003; McAllister, 2001; Ward and French, 1997). Yet, the binomial method is highly restrictive and, arguably, unsuitable for many real estate research applications. For example, it is improbable either that possible alternative future market rent levels can be known with any certainty, or that future values are limited to two possible outcomes. It is on this basis that a number of studies have focused on derivations of the Black-Scholes option pricing model as an alternative.

3.2 Models derived from Black and Scholes

When share prices are Normally distributed, and future share values belong to a distribution rather than binomial outcomes, the Black-Scholes (1973) formula can be used to value American call options:

$$V = [N(d_1) \times P] - [N(d_2) \times (E \div (1+r)^t)]$$

Where,

$$d_1 = \frac{\ln\left[\frac{P(1+r)^t}{E}\right]}{\sigma\sqrt{t}} + \frac{\sigma\sqrt{t}}{2}$$

and

$$d_2 = d_1 - \sigma\sqrt{t}$$

V	Call option value;
$N(d_1)$	The probability that a Normally distributed random variable is less or equal to d_1, the option delta;
P	Current share price;
E	The exercise price;
r	The risk-free interest rate (cost of borrowing / lending);
t	Periods (years) to exercise date.

The Black-Scholes (1973) formula considers share prices as a continuous random variable, with volatility described by the standard deviation of returns (σ). There have been a number of adaptations of this framework for real estate applications. For example, Williams (1991) demonstrates that the present value of an option to own developed property is a function of development revenues and costs, time and the riskless rate of interest. The effect of increasing uncertainty is to increase the present value of an option (development site). The Williams (1991) model, expressed as a partial differential equation, is as follows:

$$0 = \frac{1}{2}\sigma_1^2 x_1^2 V_{11} + \sigma_{12} x_1 x_2 V_{12} + \frac{1}{2}\sigma_2^2 x_2^2 V_{22} + v_1 x_1 V_1 + v_2 x_2 V_2 - iV + \beta x_2$$

where,

x_1 development cost per unit

x_2 development revenue per unit

v_i expected growth rate for two substitute securities

V_i value of substitute securities

i riskless rate of interest

V(x) option price (the value of development land), where $x=(x_1, x_2)$

βx_2 cash inflow from undeveloped land (per unit of time)

σ standard deviation of the developed property price changes

3.3 The Samuelson / McKean model

The most relevant and appropriate of the option pricing models from the perspective of this research is also the simplest – the Samuelson (1965) and McKean equation for valuation of perpetual American warrants. The latter are defined as non-time limited options to purchase shares. Options styled 'Amercian options' are those that allow acquisition (or sale) of the asset at any time up to the exercise date. Meanwhile, 'European options' are those that can be exercised on, and only on, the exercise date. Assuming perpetual development rights, outright ownership of land suitable for development can be likened to a perpetual 'American' call option to own buildings. If no rent is payable on undeveloped land, and there are no holding costs, valuation of development land using the Samuelson-McKean equation is straightforward.

The Samuelson-McKean approach encompasses two related concepts: the development 'hurdle', or residual value below which development will not occur; and the option elasticity. They are defined as follows (see Geltner, 1996):

Option elasticity:

$$\eta = \left(\delta - r + \sigma^2/2 + \left[\left(r - \delta + \sigma^2/2 \right)^2 + 2r\sigma^2 \right]^{1/2} \right) / \sigma^2$$

The optimal development hurdle is defined as:

$$V^* = (C \times \eta)/(\eta - 1)$$

Finally, the call option value (development land value) is defined as follows:

$$V = (V^* - 1)(V(t)/V^*)^\eta$$

Where,

V call option value (land value)

V(t) value of the built asset at time *t* expressed relative to the construction cost (i.e. construction cost is a numeraire; construction cost ≡ 1)

V* the 'hurdle' value or ratio of built asset value to construction cost below which the land will not be developed

η option elasticity

δ dividend rate (current rental yield)

r riskless interest rate

σ standard deviation of the built asset returns

C construction cost to build the asset, net of land costs

In some applications, the dividend rate is replaced by a construction cost yield which is, in turn, approximated by the differential of risk free rate and construction cost inflation. The riskless interest rate is commonly proxied with a long term government bond yield. Meanwhile, volatility is proxied by the standard deviation of built asset returns. In a recent application of the Samuelson-McKean approach, Ho et al (2009) calculate volatility as the standard deviation of resale returns (within a given quarter), and proceed to annualise this estimate. This estimate of volatility is held constant during their 2002-2003 study period. Similarly, average yields are calculated on the basis of average resale price and rental value, giving a constant yield estimate throughout their study period. The authors use the 5 year Singaporean government bond yield as a proxy for the risk-free rate. The Ho et al (2009) application raises interesting quetions about the appropriate method of calculating volatility. While the authors of that study focused on variability within the market in a given time period, an alternative would be to measure the variability of market-wide returns over time. Arguably, the correct measure depends on how investors view volatility, but it seems probable that investors' assessment of the volatility of returns will depend on location within an urban real estate market, and evolve over time in line with market conditions. This issue is discussed at greater length later in the report.

4. Research questions, aims and objectives

4.1 Objectives of the research

Sections 2 and 3 provided brief summaries of the development of option pricing theory in real estate research. The most commonly adopted approaches – binomial, Black-Scholes derived and Samuelson-McKean – were reviewed. In this section, the motivation for this research project is set out more clearly and the study methods are introduced.

This study is motivated by the relative lack of empirical evidence supporting the use of option pricing theory in real estate research. While this collection of theoretical ideas is intriguing, there are a number of difficulties in application. Some of these were alluded to earlier in the report, while others are implicit in the assumptions underlying option pricing theory. Perhaps the leading assumption is that of market efficiency. It is well rehearsed that the particular characteristics of property markets distinguish them from, for example, financial markets. Property markets are generally characterised by low transactions frequency, relatively small numbers of buyers and sellers and poor or asymmetric flows of information. Real estate itself is highly heterogeneous. When considered as an investment asset, this heterogeneity coupled with indivisibility and low transactions volume mean that it is not a particularly liquid asset. Thus, it is striking that the characteristics of the property market mean that it is well removed from the assumptions of market efficiency that underlie option pricing methods. As Evans (1995) argues, empirical analyses of real estate markets should explicitly account for market inefficiency.

When the problem is approached from a behavioural perspective, further doubts are raised concerning the validity of applying financial option pricing methods to real estate. Financial option pricing theory assumes that the behaviour of individuals cannot affect market outcomes (see Ball, Lizieri and MacGregor, 1998). This assumption is an essential ingredient to the efficient market assumption necessary to option pricing solutions. In addition, real estate markets are likely to vary sectorally in terms of efficiency. Given that real estate investment, as an asset, effectively competes with stock market securities, pricing is mediated by the actions of a large number of investors and traders. Given the relative efficiency of capital markets, the implication is that the real estate investment sector should also be relatively efficient. By contrast, the actions and strategies of individual developers are likely to be of importance to outcomes in the real estate development sector. For example, Ball, Lizieri and MacGregor (1998) suggest that the competition between developers means that their strategies become, to an extent, interdependent.

So, there are sound conceptual reasons for doubting the validity of financial option pricing methods to real estate research. These vary in intensity depending on application. Arguably, they may be more appropriate in investment than development or occupation contexts. Given the transactions volume and frequency dimension to market efficiency, there may be grounds for supposing that option pricing methods have greater relevance and potential validity in markets characterised by higher volumes of, and more homogenous, transactions.

Despite these concerns, the real option pricing literature suffers from a relative lack of empirical studies. Thus, while option pricing concepts have intuitive appeal, their validity rests on potentially bold assumptions and empirical outcomes remain largely untested. In part, this poorly developed aspect of the literautre may be a function of the generally poor data quality and availability with which the real estate research sector suffers. A further problem may be the hetereogenous nature of real estate transactions.

4.2 Research questions

Following on from the discussion in the previous section, this study reports the results of a series of empirical tests focused on the use of option pricing theory to value development land. The specific objectives of the study are as follows:

- Can a development land valuation methodology be developed from the standard real option pricing models?
- How do the development land prices predicted by the option model differ from those predicted by standard static valuation models?
- Are differences between the outcomes of these valuation approaches constant over time, or do they depend on macro economic, property or building cycles?
- If systematic differences do exist, what does this imply about the validity and appropriateness of traditional development site valuation approaches?

The study is based on analyses of the housing resale and development markets in the city of Perth, Western Australia. As mentioned briefly in the introduction, Australia is chosen as a case study for a number of reasons:

The structure of the housing development industry in Western Australia is quite different to that in the UK. In the latter, the market for single development plots is not a dominant element of new-build owner occupied housing supply. Instead, private developers dominate development land transactions. Sites encompass multiple building plots, with most private developers seeking to achieve a degree of economies of scale in production. In other words, development land is purchased on a bulk basis by private developers, and new-build housing units are sold individually to households. Given this disjuncture between housing and land markets, it is difficult to test option pricing models as a method of development land valuation.

Secondly, Western Australia maintains comprehensive data on land, housing and commercial property transactions in publicly available registers. These databases benefit from extensive quality checks and well developed geograpical and property identification codes.

4.3 Methods

The empirical analysis in this report is based on micro data developed from publicly available registers of land and housing transactions. These data are combined with macro data on interest rates, bond yields, real estate rental yields and housing construction costs. The transaction database is used to identify:

- A city-wide repeat-sales sample of housing transactions. This sample of data is used to estimate a city-wide Case and Shiller (1989) repeat-sales house price index. This, in turn, is put to two further uses:
    - The index is used to derive estimates of the volatility of capital returns. This information is required by the option pricing models.
    - The index is used to discount the subsequent house sale prices to the present value prevailing at the time of each identified development plot transaction.
- Instances of development plots sold in the city, together with transaction dates and prices.
- Sales of newly constructed housing, with transaction dates, prices and internal housing areas. These are then linked to their respective prior sales of development land.

The research therefore seeks to explicitly link sales of newly constructed built assets with prior purchases of development land on a unit by unit basis. Construction costs are estimated using the internal area information included in the transaction database and from published gross construction cost rates.

The Samuelson-McKean and Black-Scholes option pricing models are used to estimate the value of development plots as an option. These estimates are a form of predicted development plot value. A simple measure of residual value (the excess of built asset value over construction costs) is estimated for the purpose of comparison. The analysis considers the behaviour of land and house prices over the 1995-2008 study period. It involves explicit comparison of option model predicted values with residual values and observed land transactions prices.

5. Analysis of residential plot prices

5.1 Introduction

This section sets out the results of a Case and Shiller (1989) repeat-sales index estimation for Perth, Western Australia. As discussed in the previous section, this method of index estimation is well-rehearsed and is carried out as an intervening step to the main objective of the study: the empirical testing of option pricing models as a method of development plot valuation. The city-wide repeat-sales index provides the means for discounting house sales to the present value prevailing at time of development plot purchase. It is also used to form estimates of volatility which are a required input of option pricing models.

5.2 Estimating volatility

The estimate of volatility (standard deviation) of property capital returns is derived from a repeat-sales price index. The analysis works to the assumption of a unitary housing market without spatial divisions or submarkets. A sample of 50,148 repeat sales of residential property for the Perth Metropolitan area is used. This covers the period 1990, quarter 1 to 2008, quarter 4. The repeat sales estimation follows the Case and Shiller (1989) methodology in which squared residuals from an initial estimation are regressed on a quadratic specification of holding period (time, in months, between repeat sales). The predicted values are used as a weight to control for holding period heteroscedasticity in a subsequent repeat-sales regression.

The results of the Case and Shiller estimation are shown in table 1. They are used to form a cumulative price index for the Perth area as shown in figure 1.

****Table 1 located about here****

****Figure 1 located about here****

In order to estimate volatility, the standard deviation of capital returns is calculated for the 5 year periods prior to each of the study years 1995-2008. This yields a time series measure of volatility rather than the cross-sectional approach adopted by Ho et al (2009). However, the choice of a 5 year period for the calculation of volatility is arbitrary. The volatility estimates are calculated using the quarterly index, but aggregated to annual figures as shown in table 2.

Table 2 located about here

5.3 Land prices as a proportion of built asset prices

An initial analysis of land (plot) prices yields some interesting insights. The database of land transactions includes only those sites for which a subsequent completed house sale can be identifed. Therefore, for each observed land sale price, a subsequent completed house price can be observed. The ratio of land prices to subsequent house sales prices is not constant,but shows evidence of cyclical behaviour. Table 3 summarises the ratio of median land prices to median subsequent build asset prices (i.e. house sale prices).

The ratio of land prices to house prices diminishes gradually throughout much of the study period (between 1996 and 2005) before rising sharply towards the end of the period (2006-2008). Figure 2 reveals a similar pattern in the estimates of volatility. Volatility declines sharply from 1995 to around 200 before increasingly gradually to 2005. The period 2006-2008 represents a significantly more volatile period (reflecting a period of rising house price growth).

Table 3 located about here

Figures 2&3 located about here

A simple analysis of land prices shows strong correlation, as might be expected, between plot prices and house prices. Figure 3 summarises the house price repeat-sales index described area, together with the median land price observed from the database of land and subsequent house sales. Interestingly, while these indices clearly move together in the long run, there are periods of short run divergence. One such period is evident from 1995 to 2000 when house prices were rising at a faster rate than the static or declining land prices. Another such period occurs between 2006 and 2007 when the rate of land price increase appears to slow considerably despite continued house price growth. However, at the very end of the study period (2007-2008), the repeat sales house price index suggests a period of downturn; yet land prices continued to rise significantly during this period.

6. Estimating option prices

6.1 Introduction

As discussed in some detailed earlier in the report, land suitable for development can be conceptualised as the option to own a completed built asset in the future. On this basis, the expectation is that the transaction price of a land plot should reflect its option value. This section summarises the methodological steps taken to calculate option values using the Samuelson-McKean and the Black-Scholes option valuation models. These estimates are essentially predicted land transaction prices. The analysis in this section then examines the relationships between the two different option values and between observed and predicted land prices. Focusing on differences between observed and predicted prices, the analysis then considers spatial and time series patterns in the results.

6.2 Construction costs and residual values

The methodology employed to yield estimates of option value is relatively straightforward. The database of matched land and subsequent housing transactions yields information on the date (and price) of every plot transaction as well as the date and price of the subsequent built asset. The internal floor area and a simple categorisation of building materials are also provided in the data. Gross construction cost rates (per square metre) were applied to the internal floor area of each subsequent house sale to give a gross construction cost as at the date of land purchase. The analysis was restricted to houses with an area between 90 and 190 square metres and those constructed using standard brick construction methods. The construction rates are summarised in table 4.

****Table 4 located about here****

The repeat-sales house price index was used to bring all subsequent house sale prices back to a present value, defined as the date of land purchase:

PV house price = observed house price × RSIndex(land sale date) ÷ RSindex(house sale date)

The present values (at time of land purchase) of the subsequent house sale and construction cost were used to form an approximate estimate of the residual value for every development plot in the database.

6.3 The development hurdle

As noted earlier in the report, the 'development hurdle' is an important element of the Samuelson-McKean option valuation method. It is defined as a function of construction costs and the option elasticity:

$$V^* = C \times \frac{\eta}{\eta - 1}$$

The option elasticity ('eta') is estimated from the riskless interest rate, built asset yield and estimate of volatility:

$$\eta = \left(\delta - r + \sigma^2/2 + \left[\left(r - \delta + \sigma^2/2 \right)^2 + 2r\sigma^2 \right]^{1/2} \right) / \sigma^2$$

The estimation of volatility was discussed in the previous section – it is derived quite simply from the repeat-sales house price index, noting that the measure adopted in this study is a time series rather than cross-sectional one. The riskless interest rate and built asset yield are proxied by the average yield on 5 year bonds (reported by the Reserve Bank of Australia) and the median residential rental yield for the Perth Metropolitan Area (reported by the Real Estate Institute of Western Australia). These figures are summarised in table 5.

Table 5 located about here

The development hurdle represents the minimum built asset price (subsequent house sale price) necessary to consider development as optimal. This particular element of the Samuelson-McKean model is useful, in conjunction with the estimate of residual value, because it can be used to identify three categories of development land sale:

- Plots in which development is not optimal because the hurdle has not been reached, but there is a positive residual value;
- Plots in which development is not optimal and there is a negative residual value;
- Plots in which development is optimal because the development hurdle has been reached or exceeded (in these cases, the residual value will always be positive).

6.4 Option values – final estimation

Two option valuation models are used in this research. The first, the simplest, is the Samuelson-McKean model referred to earlier. This draws on the estimated development hurdle and option elasticity:

$$V = (V^* - 1)(V(t)/V^*)^{\eta}$$

The Black-Scholes model is also used, based on the assumption of a finite 5 year development right. The exercise price is set to the development hurdle, while the 'current' transaction price (P) is set to the present value, at time of land purchase, of the built asset price. The riskless interest rate and estimate of volatility are as used in the Samuelson-McKean model. The standard Black-Scholes valuation model is then used to estimate the development plot option value:

$$V = [N(d_1) \times P] - [N(d_2) \times (E \div (1+r)^t)]$$

6.5 Estimation results – descriptive statistics

The database of land and matched subsequent house sales contained 2,941 cases in the study period 1995-2008. The distributions of land and house sales over time are summarised in tables 6 and 7.

Tables 6&7 located about here

As might be expected given the inevitable time lag between land purcase and subsequent built asset sale, there are relatively few house sales in the early years of the study period (just over 5% of transactions are in the first 4 years of the study period). Land sales are more evenly distributed throughout the study period but the number of observations drops towards the end reflecting the diminising probability that the database will contain a subsequent house sale that can be matched to a prior land sale. Again, this is as expected. Tables 8&9 reveal considerable variation in terms of transaction price and predicted transactions prices (Samuelson-McKean, Black-Scholes option values and estimated residual value). As discussed in the previous section, land transactions can be broadly grouped into three categories reflecting sites for which development was optimal at time of sale and those for which development was not immediately optimal. The latter breaks down further into sites with a postive, and those with a negative, residual value at the time of sale.

Tables 8&9 located about here

Further analysis of transaction prices and predicted land values broken down by the three broad categories gives further insight. These figures are shown in table 10. Development plots classified as optimal for development have higher mean / median transaction prices than those for which development was not immediately optimal at the time of sale. It is worth noting that many of the development plots in the database were sold more than once prior to construction and sale of a house. Thus, a given development plot may have one or more 'development optimal' transactions in the database together with earlier 'not optimal' transactions.

The figures in table 10 also clearly show that observed transaction prices for development plots are generally considerably higher than can be readily explained either with reference to site 'option value', or to estimated residual value. One explanation for this might be that the construction costs used in this study are over-estimates. Another, and probably more likely explanation, is that development plot purchasers are willing to pay a significant premium over and above current market value. This explanation is further supported by the figures shown in table 10 for sites with a negative residual value at the time of purchase. The predictions of the Samuelson-McKean and Black-Scholes models differ significantly. In particular, the Black-Scholes model suggests that plots in this category have little or no value, while the Samuelson-McKean model suggests a mean value of around $8,200. However, this compares to an observed mean plot purchase price of $72,125. Although the mean transaction price is only just over a third of that for 'development optimal' plots, the figure is well in excess of that predicted by the option pricing models.

****Table 10 located about here****

Figures 4 and 5 examine the relationship between the predicted option values and estimated residual value (for all sites considered together, rather than by category). The scatterplots show that the Black-Scholes model implies a positive option value even for plots with a small negative residual value (around negative $20,000). Plots with a lower value than this are generally predicted to have no option value. The scatterplot then suggests a linear relationship between option value and residual value. Figure 6 shows a similar, but more dispersed relationship between Samuelson-McKean predicted option value and residual value. However, it is also immediately clear that plots are more likely to have an option value despite having a negative residual value. This finding is logical given that the Black-Scholes model in this application has been configured to predict option value assuming option exercise must be within a five year period.

****Figures 4&5 located about here****

6.6 Estimation results – time series and spatial patterns

This section extends the analysis of predicting option value results by considering a number of related questions:

- Which is the more powerful predictor of development plot sale price drawing from predicted option values and estimated residual values?
- Does the correct choice of predictor depend on whether development plots are optimal for development, or not?
- Does the performance of option pricing models, as a predictive method for land prices, vary either over time or spatially?

To answer these questions, a number of simple OLS regressions are estimated using the two predicted option values and estimated residual value as predictors for development plot transaction price (expressed as the natural logarithm of transaction price per hectare). Given the strong collinearity between the three alternative predictors, separate regressions are run – one for each predictor. The regression models include time dummy variables representing each of the study period years. In addition, locational dummy variables are used as a simple method of testing for spatial variation in the relationship between land transaction price and predicted price. The models are estimated separately for the three categories of development plot identifed earlier (optimal; not optimal but positive residual; not optimal and negative residual value). Table 11 summarises the three model estimation results for development plots for which development was already optimal at the time of land acquisition.

Table 11 located about here

The results show that model 1, which uses the Black-Scholes option value as a predictor, has strong predictive power than models 2 and 3 (Samuelson-McKean and estimated residual value respectively. However, the additional predictive power of the preferred model is marginal. All three predictors are statistically significant at the 1% level. The results also show a number of significant locational effects which are stable across the three model estimations. In some respects, this is a surprising finding because the land price predictors already encapsulate locational differences in house prices (all three predictors make use of observed rather than assumed or predicted house prices). This finding may be suggestive that construction costs also vary significantly by location, or that expectations over future house price growth differ by location and exert an important, but unmeasured, influence over development plot prices. Table 12 sets out the estimation results for development plots for which development was not optimal at the time of plot purchase, but with positive estimated residual values.

Table 12 located about here

The estimation results show more pronounced differences between the three model variants compared with table 11. The Samuelson-McKean option values are a better predictor of land prices than Black-Scholes or estimated residual value. Model 2 has a stronger empirical performance than models 1 or 3. The results also suggest weaker locational variation in model performance. Eight of the neighbourhood dummy variables are significant – four of these at the 5% level of significance. However, 14 neighbourhood dummies were significant in the estimations relating to plots for which development was optimal at time of sale – 12 of these at the 1% level of significance. The results in table 12 also reveal time series variation in development plot prices that is not completely capture by the option pricing or residual value estimates. This is a little surprising given that the option pricing models do predict temporal variation in prices as shown in figures 6 and 7.

Figures 6&7 located about here

Table 13 sets out the results of the model estimations for plots with negative residual values at the time of purchase. Somewhat surprisingly, the empirical performance of these models is superior to that of the models estimated for development optimal plots or those that were sub-optimal at time of purchase, but with positive residual values. The preferred model is that which includes the Samuelson-McKean option value as a predictor. This has an adjusted R square of 0.64. Interestingly, all the time and neighbourhood dummy variables are statistically significant in this estimation. This is strongly suggestive of locational and time series effects that are not fully captured by the option pricing models.

Table 13 located about here

7. Summary and conclusions

This study set out to empirically apply and test option valuation models for the purpose of predicting the price of land suitable for development. The key findings are as follows:

Option pricing models appear to have considerable potential for the valuation of development land for which immediate development is not optimal. Traditional valuation methods (such as a residual valuation or discounted cash flow) cannot adequately reflect the 'hope value' of a site which has a very low or negative current development value. For all three categories of development plot examined, land value as predicted by one of the two option pricing models represented a more accurate predictor of land transaction price than the estimate of residual value.

For development plots with an apparent negative residual value, the option pricing models examined in this study predicted considerably lower transaction prices than actually observed. This may suggest that vendors have a reservation price, below which they will not sell. It may also suggest that prospective purchasers are willing to pay a significant premium that cannot be explained either by current market value or option value. These suggestions raise significant concerns regarding the efficiency of the market for single unit development plots.

There is evidence of significant variation in the accuracy of option pricing models within an urban area. To an extent, this is surprising because option pricing models already make allowance for intra-urban variation in house prices. However, construction costs, the cost of borrowing, rental yields and the volatility of returns are assumed to be set at the market, rather than neighbourhood, level. Further research would usefully examine whether intra-urban variation in these key option pricing variables leads to an improvement in predictive performance.

The results also suggest that the predictive performance of option pricing models is not constant over the economic cycle. Option pricing models are clearly 'time series' in construction, with predictions depending on key financial variables such as estimated volatility, riskless interest rates and rental yields. The empirical tests show that the option pricing models tested in this study tend to under-predict development plot transaction prices significantly in a period of strong property market growth. This may suggest that expectations play a more important role in determining the option value of development land than currently suggested by the literature.

References

Black, F. and Scholes, M. (1973) The pricing of options and corporate liabilities, *Journal of Political Economy*, Vol.81, 637-659

Brennan, M.J. and Schwartz, E.S. (1985) Evaluating natural resource investment, *Journal of Business*, Vol.58, No.2, 1135-1157

Case, B. and Shiller, R. (1989) The efficiency of the market for single family homes, *American Economic Review*, Vol. 79, No. 1, 45-56

Geltner, D., Riddiough, T. and Stojanovic, S. (1996) Insights on the effect of land use choice: the perpetual option on the best of two underlying assets, *Journal of Urban Economics*, Vol. 39, No. 1, 20-50

Grenadier, S. R. (1995) The valuation of leasing contracts: a real options approach, *Journal of Financial Economics*, Vol. 38, No. 3, 297-331

Grenadier, S.R. (1996) The strategic exercise of options: Development cascades and overbuilding in real estate markets, *Journal of Finance*, Vol.51, No.5, 1653-1679

Ho, D.L., Hui, E.C. and Faishal Bin Ibrahim, M. (2009) Asset value enhancement of Singapore's public housing main upgrading programme (MUP) policy: a real option analysis approach, Urban Studies, Vol. 46, No. 11, 2329-2361

Leishman, C., Jones, C. and Fraser, W. (2000) The Influence of Uncertainty on House Builder Behaviour and Residential Land Values, *Journal of Property Research*, Vol. 17, No. 2, 147-168

Lucius, D.I. (2001) Real options in real estate development, *Journal of Property Investment and Finance*, Vol. 19, No. 1, 73-78

Morck, R., Schwartz, E. and Stangeland, D. (1989) The valuation of forestry resources under stochastic prices and inventories, *Journal of Financial and Quantitative Analysis*, Vol.24, No.4, 473-487

McAllister, P. (2001) Pricing short leases and break clauses using simulation methodology, *Journal of Property Investment and Finance*, Vol. 19, No. 4, 361-374

Paddock, J.L., Siegel, D.R., and Smith, J.L. (1988) Option valuation of claims on real assets - the case of offshore petroleum leases, *Quarterly Journal of Economics*, Vol.103, No.3, 479-508

Samuelson, P.A. (1965) Proof that properly anticipated prices fluctuate randomly, *Industrial Management Review*, Volume 6, 41-49

Titman, S. (1985) Urban Land Prices Under Uncertainty, *The American Economic Review*, Vol. 75, No. 3, 505-514

Ward, C. and French, N. (1997) The valuation of upwards-only rent reviews: an option pricing model, *Journal of Property Valuation and Investment*, Vol. 15, No. 2, 171-182

Ward, C., Hendershott, P.H. and French, N. (1998) Pricing upwards-only rent review clauses, *Journal of Property Investment and Finance*, Vol. 16, No. 5, 447-454

Williams, J.T. (1991) Real estate development as an option, *Journal of Real Estate Finance and Economics*, Vol.4, 191-208

Williams, J.T. (1993) Equilibrium and Options on Real Assets, *The Review of Financial Studies*, Vol.6, No.4, 825-850

Table 1 Results of Case and Shiller repeat sales estimation

Variable	Coefficient	t statistic	
Constant	0.1173	10.5485	***
1990: Q2	-0.0700	-1.5141	
1990: Q3	-0.0803	-1.7587	*
1990: Q4	-0.1823	-3.7968	***
1991: Q1	-0.0835	-1.8217	*
1991: Q2	-0.1171	-2.6554	***
1991: Q3	-0.1260	-2.8071	***
1991: Q4	-0.1386	-2.9036	***
1992: Q1	-0.1099	-2.6545	***
1992: Q2	-0.1833	-4.4715	***
1992: Q3	-0.0674	-1.6493	*
1992: Q4	0.0186	0.4542	
1993: Q1	0.0117	0.2887	
1993: Q2	-0.0183	-0.4626	
1993: Q3	0.0357	0.909	
1993: Q4	0.0678	1.7094	*
1994: Q1	0.1525	3.9926	***
1994: Q2	0.1115	2.8411	***
1994: Q3	0.1409	3.6172	***
1994: Q4	0.1350	3.3036	***
1995: Q1	0.2074	5.1712	***
1995: Q2	0.1698	4.1492	***
1995: Q3	0.1777	4.4596	***
1995: Q4	0.1916	4.7957	***
1996: Q1	0.2005	5.2050	***
1996: Q2	0.1839	4.6327	***

Variable	Coefficient	t statistic	
1996: Q3	0.2227	5.6489	***
1996: Q4	0.2331	5.9762	***
1997: Q1	0.2521	6.2585	***
1997: Q2	0.2127	5.4654	***
1997: Q3	0.2278	5.9981	***
1997: Q4	0.2323	6.1843	***
1998: Q1	0.2516	6.7093	***
1998: Q2	0.2691	7.2475	***
1998: Q3	0.2617	6.9146	***
1998: Q4	0.2516	6.7922	***
1999: Q1	0.2832	7.8759	***
1999: Q2	0.2999	8.2823	***
1999: Q3	0.344	9.6124	***
1999: Q4	0.4008	11.0490	***
2000: Q1	0.4301	12.0276	***
2000: Q2	0.4061	11.0339	***
2000: Q3	0.4414	12.2949	***
2000: Q4	0.4462	12.3163	***
2001: Q1	0.4500	12.7774	***
2001: Q2	0.4515	12.8627	***
2001: Q3	0.4743	13.5487	***
2001: Q4	0.5494	15.7325	***
2002: Q1	0.5619	16.2654	***
2002: Q2	0.5676	16.4691	***
2002: Q3	0.6216	17.9070	***
2002: Q4	0.6433	18.6039	***
2003: Q1	0.6760	19.7728	***

Variable	Coefficient	t statistic	
2003: Q2	0.6992	20.6189	***
2003: Q3	0.7708	22.5497	***
2003: Q4	0.8487	24.5601	***
2004: Q1	0.8340	24.3771	***
2004: Q2	0.8489	24.6845	***
2004: Q3	0.9215	27.1500	***
2004: Q4	0.9640	28.2695	***
2005: Q1	0.9911	29.2847	***
2005: Q2	0.9847	29.1414	***
2005: Q3	1.0642	31.6352	***
2005: Q4	1.1253	33.4668	***
2006: Q1	1.2247	36.4822	***
2006: Q2	1.3501	39.8794	***
2006: Q3	1.4561	42.3027	***
2006: Q4	1.4254	39.8802	***
2007: Q1	1.4959	43.5694	***
2007: Q2	1.5162	44.0858	***
2007: Q3	1.5292	44.3005	***
2007: Q4	1.5359	44.3085	***
2008: Q1	1.5381	44.2847	***
2008: Q2	1.5186	43.5497	***
2008: Q3	1.5010	43.0715	***
2008: Q4	1.4909	42.6685	***
Adjusted R Square	0.5304		
Std. Error	0.2512		
F statistic	756.15		
N	50148		

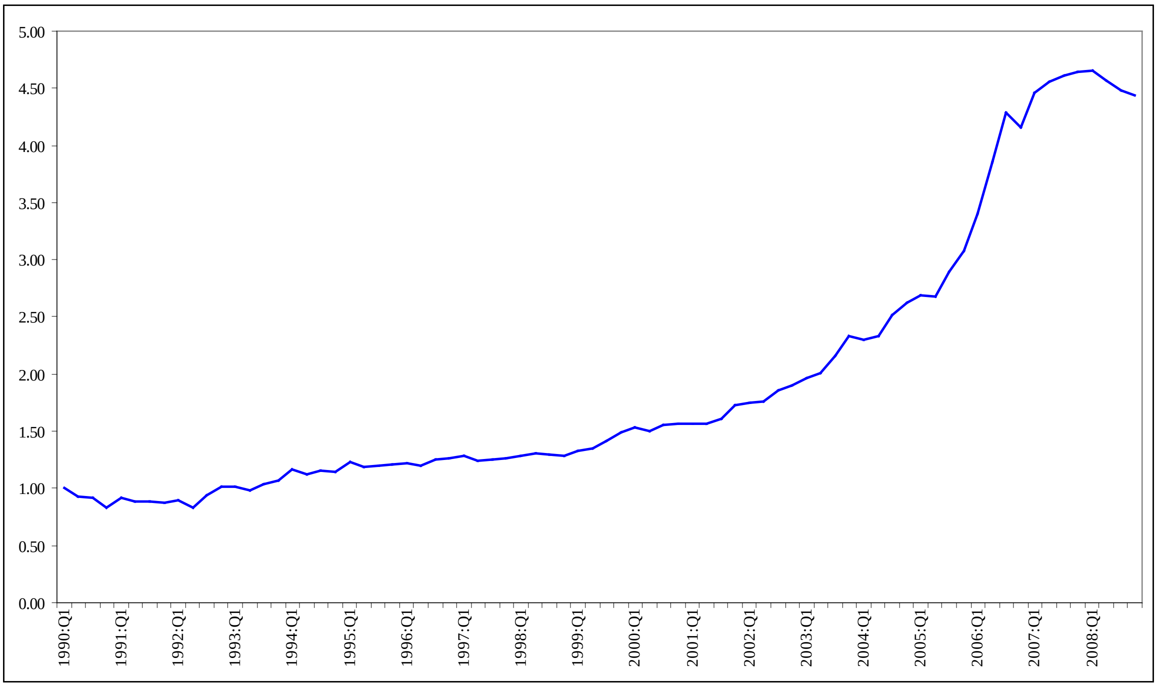

Figure 1 **Cumulative repeat-sales price index for the Perth Metropolitan Area**

Table 2 Volatility estimates derived from the repeat sales index

Year	Volatility
1995	0.105
1996	0.096
1997	0.070
1998	0.065
1999	0.056
2000	0.048
2001	0.053
2002	0.049
2003	0.054
2004	0.060
2005	0.061
2006	0.085
2007	0.085
2008	0.094

Note: figures are standard deviation of property capital returns over the previous 5 years

Table 3 Plot prices as a proportion of subsequent house sale prices

Year	Ratio of land prices to built asset prices	N
1995	0.337	126
1996	0.381	193
1997	0.366	271
1998	0.371	407
1999	0.368	620
2000	0.350	621
2001	0.340	825
2002	0.318	1005
2003	0.315	1145
2004	0.305	1063
2005	0.301	1374
2006	0.317	1315
2007	0.340	1076
2008	0.421	1039

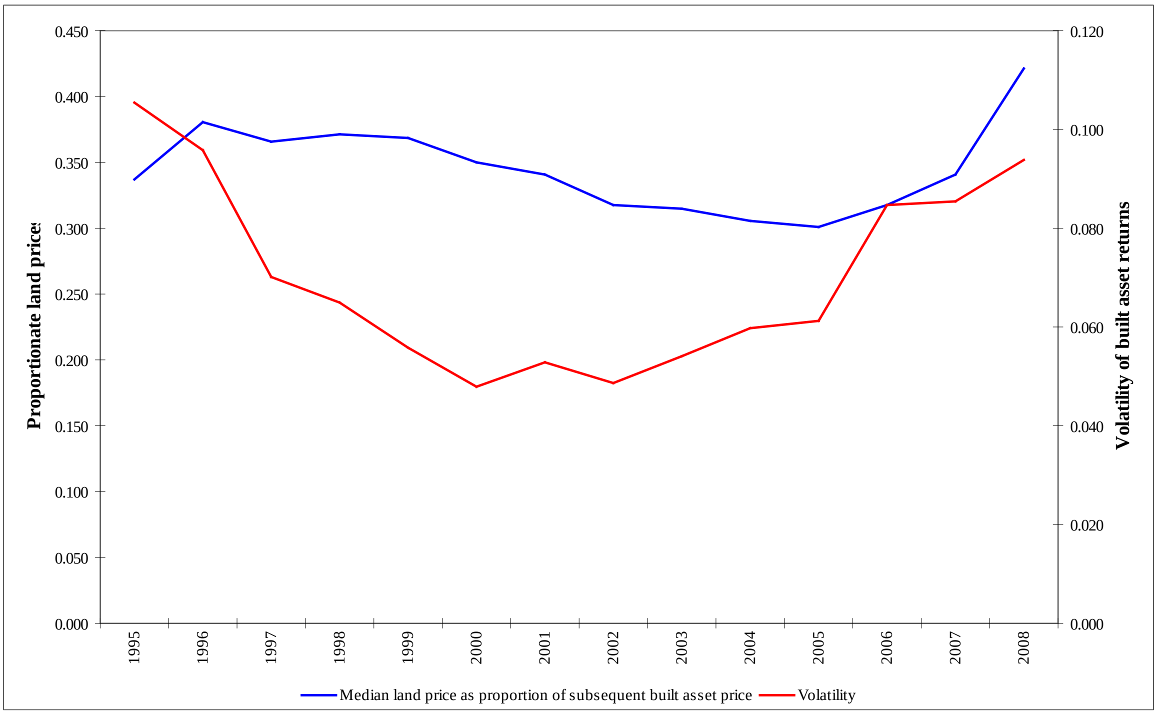

Figure 2 Time series behaviour of land:house prices and price volatility

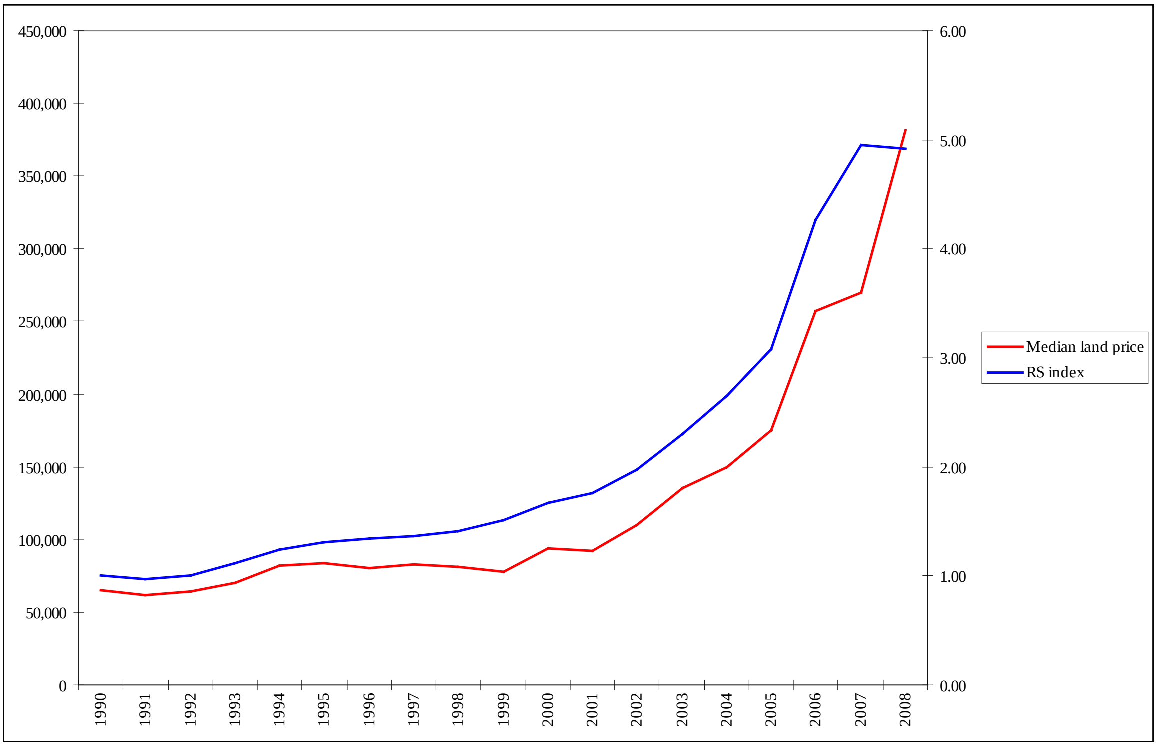

Figure 3 Median land prices and the house price repeat-sales index

Table 4 Gross construction cost rates (standard brick construction)

Year	90-115 sq. m.	116-150 sq. m.	151-190 sq. m.
1995	450	528	500
1996	465	528	510
1997	465	518	510
1998	460	518	500
1999	465	528	510
2000	500	563	545
2001	545	593	570
2002	555	603	580
2003	570	623	595
2004	610	668	635
2005	685	748	710
2006	730	795	758
2007	805	878	833
2008	845	920	873
2009	888	965	915

Source: Construction Cost Guide, Perth, Western Australia: Rawlinsons Publishing

Table 5 Average bond and median residential rental yields

Year	Average yield on 5 year government bonds (%)	Median residential rental yield (%)
1995	8.63	6.00
1996	7.80	6.40
1997	6.55	7.00
1998	5.24	6.40
1999	5.74	6.40
2000	6.27	6.20
2001	5.26	5.75
2002	5.57	5.50
2003	5.13	5.10
2004	5.45	4.20
2005	5.32	4.00
2006	5.65	4.10
2007	6.22	3.75
2008	5.70	4.00

Table 6 Annual distribution of land sales

Land sale year	Frequency	Percent
1995	373	12.68
1996	318	10.81
1997	324	11.02
1998	350	11.90
1999	323	10.98
2000	183	6.22
2001	243	8.26
2002	201	6.83
2003	229	7.79
2004	145	4.93
2005	160	5.44
2006	84	2.86
2007	8	0.27
Total	2941	100

Table 7 Annual distribution of subsequent house sales

House sale year	Frequency	Percent
1996	4	0.14
1997	9	0.31
1998	47	1.60
1999	99	3.37
2000	133	4.52
2001	187	6.36
2002	290	9.86
2003	334	11.36
2004	309	10.51
2005	433	14.72
2006	395	13.43
2007	348	11.83
2008	353	12.00
Total	2941	100

Table 8 Land transactions – descriptive statistics

Variable	Mean	Median	St. Dev.
Land sales price	96,994	67,000	137,399
House area	157.50	160.00	23.53
SM option value	15,277	7,946	22,433
BS option value	17,160	0.87	53,786
Residual value	-17,816	-36,842	68,356

Table 9 Count of land transactions by viability status

Category	Number
Optimal	568
Not optimal; positive residual site value	229
Not optimal; negative residual site value	2712

Table 10 Land price and value statistics by category

Development optimal	Mean	Median	St. Dev.
Land sales price	196,782	156,750	147,396
SM option value	42,643	28,975	41,293
BS option value	96,660	68,943	100,830
Residual value	93,703	67,800	104,264
Not optimal, but positive residual value			
Land sales price	144,003	140,000	78,042
SM option value	31,107	31,135	16,664
BS option value	19,098	17,669	9,780
Residual value	17,305	11,968	15,229
Not optimal and negative residual value			
Land sales price	72,125	59,000	128,377
SM option value	8,209	6,161	6,572
BS option value	346	0.006	1,323
Residual value	-44,138	-44,979	18,711

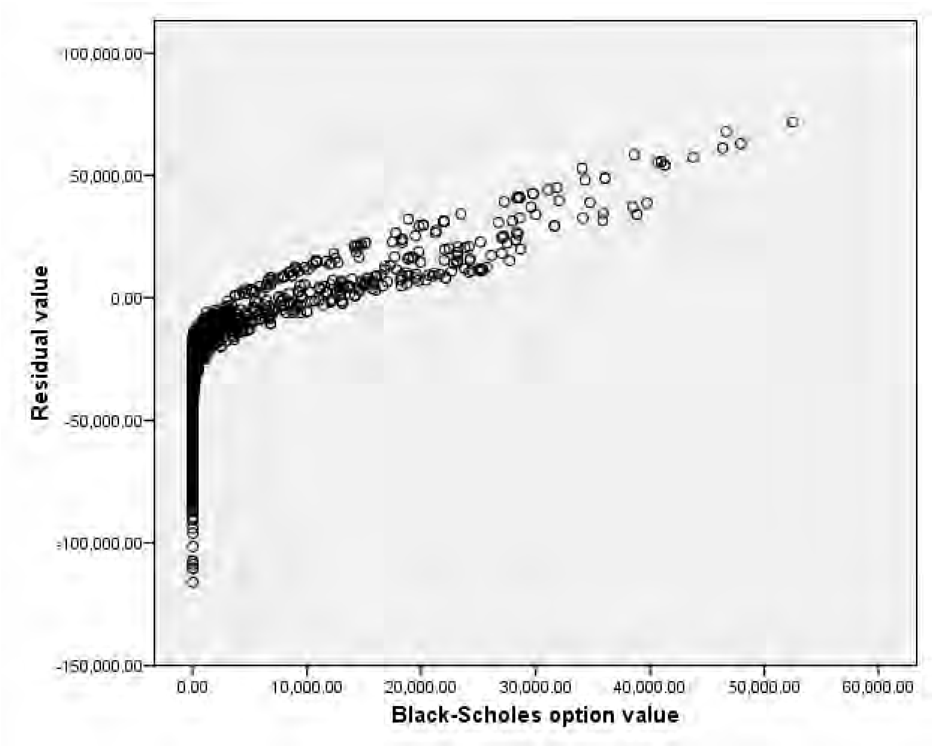

Figure 4 Relationship between residual value and Black-Scholes option value

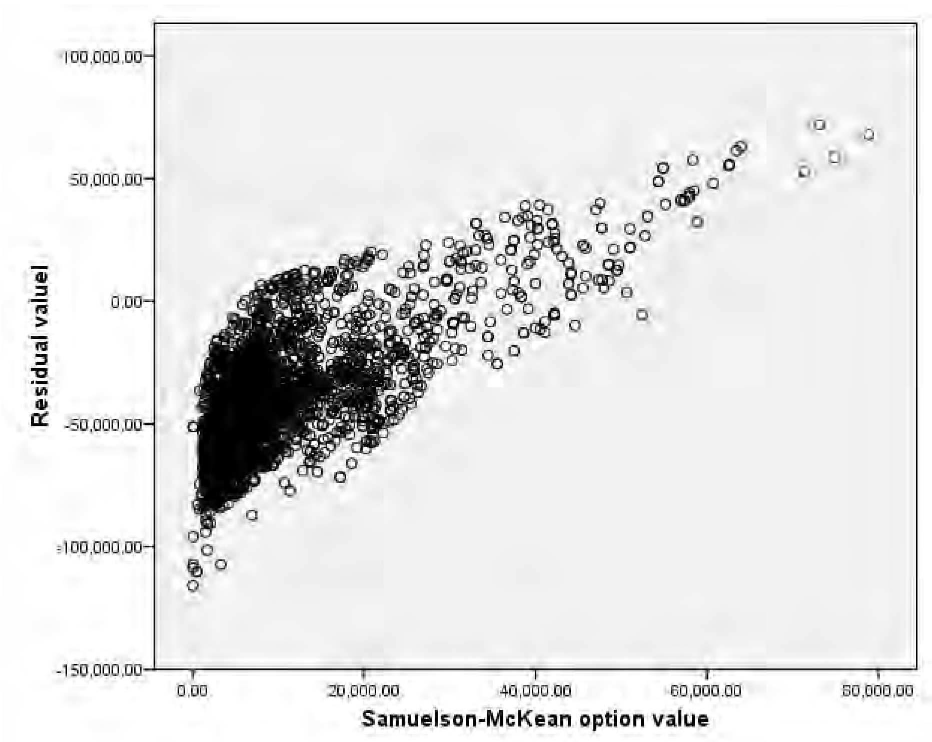

Figure 5 Relationship between residual value and Samuelson-McKean option value

Table 11 **Estimation results – plots for which development was optimal**

Variable	Model 1		Model 2		Model 3	
Constant	14.776	***	14.569	***	14.777	***
y1996	-0.283	**	-0.212		-0.278	**
y1997	-0.347	***	-0.145		-0.33	***
y1998	-0.215		0.037		-0.2	
y1999	-0.16		0.066		-0.141	
y2000	-0.133		0.122		-0.107	
y2001	-0.042		0.19		-0.023	
y2002	-0.068		0.141		-0.049	
y2003	0.148		0.335	***	0.16	
y2004	0.219		0.264	**	0.213	
y2005	0.538	***	0.538	***	0.528	***
y2006	0.864	***	0.759	***	0.842	***
y2007	0.864	***	0.467	**	0.831	***
y2008	1.279	***	0.715		1.218	***
Armadale / Serpentine	-0.646	***	-0.613	***	-0.647	***
Bassendean / Bayswater	0.288		0.275		0.29	
Belmont	0.209		0.195		0.215	
Canning	-0.032		-0.048		-0.035	
Cockburn	-0.312	***	-0.322	***	-0.315	***
Fremantle	0.566	***	0.61	***	0.576	***
Gosnells	-0.444	***	-0.412	**	-0.443	***
Hills	-0.272		-0.268		-0.273	
Joondalup North	-0.056		-0.047		-0.054	
Joondalup South	-0.027		-0.099		-0.027	
Melville	0.471	***	0.502	***	0.475	***
Rockingham	-0.411	***	-0.4	***	-0.411	***

Variable	Model 1		Model 2		Model 3	
South Perth / Victoria Park	0.366	***	0.357	***	0.368	***
Stirling East	0.307	**	0.302	**	0.31	**
Stirling West	0.595	***	0.612	***	0.6	***
Swan	-0.283	**	-0.277	**	-0.284	**
Vincent / Stirling SE	0.552	***	0.517	***	0.568	***
Wanneroo North East	-0.251		-0.229		-0.251	
Wanneroo North West	-0.271	***	-0.27	***	-0.271	***
Wanneroo South	-0.145		-0.172		-0.144	
Western Suburbs	0.822	***	0.87	***	0.838	***
BS option value p/ha	0.001	***				
SM option value p/ha			0.003	***		
RV p/ha					0.001	***
Adjusted R Square	0.53		0.52		0.527	
Std. Error	0.526		0.531		0.527	
F statistic	19.266	***	18.583	***	19.079	***
N	567		567		567	

Table 12 Estimation results – plots for which development was not optimal but residual value is positive

Variable	Model 1		Model 2		Model 3	
Constant	13.674	***	13.448	***	13.828	***
y1996	0.237		0.242		0.27	
y1997	0.157		0.474	***	0.316	**
y1998	0.406	**	0.796	***	0.569	***
y1999	0.066		0.488	**	0.229	
y2000	-0.063		0.324		0.099	
y2001	0.167		0.492	***	0.263	
y2002	0.326		0.62	***	0.412	**
y2003	0.518	***	0.724	***	0.579	***
y2004	0.914	***	0.712	***	0.86	***
y2005	0.938	***	0.603	***	0.833	***
y2006	0.91	***	0.29	**	0.828	***
y2007	0.62	***	-0.198		0.539	**
Armadale / Serpentine	-0.115		-0.096		-0.136	
Bassendean / Bayswater	0.543	***	0.43	***	0.639	***
Belmont	0.386	**	0.316	**	0.432	***
Canning	0.791	***	0.693	***	0.901	***
Cockburn	0.016		-0.021		0.023	
Fremantle	0.518	**	0.451	**	0.566	**
Gosnells	-0.022		-0.128		-0.014	
Hills	0.145		0.16		0.149	
Joondalup North	0.253		0.223		0.231	
Melville	0.771	**	0.79	**	0.912	***
Rockingham	0.006		-0.02		0.017	
South Perth / Victoria Park	0.603	***	0.546	***	0.703	***
Stirling East	0.369	**	0.351	**	0.403	**

Variable	Model 1		Model 2		Model 3	
Stirling West	0.38		0.385		0.579	
Swan	0.1		0.061		0.07	
Vincent / Stirling SE	0.484		0.254		0.486	
Wanneroo North East	0.009		0.05		0.005	
Wanneroo North West	0.231		0.173		0.283	**
Wanneroo South	0.152		0.073		0.176	
Western Suburbs	0.743	***	0.722	***	0.816	***
BS option value pha	0.01	***				
SM option value pha			0.012	***		
RV pha					0.006	***
Adjusted R Square	0.548		0.572		0.489	
Std. Error	0.407		0.396		0.433	
F statistic	9.393	***	10.22	***	7.604	***
N	228					

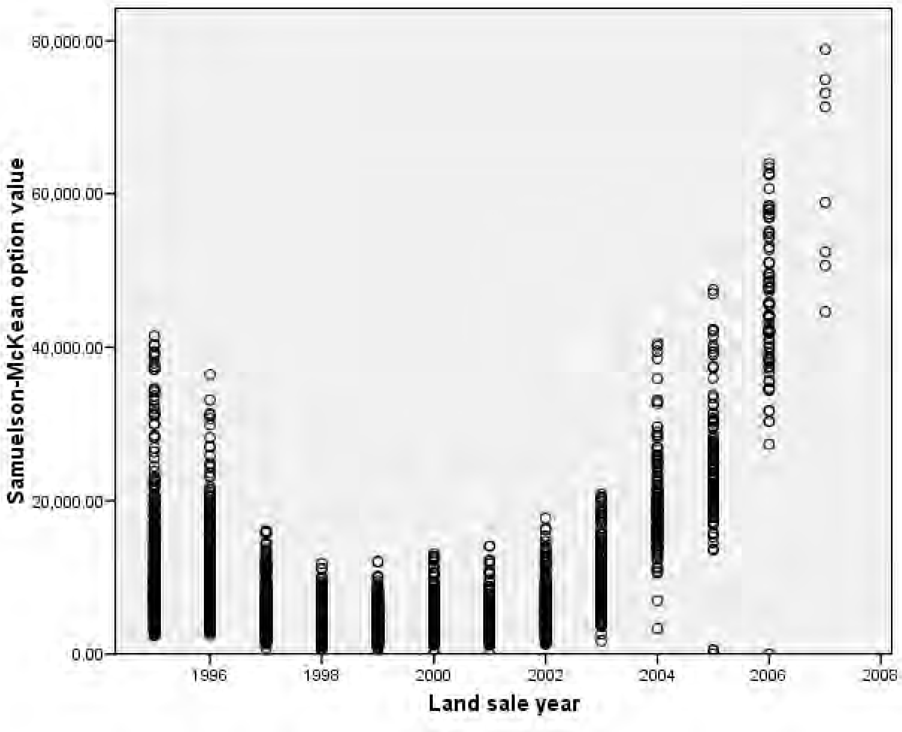

Figure 6 **Predictions of the Samuelson-McKean option pricing model over time**

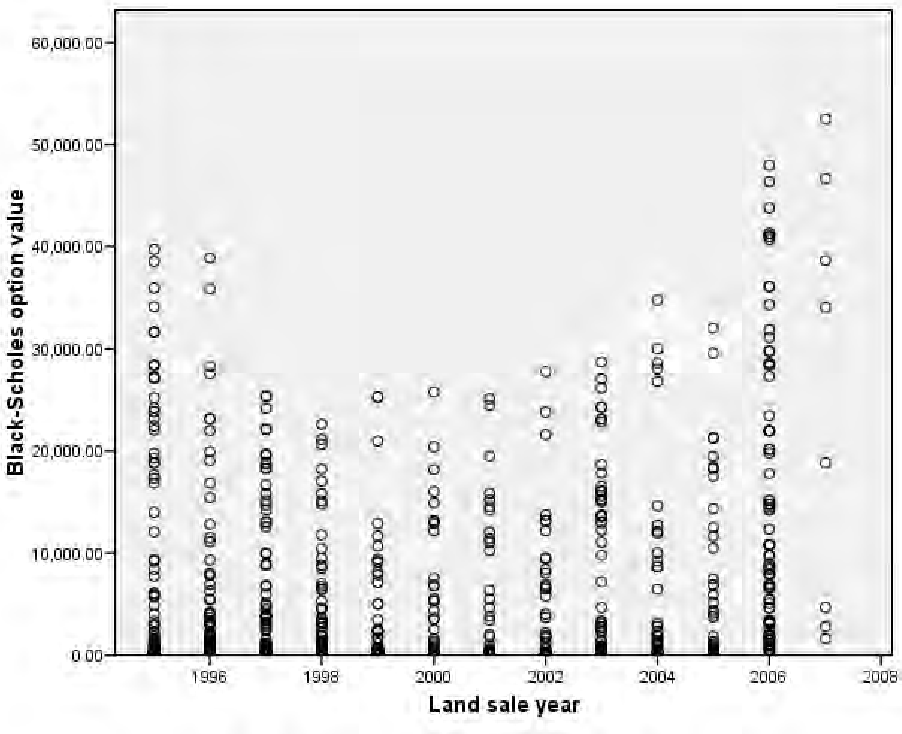

Figure 7 **Predictions of the Black-Scholes option pricing model over time**

Table 13 **Estimation results – plots for which development was not optimal and residual value is negative**

Variable	Model 1		Model 2		Model 3	
Constant	13.143	***	12.687	***	13.209	***
y1996	0.143	***	0.154	***	0.15	***
y1997	0.088	**	0.393	***	0.1	***
y1998	0.125	***	0.492	***	0.131	***
y1999	0.138	***	0.518	***	0.147	***
y2000	0.178	***	0.485	***	0.205	***
y2001	0.273	***	0.592	***	0.293	***
y2002	0.377	***	0.576	***	0.409	***
y2003	0.781	***	0.767	***	0.796	***
y2004	1.011	***	0.347	***	1.017	***
y2005	1.255	***	0.324	***	1.261	***
y2006	1.054	***	-0.775	***	1.134	***
y2007	1.372	***	-1.179	***	1.462	***
Armadale / Serpentine	-0.394	***	-0.226	***	-0.4	***
Bassendean / Bayswater	1.038	***	0.685	***	1.096	***
Belmont	1.011	***	0.604	***	1.066	***
Canning	0.837	***	0.601	***	0.864	***
Cockburn	0.604	***	0.428	***	0.634	***
Fremantle	1.705	***	1.013	***	1.972	***
Gosnells	0.38	***	0.319	***	0.382	***
Hills	0.312	***	0.243	***	0.299	***
Joondalup North	0.759	***	0.475	***	0.792	***
Joondalup South	1.042	***	0.682	***	1.087	***
Melville	0.86	***	0.61	***	0.946	***
Rockingham	0.145	***	0.143	***	0.154	***

Variable	Model 1		Model 2		Model 3	
South Perth / Victoria Park	1.226	***	0.769	***	1.304	***
Stirling East	0.798	***	0.545	***	0.862	***
Stirling West	1.215	***	0.82	***	1.377	***
Swan	0.518	***	0.38	***	0.536	***
Vincent / Stirling SE	1.601	***	1.085	***	1.803	***
Wanneroo North East	0.452	***	0.376	***	0.445	***
Wanneroo North West	0.292	***	0.196	***	0.298	***
Wanneroo South	0.615	***	0.449	***	0.618	***
Western Suburbs	1.731	***	1.018	***	1.968	***
BS option value pha	0.032	***				
SM option value pha			0.033	***		
RV pha					0.001	***
Adjusted R Square	0.534		0.64		0.517	
Std. Error	0.465		0.409		0.473	
F statistic	92.27	***	142.561	***	86.194	***
N	2710					