**The Option in Auto Leases**

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**Abstract**

**The Option in Auto Leases**

This paper outlines the structure of a standard auto lease contract, and identifies the call option within the lease contract. I then explore a method which allows for the exercise of the option. To value the option sold in an auto lease I bound the option price below by valuing the option as a European call, and above by valuing the option as an American call. I note why the true value of the option should be between the European and American call values. Finding the option value assists in the lease or buy decision. The lessee should lease if the lease option value is greater than the rent charge. In the case of the lessor, I show how to find the threshold rent factor. This rent factor is invaluable for risk management in auto finance companies.

*Keywords:* Leasing, Real options.

*JEL Codes:* G12, G21, G32

**INTRODUCTION**

The purpose of this paper is to value the call option sold when an auto finance company leases a car to a consumer, and to use this value to gain insight into the lease or buy question. There are particular aspects of an auto lease which leave previous research on leasing, and the valuing of the option in leasing contracts, inapplicable. Namely, when a consumer agrees to lease a car they agree to pay a certain fixed amount of money to the auto finance company. That is, there is no possibility of cancelling the lease once signed. This means a compound option approach, such as McConnell and Schallheim (1983), may not be applied.

In order to value the call option sold in auto leases we must first look at how such a lease is structured, and so we will investigate a standard auto lease contract. From there we will show how one can value the call option as a European call. We then show it is possible that the lease option may be exercised before the end of the lease. This latter point requires that we value the option as an American call. To do this we use the binomial method for valuing an American call option. The value of the European and American call options will form a lower and upper bound for the true value of the lease option.

The goal of valuing the option in an auto lease is not purely academic. Presently, few auto companies, if any, consider the value of the option sold within their leases. Accordingly, these companies are more vulnerable to residual losses on the automobiles returned at the end of the lease. This was a significant problem as the United States went into a brief recession in late 2001. Residual losses during this period struck all in the auto leasing business, and were the catalyst for the reduction in auto lease offers through 2004. Proper valuation of the option in auto leases will help the management of cash reserves in auto finance companies.

Finding the value of the option sold in a lease will give us insight into the lease or buy question by identifying particular circumstances where leasing is preferable to buying. Though, the option price will also give the lessor a lower bound for the price of the lease, helping to ensure that leases are not priced too favorably toward the lessee at the expense of the lessor.

As a further note before we begin the description of the auto lease, much of the prior research on financial leases deals with the tax implication to the lessee. In leasing, the lessee gives up the tax shield afforded by the interest payments on the debt required to purchase the asset. We will not consider how the auto lease affects the personal taxes of the lessee.

This paper builds on previous research which applied real-options valuation to financial leases. McConnell and Schallheim (1983) used a compound options approach to value various financial leases. Grenadier (1995) derived a term structure of lease rates using real-options methodology. This term structure was then applied to valuing leases to renew or cancel, adjustable rate leases, leases dependent on asset usage, among other types of leases. Finally, Giaccotto, Goldberg, and Hegde (2007) used a real-options approach to value the cancellation and lease-end purchase options in automobile lease contracts. They conclude the early cancellation option has little value, though the lease-end purchase option is on average 16% of the value of the underlying used vehicle. Since the authors considered exercise of the option only at the end of the lease, they were able to use the Black-Scholes European option value of the lease. The present paper builds on this by considering early exercise of the option, which is standard in vehicle lease contracts.

**THE AUTO LEASE**

In this section we will lay out the structure of the auto lease. Leases may be slightly different from one company to the next, however, they generally will not differ enough to invalidate the following valuation methods. The described lease is a lease contract from World Omni Financial Corporation, which originates loans and leases on behalf of Southeast Toyota Finance. Lease terms, and the calculation of the monthly payment, is also summarized in tables 1 and 2 below.

[INSERT TABLE 1 HERE]

The calculation of monthly payments starts with the Gross Capitalized Cost, which is the agreed upon value of the automobile plus any of the following items: Taxes; Initial Title, License, and Registration fees; Maintenance Agreement; Life or Disability Insurance; Outstanding Credit or Lease Balance; Acquisition fee. Deducted from the Gross Capitalized Cost is the Capitalized Cost Reduction which is the sum of any net trade-in allowance, rebate, noncash credit, or cash paid by the lessee to lower the Gross Capitalized Cost. The difference of the aforementioned is the Adjusted Capitalized Cost which is the amount used to calculate the Base Monthly Payment. Deducted from the Adjusted Capitalized Cost is the Residual Value. The Residual Value is the amount for which the lessee can purchase the vehicle at the end of the lease. This value is an estimate of the value of the vehicle in the month and year in which the lease ends and is generally bought from a service such as Automotive Lease Guide (ALG). The difference of the Adjusted Capitalized Cost and the Residual Value is the Depreciation and any Amortized Amounts. Added to this is a Rent Charge. The sum of the Depreciation and the Rent Charge is divided by the number of lease payments to arrive at the Base Monthly Payment. Added to the Base Monthly Payment is the Monthly Sales and Use Tax to arrive at the Monthly Payment that the lessee will pay. There are also penalties for excessive wear and tear that we will not consider.

[INSERT TABLE 2 HERE]

Once the lease is signed the lessee is obligated to pay a specific amount to the lessor. The lease can be ended prior to scheduled end of the lease in either of two ways. The lessee can elect to terminate the lease by returning or purchasing the vehicle. If the lessee chooses to purchase the vehicle the lessee must pay the sum of any due monthly payments, any applicable fees or taxes, any amounts necessary to meet legal selling requirements, and the Adjusted Lease Balance.

The adjusted lease balance is defined as the sum of the Base Monthly Payments not yet due and the Residual Value, minus the unearned Rent Charge. That is to say, the Adjusted Lease Balance is the Residual Value plus the Monthly Payments less the monthly sales and use tax, and also less the Rent Charge. Note that the contract specifies that the present values of the amounts are not to be paid, but rather the undiscounted values. In the following we will not consider legal selling costs and other fees not applicable in all cases are they are undetermined, though if average amounts of these fees are known they can be incorporated in the following valuations by simply raising the purchase price by an appropriate amount.

So, the purchase price of the car to the lessee at time t, in a lease with 1,2,….T monthly payments is:

P(t) = RV + nBMP – RCδ[t,T]  (1)

where P is the purchase price

RV is the residual value

BMP is the base monthly payment

n is the number of remaining lease payments

δ[t,T] is the percent of the lease remaining from t to T, [ (T-t)/T ], where *t* is defined on the natural numbers, and 0 ≤ *t* ≤ T.

RC is the Total Rent Charge

We want to show that P(t) is a decreasing function of t, or rather that P(t) > P(t+1) which is equivalent to showing that:

RV + nBMP - RCδ[t,T]  > RV + (n-1)BMP – RCδ[t+1,T]

**=>** nBMP - RCδ[t,T]  > (n-1)BMP – RCδ[t+1,T]

**=>** RCδ[t,T]  < BMP - RCδ[t+1,T]

=> BMP > RCδ[t,T]  - RCδ[t+1,T]  = RCδ[t,t+1]

So if we know BMP > RCδ[t,t+1]  then we know that P(t) > P(t+1). Using that

δ[t,t+1]  ≡ 1/T and letting SBMP be the sum of all base monthly payments so that BMP = SBMP(1/T) we have:

BMP = SBMP(1/T) > RC(1/T) => SBMP > RC

which we know to be true as RC is a component of SBMP.

Therefore we know P(t) > P(t+1). Further, P(t) is linear, so the price at which the lessee can purchase the car decreases at a constant rate. To show that P(t) is linear consider:

∆P = P(t+1) – P(t) = RV + (n-1)BMP - RCδ[t+1,T]  - RV – nBMP + RCδ[t,T]

= RC(1/T) – BMP < 0 and constant for all t. (2)

So P(t) is decreasing and linear. Moreover, you may note that RC(1/T) – BMP is the slope of the line. Below the P(t) line is graphed for a lease on a vehicle with a selling price of $30,000, an estimated residual value of $10,000,a rent charge of $5,000, which implies a base monthly payment of $520.84. This line is the strike price of the option at time t.

[INSERT FIGURE 1 HERE]

The dynamics of P(t) are of the utmost importance as throughout the paper the function P(t) is the strike price of the call option. Therefore, when the lease is signed we must know the function P(t) for all t.

**EXERCISING THE OPTION**

Call options, for which there is a market where these options may be freely traded, will never be exercised before expiration. This is because the option price must be greater than the value of the underlying asset minus the strike price of the option. Informally, this is due to the time value of money and the downside insurance offered by an option as can be seen in put-call parity. The aforementioned of course does not apply to options on dividend paying stocks.

However, a great many types of options do not have a market in which they can be traded. For example, options granted by corporations to their employees may not be sold, and the employee must exercise the option to realize any gain. The option surely has value, or rather a measurable expected cost to the corporation, though not the value afforded by the many famous option pricing models.

Similarly, there is no market in which to sell the American call option embedded in a vehicle lease contract. For the option’s value to be realized the lessee must exercise the option. Some may be skeptical about the option in the auto lease being exercised for reasons such as the lessee’s lack of information as to the price for which she may sell the vehicle, and large transaction costs, among other reasons. Yet, the option exists and has been exercised.

A possible avenue toward exercising the option that solves many problems associated with such a transaction is the common trade-in. A trade-in is defined as the transferring of ownership of one’s present vehicle to lower the price of another vehicle or vehicle lease by an agreed upon amount. In short, one sells their vehicle to the dealership for a price, with the condition that the proceeds of the sale are spent at the dealership.

This transaction actually solves the problem of the lack of a well-functioning market for the asset underlying the option. There are auctions for used vehicles that serve each area of the United States. So, a car dealer in Florida may send vehicles to the south-east auto auction. Further, the outcomes of these auctions are recorded and distributed to anyone for a fee. As such, at any time a car dealer will be able to value a vehicle. Through the car dealership, the lessee may at any time access the market for the underlying asset.

Though, would the car dealership offer the lessee a trade-in value that is an unbiased estimate of the value which would be receives at the auction? Certainly, the most obvious reason being the competitiveness of the auto industry. If one car dealer offered a price that was too low the dealer across the street would have an incentive to offer a more appropriate price. This is particularly true insofar as a great deal of a car dealerships revenue is from finance and insurance as well as maintenance fees. Therefore a car dealer who on average receives $1,000 in finance and insurance per vehicle would gladly offer $600 over the price for which the vehicle may sell at auction, netting the dealership $400.

The possibility of trading-in the vehicle offers the lessee an unbiased estimate of the value of their vehicle, and a way to realize that value with minimal transactions costs. This assumes that they wish to have a vehicle, which only negates this possibility for the percentage of the population who will be retiring from driving.

So, we have established that, similar to many other options, the American call option in an auto lease must be exercised in order for the lessee to receive the value of the option. Further, we have shown that there exists a market for the lessee’s vehicle and the lessee has access to the information on prices in that market (for a small fee or from shopping their vehicle around at a few dealerships) and also the lessee can sell the car for the price stated in that market. As most dealerships handle trade-ins, the value gained by selling the vehicle can be used to purchase most types of vehicles.

**A METHOD OF VALUING THE OPTION**

In this section we will be considering an auto lease with the following characteristics. The length of the lease will be one year, the selling price of the vehicle at the signing of the lease will be $30,000, the estimated residual value of the vehicle at the end of the year (termination of the lease) will be $20,000, both the volatility of the estimate of the residual value and the volatility of the price of the leased vehicle in the auto auction (the price for which the vehicle may be traded-in) is 0.2, and the continuously compounded risk-free interest rate is 0.05. The rent charge for the term of the lease is $2,500, which implies a monthly rent charge of $208.33. The total depreciation of the vehicle over the lease term is $10,000, which implies a monthly depreciation of $833.33. The sum of the monthly rent charge and the monthly depreciation gives us our base monthly payment of $1,041.67.

**THE VALUE AS A EUROPEAN CALL**

To begin our valuation of the call option sold within an auto lease, we will consider the call as of the European type. We know that if the only difference between two call options is that one is European and the other American, then the American call option will always have a higher price. This is because within the American call option is a European option. So, with owning an American call you own a European call plus the opportunity to exercise before expiration.

Finding the value of a European call option sold within an auto lease will give us a lower bound for the value of the American call option. To set up the option as of the European type we will take So as the time 0 (when the lease is signed) estimate of the vehicles residual value. We will denote X as the strike price, r the continuously compounded interest rate, σ is the volatility of the estimate of the residual value, and T is the time to maturity of the option.

In the option we are valuing we have that So is equal to X, that is, the time 0 estimate of residual value is used as the actual residual value in the lease contract. The only weakness in this formulation of the option is σ. In the Black and Scholes pricing formula for a European call option the variance is assumed to be constant. However, the variance of the expectations of the vehicles residual value will decrease with time. This may lead the option to be valued slightly higher than would be if the variance is constant. Of course, we can simply adjust the variance downward toward the mean variance over the period or by some factor found empirically. Further, there are methods that can be employed to deal with a non-constant variance. In other words, the problem is surmountable and will not affect the conclusions of the present paper. Moreover, most securities suffer from a non-constant variance.

To value the European call we will use the Black-Scholes formula:

C(0) = SoN(d1) – Xe-rTN(d2) (3)

where C(t) is the value of the call option at time t, N(.) is the cumulative normal distribution function (for a normally distributed random variable with a mean of 0 and a variance of 1). The values of d1 and d2 are defined as:

d1 = [ln(So/X) + (r + (σ2/2))T] / σ(T)0.5

and

d2 = d1 - σ(T)0.5.

For the lease we are considering the Black-Scholes formula gives the value for the option sold within the lease at time 0 as:

C(0) = $2,090.12.

This establishes a lower bound for the value of the actual American option.

**THE VALUE AS AN AMERICAN CALL (BINOMIAL METHOD)**

To show that we may value the lease as an American call option, and to serve as a first upper boundary for the option, we will value the option using the binomial method introduced by Cox, Ross, and Rubinstein (1979)1. The binomial method allows for the option to be exercised on fixed dates defined in the option contract. In the case of the auto lease, the option is exercisable on any monthly payment date. The terms of the lease are the same as in the European call calculation, though there are differences in the interpretations of the volatility, strike price, and the underlying security.

In this example there will be two chances to exercise the option before expiration, so we have times t = 0,1,2,3. The length of the lease, as above, is one year and so Δt = 1/3 years.

A major difference between the European and American options is how we define the underlying security and the strike price. The strike price is defined by the equation for the value at which the lessee can purchase the vehicle:

P(t) = RV + nBMP – RCδ[t,T]. (4)

So, we have a deterministic function for our strike price that relies on the value of t. Of course, we must make sure that the values of the vehicle St also takes into account the depreciation of the vehicle that is included in P(t). The way in which this done will be illustrated in the following example, and for now we may note that the price process is a binomial tree centered on a negatively sloped P(t). Further, we have So = P(0).

As mentioned earlier, the volatility parameter σ is here the actual volatility of the vehicle’s selling price as calculated from auction results. Similar to an option on a stock, σ may be the annualized historical standard deviation of the auction price of the particular make and model of automobile. In this case σ = 0.2. Note, here we suffer less from a non-constant variance.

It is important to note here that we are valuing the same lease, and the only difference between the American and European call, along with the methodology of the calculation, is how we interpret various parameters. As such, the selling price ($30,000), residual value ($20,000), rent charge ($2,500), base monthly payment ($1,041.67), term (1 year), volatility (0.2), and risk-free interest rate (0.05) are all the same. So, with the new interpretations of the parameters, if we assumed that there only existed t = 0,1, we would get the same value for the option as in the European case.

The first step in the binomial valuation of the American call option is to calculate the strike price P(t) for t = 0,1,2,3. We know that So = P(0) = $30,000. For t = 1,2 we have:

P(1) = $20,000 + 8\*1041.67 – 2500\*(2/3) = $26,666.67

P(2) = $20,000 + 4\*1041.67 – 2500\*(1/3) = $23,333.33.

We know that P(3) = $20,000 which is the residual value. We can easily see that between each chance to exercise the option the value of the strike price decreases by $3,333.33.

The next step in the option valuation is to calculate the binomial tree with an initial price, S0 = $30,000, and our parameters of r = 0.05, σ = 0.2, Δt = 1/3, under a risk-neutral probability distribution. Doing so we find that the probability of an up move is p = 0.6093 and the probability of a down move is accordingly 1-p = 0.3907. The magnitude of an up or down movement is 1.069 and 0.936 respectively. With this information we can calculate what we will call an unadjusted binomial tree. We need to label this tree unadjusted as it does not yet take into account for the declining strike price P(t).

To take into account that at each exercise opportunity the strike price decreases by $3,333.33 we will subtract $3,333.33 from the two t = 1 values in our binomial tree. Similarly, we will subtract 2\*($3,333.33) from the three t = 2 values in our binomial tree and further subtract 3\*($3,333.33) from the four t = 3 values. On so doing we have adjusted our binomial tree for the declining strike price.

From the adjusted tree we may value our American option using the binomial method. We start at the end of the tree when the price of the option (max(ST – P(T)), 0) is known. To calculate the T – 1 nodes, because we are dealing in a risk-neutral world, we calculate the expected value at time T of the two possible paths from the T - 1 node, and discount this value at the risk-free interest rate. We do the same for the T – 2 nodes by taking the expected value at T – 1 and discounting by the risk-free interest rate.

Because this is an American call it is not sufficient to calculate the expected value at time T – n by taking the probability weighted average of the two possible option prices at time T – (n – 1). This is because at a given node before T, it may be better to exercise the option than to hold the option to the next period. That is to say, it may be that at a node T - n:

ST-n – P(T-n) > p\*w(T-(n-1)) + (1-p)\*w(T-(n-1))

where w(t) is the value of the American call at time t. Therefore at each node less than T we find:

max(ST-n – P(T-n), p\*w(T-(n-1)) + (1-p)\*w(T-(n-1))) (5)

and use this value to calculate the price of the option at t = T – (n+1). Following this procedure we work backwards to the t = 0 price of the option.

For our example, using the same lease as we used for the calculation of the European call, we find that the t = 0 price of the American call is $2,285.18. The calculation is in the appendix. Recalling that the price of the European call was $2,090.12, we have a difference between the European and American calls of $195.06.

**BOUNDS**

We have found that the difference between the value of the American and European calls in our example is less than 10% of the value of the option2. Further, we may see that the true value of the option will tend to be strictly between the American and European values. Trivially the true value of the option is above the value of the European call as the lease option is a European call plus the opportunity to exercise prior to the term of the lease.

Experience will show that the true value of the option is less than that calculated by the American call because of the manner in which the price of a vehicle will drop significantly just after the purchase as the vehicle goes from new to used and will drop more slowly thereafter. In other words the path of the price from the selling price to the residual value will be concave upward. Therefore we will know from experience that we will not be able to exercise the option for a positive value shortly after signing the lease and that in practice the probability of exercising for a positive return will increase toward the end of the lease. This will tend to make the option less desirable and put the value less than the American call.

Thus far we have bounded the option sold in an auto lease between the value of a European and American call and shown how the lease may be calculated in each case. Moreover, we have shown with an example that the bounds are not so far apart as to render the analysis moot.

**VALUATION OF 3-YEAR LEASE OPTION**

While a 1 year lease with 2 exercise dates prior to expiration is a useful heuristic approach, we are ultimately interested in the valuation of actual auto leases. To this end consider a 3-year lease with exercise allowed every month. The selling price will remain $30,000, but set the residual value to $10,000 to reflect the additional 2 years of use. Further let the yearly volatility and risk-free rate remain at 0.2 and 0.05 respectively.

Valuing the above option as an American using a binomial tree affords a value of $4,180. Valuing the 3-year lease as a European gives a $2092 option value, which means the American is now approximately twice the European value. The marked increase of the American option with respect to the European shows the effect of the additional exercise possibilities. Note, however, lease holders are unlikely to consider exercising the option monthly, and any reduction in the number of exercise dates will cause the American Value to approach the European.

The volatility parameter also has a large effect on the ratio of American to European call option values. Dropping yearly volatility to 10% causes the ratio of American to European values to rise to 2.67. Alternatively raising the value to 0.3, 0.4, and 0.5 causes the ratio to fall to 1.57, 1.31, and 1.16 respectively. Clearly, our bounds on the value of a lease call option are better for vehicles with high residual value volatility.

**LEASE OPTION VALUE AND RENT CHARGE**

In the function P(t), an increase in the rent charge will also increase the base monthly payment, and since the base monthly payment is added and rent charge subtracted, the changes offset each other leaving P(t) unchanged. In short, changing the rent charge (or rent factor) has no effect on P(t). Further, changing the rent charge has no affect on the price of the option.

Therefore, when we find the price for the lease option we are also finding a threshold rent factor. A lessor would not want to lease a vehicle under a contract in which the option value exceeded the rent charge. In our example, using the value of the American call, we see that the lessor would not charge a rent factor less than 0.2285. If the lessor were to do so the value of what the lessor is selling (the sum of depreciation and the lease option value) would be worth more than what the lessor received (the sum of depreciation and the rent charge).

Of course, the lessee would prefer as low a rent charge as possible. Given that the lessee knows the rent factor and depreciation amount at the time of signing the lease contract, using the option value the lessee can know the difference between the option value and the rent charge and can search for as small a difference as possible.

Comparing the rent charge with the lease option value would give a clear answer to the lease or buy question in the situation where the option value is greater than the rent charge. Without considering tax implications, one should lease if the option value is greater than the rent charge. If the rent charge is more than the option value, one must look to other factors for guidance.

**CONCLUSION**

In this paper we have considered the structure of a standard auto lease contract, and have identified the call option within the lease contract. We have shown that the call option may be exercised by the lessee before the end of the lease as a lessee can reach the secondary vehicle market by trading in the vehicle. To find the value of the option sold in the lease contract we first valued the option as a European call in order to find a lower bound for the option price. Then we valued the option as an American call and noted that the true price of the lease option was between the prices of the European and American calls.

Once we know the value of the option we are in a better position to know whether to lease or to buy. Knowing the option value does not answer the lease or buy question in all cases, only when the lease option price is above the rent charge.

In the case of the lessor, we have shown how to find the threshold value for the rent factor. Knowing the threshold rent factor will be invaluable for risk management in auto finance companies. As many auto finance companies do not at present consider the value of the option that they are selling in each lease, and therefore do not know the threshold rent factor, the procedure herein could be implemented immediately. Further, given the data that auto finance companies have on the auction market for used vehicles, better Monte Carlo approaches could be used to value the option. Lastly, considering the large losses on lease portfolios in the wake of the stock market bubble in 2000 and the following years, improvements in leasing risk management are needed.

FOOTNOTES

**1**A standard introduction to binomial option pricing is in the text ‘Options Futures and Other Derivatives’ by J.C. Hull.

2I’ll show shortly that this value can vary.

APPENDIX



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Lease contract provided by:

World Omni Financial Corp., a subsidiary of Southeast Toyota Finance

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| --- | --- |
| **Table 1. Summary of Terms** | |
|  | |
| Gross Capitalized Cost | Selling price plus tax, tag, title, and other various fees. |
| Capital Cost Reduction | The sum of any trade-in value (if applicable), rebate, or down payment. |
| Adjusted Capital Cost | Gross Capitalized Cost less the Capital Cost Reduction |
| Residual Value | Estimated value of the vehicle at the end of the lease (amount for which the lessee may purchase the vehicle). |
| Depreciation/Amortization Amount | Adjusted Capitalized Cost less the Residual Value |
| Rent Charge | Represents the sum of interest and the call option value. |
| Base Monthly Payment | The sum of the Depreciation/Amortization Amount and the Rent Charge, divided by the number of monthly payments. |
| Monthly Payment | The sum of the Base Monthly Payment and various taxes. The actual monthly payment the lessee pays. |

|  |
| --- |
| **Table 2. Monthly Payment Calculation.** |
| Gross Capitalized Cost |
| -Capital Cost Reduction |
| = Adjusted Capital Cost |
| -Residual Value (RV) |
| = Depreciation/Amortization Amount |
|  |
| (Depreciation/Amortization Amount + Rent Charge (RC)) |
| ÷ Number of Monthly Payments  = Base Monthly Payment (BMP) |
| + Monthly Sales and Use Taxes |
| = Monthly Payment |

**Figure 1. Lease Option Strike Price.**

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