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Options Vs. Futures: Which on Average Will Have the Greater Payoff?

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Introduction

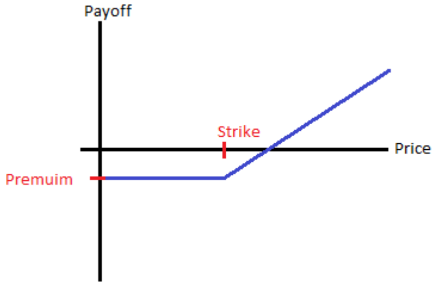
The use and idea of futures contracts has been around for almost as long as humans have existed. Many of these contracts can be as simple as the shaking of someone's hand with the agreement to trade an asset for an agreed upon price in the future. These contracts have often been used by farmers to ensure a needed price for an asset, or for a store owner to ensure a needed asset for a given price. The idea of a futures contract is to either buy or sell an asset later on at a specified price. In this paper I will look at both positions. First, wanting to buy an asset in the future is said to be long a futures contract, and to sell an asset in the future is said to be short a futures contract. The benefit of these contracts is that it gives the seller peace of mind to know that they will get paid a specified amount for an asset in the future; or the buyer will not have to pay more than the specified amount for an asset in the future. There can be disadvantages to these types of contracts as well. For example, if in the time between making the contract and the exchange of the asset the price moves in your favor, you will have lost out on the price move.

This brings up the idea of the options market. I will focus on the basic European call and put options. A European option means that the options can only be exercised at the expiration date of the options. A call option is used when one is looking to buy an asset in the future, with a desire to put a cap on the amount that will be paid for the asset. A put option is used when someone is looking to sell an asset in the future and wants to put a floor on how much will be received for the asset.

There are a couple differences between the options and futures contracts. First, with a futures contract no money is exchanged until the expiration of the contract; whereas with an options contract the person purchasing the contract will pay a fee for the contract up front, similar to an insurance premium. The second difference is with a futures contract, the agreed upon amount must be paid and received whether or not it is to your benefit; whereas with an options contract, the purchaser of the contract has the choice to look for a better price in the market, and if found, they can simply walk away from the contract. Thus, for an options contract, a premium is paid to be able to walk away from the contract.

These differences lead to different payoffs for each of the types of contracts. First, to compare the contracts that deal with purchasing an asset in the future, we will look at a call option and a long futures contract. The call option payoff formula is: payoff = Max(P_T – K, 0) – Premuim; This will yield a payoff that looks like figure one, Where P_T is the price of the asset at the end of the contract and K is the strike price. It starts negative, the amount of the premium, and continues to stay flat until it reaches the strike price then it increases upward. The long futures contract payoff formula is: payoff = P_T – K; This will yields a payoff that looks like figure two. It starts negative, the set price, and then continues upward crossing through the zero payoff line at the set price and continues up. One can see that if compared, the call option will outperform the long future contract up until a point just before the strike price and then the future contract will outperform the call option. The call option outperforms the long futures contract by more in the beginning, than the amount that the long futures contract outperforms the call option in the end. Thus the long futures contract has a lot of ground to make up to come out even or on top.

Figure one



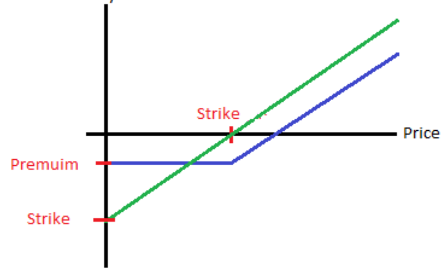
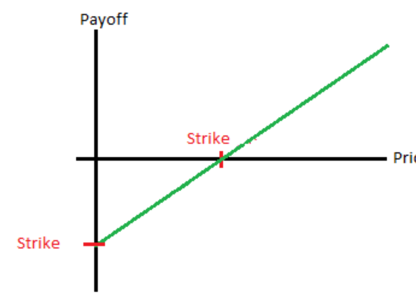
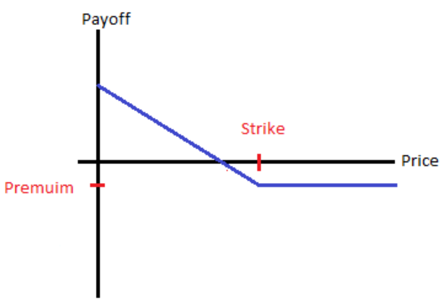


Figure two



Now, to look at the contracts that deal with selling of an asset, we look at a put option and a short futures contract. The put option payoff formula is: payoff = Max($K - P_T$, 0) – premium; this will yield a payoff that looks like figure three. It starts positive and decreases until it reaches the strike price at which it is negative, the amount of the premium, and then it continues flat. The short futures contract payoff is: payoff = $K - P_T$; this will yield a payoff that looks like figure four. It starts positive, the amount of the set price, and continues down crossing the zero payoff line at the set price and then continues to decrease. One can see that if compared, the short futures contract will outperform the put option until a point just after the strike, at which the put option will then outperform the futures contract. The put option outperforms the short futures contract by more at the end, than the short futures contract outperforms the put option at the beginning, like the call option outperformed the long futures contract.

Figure three



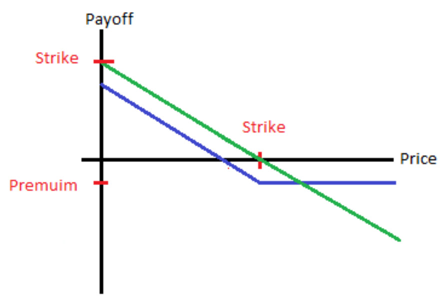
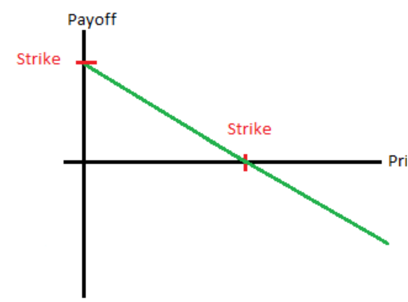


Figure four



Now that I have laid out the different payoffs of these contracts, I want to know which of these contracts on average will outperform the other. In each of the two comparisons, either of the contracts has the possibility of outperforming the other, depending upon what the final price is. Using the examples from before, if I were a farmer trying to get the most out of my harvest which of these contracts should I use? Or, if I were a store owner trying to get the needed assets for my store at the cheapest price, which of these contracts should I use?

To answer these questions, I use Monte Carlo simulation to create data. I simulate a year's worth of price changes, where price changes happen on every minute. I do this ten thousand times for each of my models. I then take the ending price and apply the payoff rule for each of the four contracts; a call option, a long future, a put option and a short future contract. I calculated the mean and the standard deviation of these payoffs to compare the difference between the contracts.

Research Design

I use four different models to simulate from. I use each of these models multiple times with different parameters to check for robustness in the results. The parameters that are needed for the models are: the initial price of the asset, which I will set at $50; the strike price of the contracts, which will also be set at $50; the volatility of the asset, which will take on the values 0.1, 0.3 and 0.5; the risk free rate, which will be set at 0.08; the dividend yield, which will be set at 0; the drift term, which will be set at 0.02; and the time will be one year. I will use the Black-Scholes-Merton model to price the option premium that will be used to calculate the option payoff. I will then compare each of the contracts in the different models to see if any conclusion can be reached as to which of these contracts has the greater payoff.

The first model I use is the Geometric Browning Motion. This is a stochastic process that is a random walk in continuous time. A process is said to follow a Geometric Browning Motion if it satisfies the stochastic differential equation $dS(t) = \mu[S(t)]dt + \sigma[S(t)]dZ(t)$. Using Itô Lemma we have the analytic solution to this stochastic differential equation and can simulate asset prices using the following formula:

$$S_t = S_0\exp[(\mu + r - \delta - (\sigma^2/2))t + \sigma^*Z(t)$$

Where S_t is the price of the asset at time t, S_0 is the initial price, μ is the drift term, r is the risk free rate, δ is the continuously compounded dividend of the asset, σ is the volatility of the price, and Z(t) is a random draw from a standard normal distribution. This model is an accurate simulation of prices, but is disadvantaged because of the assumption that volatility is constant and known.

The second model is also Geometric Browning Motion, but I add in some microstructure noise, that would come from trading, into the simulations. I do this by taking each S_t and multiplying it by $\alpha^*W(t)$ to get the final S_t. Where α is an amount of micro structure noise that can occur and W(t) is a random draw from a standard normal distribution.

The third model I use is the Heston model. This process differs from a Geometric Browning Motion because it does not assume the variance of an asset is constant, but that it follows a random process. The Heston model assumes that the price of an asset, S_t, is determined by the stochastic process $dS_t = \mu S_t dt + dZ^s(t)$ where V_t follows a process $dV_t = K(\sigma - V_t)dt + \theta\, dZ^v(t)$. We simulate from this model using the following formulas:

$$\ln(S_t) = \ln(S_0) + (\mu + r - \delta - (V_t^2/2))t + *Z^1(t)$$

$$V_t = V_{t-1} + K(\tilde{V} - V_{t-1})t + \theta\, Z^3(t)$$

Where S_t is the price of an asset at time t, S_0 is the initial price of the asset, μ is the drift of the price, r is the risk free rate, δ is the continuously compounded dividend, σ is the long run variance, K is the rate at which V_t reverts to $\tilde{V}$, $\tilde{V}$ is the mean variance, θ is the volatility of the volatility, $Z^1(t)$ and $Z^2(t)$ are random draws from a standard normal distribution, and $Z^3(t) = \rho Z^1(t) + Z^2(t)$ because $Z^1(t)$ and $Z^3(t)$ have correlation of ρ.

The fourth model is also a Heston model, but again I add in microstructure noise into the simulations. This is done in the same way as before to get our final S_t by multiplying our S_t's from the simulations by α*W(t).

Results

First to look at the results from when I have volatility set at 0.3 (figure five). On average in every model, except the Heston model without microstructure noise, the call option outperforms the long futures contract. The reason the call option doesn't outperform the futures contract in the Heston model, could be from the fact that the Black-Scholes-Merton model overvalue options with stochastic volatility; as shown by Hull and White in "The Pricing of Options on Assets with Stochastic Volatilities." Also I noticed that the standard deviation is smaller on the call option, which is not surprising because it has a bottom on the amount it can lose. The call option outperforms the long futures contract by anywhere from fifty cents to almost four dollars in these cases. Hypothetically, if this was scaled up for a small company that needed a thousand of an asset to use throughout the year this would be somewhere between five hundred dollars to four thousand dollars. That would be a significant amount to a small company. Also in every model, except the Heston model without microstructure noise, the put option outperforms the short futures contract. And again, not surprisingly, the put option has a smaller standard deviation. The put option outperforms the short futures contract by around a dollar every time. Again, this would be a significant amount for a farmer or a small company making this contract for a thousand of an asset.

Figure Five

σ = 0.3	Geometric Browning Motion			GBM W/ Microstructure			Heston Model			Heston W/ Microstructure	
	Mean Payoff	Standard Deviation		Mean payoff	Standard Deviation		Mean Payoff	Standard Deviation		Mean Payoff	Standard Deviation
Call Option	1.823	13.386		1.533	12.900		-4.218	6.033		1.976	17.006
Long Futures Contract	1.397	17.007		0.914	16.772		-1.234	9.963		-2.018	22.760
Put Option	0.115	6.081		0.299	6.330		0.891	5.623		3.875	9.299
Short Futures Contract	-1.397	17.007		-0.914	16.772		1.234	9.962		2.018	22.760

Next, looking at the results from when I raise the volatility to 0.5 (figure six). With a higher volatility, the cost of the options' premiums is going to increase. This could offset its ability to outperform the futures contract, but there are similar results to the first time. The call option is outperforming the long futures contract except in the Heston model without microstructure. This could again be from the Black-Scholes-Merton model overvaluing options with stochastic volatility. The put option outperforms the short futures contract in all the models except the Heston model with microstructure noise. Thus the options still seem to, on average, outperform the futures contracts even with the higher premium cost.

Figure six

σ = 0.5	Geometric Browning Motion			GBM W/ Microstructure			Heston Model			Heston W/ Microstructure	
	Mean Payoff	Standard Deviation		Mean payoff	Standard Deviation		Mean Payoff	Standard Deviation		Mean Payoff	Standard Deviation
Call Option	2.865	23.179		2.392	22.825		-7.000	6.081		-0.931	17.212
Long Futures Contract	1.277	29.094		0.573	28.841		-1.471	10.181		-2.369	23.019
Put Option	1.268	10.091		1.501	10.256		1.684	5.799		1.118	9.408
Short Futures Contract	-1.277	29.094		-0.573	28.841		1.471	10.181		2.369	23.019

Finally, to look at the results from when the volatility is reduced to 0.1 (figure seven). With the decreased volatility, the premiums for the options will be reduced, but so will the movement away from the strike price. These results are even more in favor of the options over the futures contracts. The call option outperforms the long futures contract, but the difference is only about twenty cents in this case. Twenty cents on a thousand assets or even hundreds of thousands of assets is a lot of money that could be made. The put option outperforms the short futures contract by over a dollar in every model.

Figure seven

σ = 0.1	Geometric Browning Motion			GBM W/ Microstructure			Heston Model			Heston W/ Microstructure	
	Mean Payoff	Standard Deviation		Mean payoff	Standard Deviation		Mean Payoff	Standard Deviation		Mean Payoff	Standard Deviation
Call Option	1.312	4.897		1.315	4.915		-1.134	5.769		4.895	17.015
Long Futures Contract	1.134	5.528		1.153	5.132		-1.245	9.650		-2.341	22.670
Put Option	-0.140	1.284		-0.158	1.232		3.956	5.500		6.916	9.223
Short Futures Contract	-1.134	5.528		-1.153	5.132		1.245	9.650		2.341	22.670

Conclusion

Options and futures contracts have been used to ensure a price of an asset for many years. They both can be used to ensure the price to be paid for the asset, or for the price to be received for an asset. They each have a different type of payoff which makes it possible to lose or win at the end of the contract. No one can know which one of these contracts will give the best result in any given time period, but one can look to see which does the best on average. The results in this paper lead to the idea that, on average, options will outperform futures contracts. This is robust over different starting volatilities, from large 0.5 to small 0.1. This suggests those companies, farmers, or anyone that is looking to set a price for an asset they are going to buy or sell in the future should look to the options market rather than the futures market.

Another benefit exclusive to options is to set a price that is far away from the current spot rate. Say a farmer doesn't care if the price of his commodity changes a little bit, but he won't be able to survive if the price drops below a certain level. He can buy a put option that has a strike at that level, and because it is a lot lower than the current spot rate it will not cost very much. Therefore, the farmer is protected against an extreme price drop. The reverse can also be done with a call option and an extreme price increase on an asset one needs to buy.

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