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How Does "Cost Risk" Influence Producers' Decision to Hedge?

By
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Several studies have investigated transaction costs in futures trading and found that optimal hedge ratios tend to be smaller in their presence. However, those studies consider transaction costs deterministically, i.e. hedgers know the exact amount of transaction costs when the hedge is placed. The current research relies on the notion that some transaction costs are uncertain when the producer decides to place a hedge. The uncertainty originates from the fact that some costs, such as margin deposits and taxation, depend on the trajectory of futures prices during the hedging period. The objective of the paper is to investigate how the uncertainty associated with transactions costs can influence producers’ decision to hedge. In addition, a broader range of costs involved in hedging operations will be introduced. Two main results emerge from this study. First, consistent with previous studies, introduction of transaction costs in futures trading leads to smaller hedge ratios. Second, allowing for uncertainty in transaction costs does not seem to have a larger impact on hedge ratios. In fact, the introduction of stochastic transaction costs causes optimal hedge ratios to increase relative to the case with deterministic costs.

Keywords: hedge, risk, transaction cost

INTRODUCTION

The relevance of transaction costs in futures and stock exchanges has been studied for over four decades. Demsetz (1968), for example, sought to explain the centralization of trading activity in the New York Stock Exchange (NYSE) based on the reduction of transaction costs involved. More specifically, in the case of futures exchanges, several recent studies tried to reinforce the importance of costs involved in derivatives positions (Albanese and Tompaidis, 2008; Lai and Lim, 2009; Fleten and Lindset, 2008; Rogers and Singh, 2010).

In this context, the present research argues that transaction costs are an important factor to explain the limited use of futures contracts to hedge. Lence (1995) and Mattos et al. (2008) explored how transaction costs affect the calculation of optimal hedge ratios for grain producers. Their findings indicate that optimal hedge ratios are smaller when transaction costs are included in the model as opposed to when they are assumed to be zero. However, studies on futures hedging like Lence (1995) and Mattos et al. (2008) incorporate transaction costs in a deterministic manner.

This research relies on the notion that some transaction costs are uncertain when the producer decides to place a hedge. The uncertainty originates from the fact that some costs, such as margin deposits and taxation, depend on the trajectory of futures prices during the hedging period.

The objective of the paper is to investigate how the uncertainty associated with transactions costs can influence producers’ decision to hedge. An expected utility framework will be adopted in this study, and Monte Carlo simulation will be used to simulate different price trajectories and their respective hedging costs. The uncertainty associated with hedging costs will be incorporated as an additional source of risk in the expected utility model, where hedger’s trade-off between return and risk will be discussed. The simulation will be based on the Brazilian cattle market. A representative cattle producer will be assumed and optimal hedge ratios will be estimated under different levels of transaction costs, producers’ risk aversion and hedging horizons. Returns and price risk will be based on cash and futures markets in Brazil, along with all costs involved in futures hedging in that market.

A number of costs need to be considered in futures hedging. In addition to standard transaction costs (such as brokerage fees) this study will also consider opportunity costs and taxation. Opportunity costs arise from possible payments concerning the daily settlement of futures positions. So producers may need more funds to make extra margin deposits, configuring an opportunity cost. On the other hand, Brazilian laws determine that capital gains are taxed at a rate of 15% when profits are made with the futures position. Thus, when the hedging decision is made the producer is faced with uncertainty about how much the hedge will cost. In addition, income tax on the producer's spot position will also be considered.

Understanding how cost risk can influence hedging decisions might provide more insights to the debate on why producers make little use of futures markets to hedge. Moreover, this research expands on the discussion of risks involved in futures hedging. In addition to basis risks traditionally addressed in the literature, this study also considers the uncertainty with transaction costs.

Results can be useful for government and futures exchanges to better understand all risks involved in futures hedging and help them improve the design of contracts and regulations related to risk management.

TRANSACTION COSTS IN BRAZIL

Two sets of transaction costs for Brazilian cattle producers are considered in this study. First, producers have to pay income tax on gains in their spot position. If a producer indicates a profit with his cattle business when income tax is filed, he has to pay a tax rate of up to 27.5% (the exact rate varies according to the magnitude of profit). Income tax is the only cost related to the spot market considered in this study.

A second set of transaction costs is associated with trading futures contracts, which comprises three types: income tax, margin costs (daily mark-to-market), and exchange fees. Income tax is charged from producers on their monthly gains in their futures positions. If producers have a gain in their futures position at the end of each month they are charged an income tax rate of 15%. The margin costs refer to possible margin calls when the daily balance of producer's margin account drops below the maintenance margin when accounts are marked-to-market every day. This cost can be viewed as either the borrowing cost of raising extra funds to meet margin calls or the opportunity cost of using own funds to meet the margin calls. Finally, a third component of transaction costs in futures trading are the exchange fees. Producers who trade futures contracts at the Brazilian Securities, Commodities and Futures Exchange (BM&FBOVESPA) have to pay four types of fees: exchange/brokerage fees, settlement fees, permanence fees, and registration fees. Exchange fees account for the trading service provided by the exchange or operation registration. Their value ranges from R$ 1.76 and R$2.40 per contract (the actual value depends on the total volume traded by the producer).[1] Brokerage fees are charged by brokers but regulated by the

[1] R$ refers to Real, the Brazilian currency. In the last week of May 2012 it was quoted around US$/R$ 2.

exchange. For live cattle futures contracts, these fees represent 0.3% of the total volume traded by the hedger (both when opening and closing the futures position). Permanence fees are intended to cover operational costs incurred by the clearing house to keep track of hedgers' positions. Hedgers are charged R$0.026 per day. Registration fees are also related to the clearing house and aim to cover expenses with registration service. Its value is R$0.10.

With respect to transaction costs related to futures trading, note that only exchange fees are fixed and thus known to hedgers by the time they place their hedges. Given the initial futures price on the day the hedge is placed, it is possible to calculate the total value of exchange/brokerage fees. On the other hand, income tax and margin costs are unknown to the producers at the moment they place their hedges. Producers might not need to pay income tax if their futures positions exhibit losses at the end of each month during the hedging period. If they do need to pay income tax, the actual value will depend on the magnitude of the gains in their futures position. Margin costs might also be zero if the balance of producer's margin account never falls below the maintenance margin. But if they receive margin calls the actual amount to be deposited in their margin accounts will vary according to the changes in futures prices.

RESEARCH METHOD

The hedging decision of a producer in the presence of transaction costs will be explored using an expected utility framework. It is assumed that a producer starts a short hedge with futures contracts in period t=0 and holds the hedge until period t=1, when his production is sold in the spot market and the futures hedge is terminated. The producer's final wealth in period t=1 is given by W_1 as defined in equation (1), where W_0 is initial wealth in period t=0, S_1 is the spot price in period t=1, *CP* is the cost of production, *Q* is the quantity produced and sold by the producer, *tax* is the income tax rate on the spot position, F_0 and F_1 are the respective futures prices in periods t=0 and t=1, *h* is the hedge ratio, and *TC* is the total transaction cost involved in trading futures contracts.

$$W_1 = W_0 + (S_1 - CP)Q(1 - tax) + (F_0 - F_1)Qh - TC \tag{1}$$

A power utility function will be adopted to represent producer's preferences and final wealth will be the argument of this function (equation 2). The parameter α is the coefficient of absolute risk aversion. Since the return *R* generated between periods t=0 and t=1 can be calculated by dividing final wealth by initial wealth $(R = W_1/W_0)$, final wealth can be expressed as $W_1 = W_0 R$. Thus return R can be used as the argument of the utility function as in equation (3), where θ is the coefficient of relative risk aversion $(\theta = \alpha W_0)$.

$$U(W_1) = -\exp(-\alpha W_1) \tag{2}$$

$$U(W_1) = -\exp(-\alpha W_0 R) = -\exp(\theta R) \tag{3}$$

If the probability distribution of return *R* is elliptically symmetric, then expected utility can be characterized by a function of the mean and variance of *R* (Chamberlain, 1983). In addition, when the return distribution is elliptically symmetric, then the distribution of final wealth satisfies the location and scale condition, which allows a two-parameter ranking of these risky alternatives to be consistent with an expected utility ranking (Sinn, 1983;

Meyer, 1987). In this case expected utility of return R can be expressed in terms of its mean and variance as in equation (4), where μ_R and σ_R^2 are the mean and variance of the return distribution, respectively.

$$EU(R) = \mu_R - \frac{\theta}{2}\sigma_R^2 \tag{4}$$

Since return is defined as W_1/W_0, equation (1) can be algebraically manipulated and lead to an expression of R given in equation (5), where $r_{spot} = (S_1 - CP)/CP$ and $r_{fut} = (F_0 - F_1)/F_0$ are the respective returns on the spot and futures positions, *tax* is the income tax rate on the spot position, *h* is the hedge ratio, *tc* is the total transaction cost of trading futures contracts as a proportion of the initial futures price $(tc = TC \cdot F_0 \cdot h \cdot Q)$ and $z = F_0/CP$. The mean and variance of *R* are then given by equations (6) and (7), where μ_{spot} and σ_{spot}^2 are the mean and variance of spot return distribution, μ_{fut} and σ_{fut}^2 are the mean and variance of the futures return distribution, μ_{tc} and σ_{tc}^2 are the mean and variance of the futures transaction cost distribution, $\sigma_{spot,fut}$ is the covariance between spot and futures returns, $\sigma_{spot,tc}$ is the covariance between spot returns and transaction costs, and $\sigma_{fut,tc}$ is the covariance between futures returns and transaction costs.

$$R = \lfloor 1 + r_{spot}(1 - tax) \rfloor + h(r_{fut} - tc)z \tag{5}$$

$$\mu_R = \lfloor 1 + \mu_{spot}(1 - tax) \rfloor + h(\mu_{fut} - \mu_{tc})z \tag{6}$$

$$\begin{aligned} \sigma_R^2 = {} & (1 - tax)^2 \sigma_{spot}^2 + h^2 z^2 \sigma_{fut}^2 + h^2 z^2 \sigma_{tc}^2 \\ & + 2(1 - tax)hz\sigma_{spot,fut} - 2(1 - tax)hz\sigma_{spot,tc} - 2h^2 z^2 \sigma_{fut,tc} \end{aligned} \tag{7}$$

Replacing expressions (6) and (7) in (4), the optimal hedge ratio is determined by maximizing expected utility in (4) with respect to the hedge ratio *h*. Assuming that spot returns are uncorrelated with transaction costs in futures trading $(\sigma_{spot,tc} = 0)$, the optimal hedge ratio is given by equation (8). This expression will be used to calculate hedge ratios in the simulations performed in this study.

$$h = \frac{\mu_{fut} - \mu_{tc} - \theta\sigma_{fut,spot}}{\theta z(\sigma_{fut}^2 + \sigma_{tc}^2 - 2\sigma_{fut,tc})} \tag{8}$$

DATA

This research focuses on cattle producers who use futures contract to hedge in Brazil. Live cattle futures contracts on the Brazilian Securities, Commodities and Futures Exchange (BM&FBOVESPA) are traded for each month of the year, but the majority of the trading volume is concentrated in the May and October maturities. The last trading day of a contract is the last business day of the maturity month. The underlying commodity is an animal ready for slaughter with weight ranging between 450 and 550 kilograms. The futures contract size is 4,950 kilograms (330 units of 15kilograms), which corresponds to approximately 10 animals. Prices are quoted in the Brazilian currency–Reais (R$)–per 15 kilograms.

Two hedging horizons are considered: 2-month (42 trading days) and 4-month (84 trading days). Futures price data between October 2008 and May 2011 are used in this study to generate probability distributions for the two hedging horizons. Since futures trading is heavily concentrated in the May and October contracts, only these two maturities are used. The first step is to obtain the whole daily price series for the October 2008, May 2009, October 2009, May 2010, October 2010, and May 2011 contracts. Then daily futures returns r are calculated as $r_t = \ln(p_t / p_{t-1})$, where p are daily futures prices, and series of daily futures returns are created for each maturity. The annualized standard deviation (volatility) is calculated for each series of futures returns, ranging from 8.6% to 22.3%.[2] Based on observed volatility, three values are selected to be used as parameters to generate a probability distribution of daily futures returns. The three values of annualized volatility are 10%, 20%, and 30%. Round numbers are selected for ease of exposition, and the first two values are chosen based on their proximity to the lowest and highest values calculated from the data on returns. The last value was chosen to represent a scenario with higher uncertainty.

Following Lence (1995) and Mattos et al. (2008), it is assumed that the expected return on futures contracts is zero $(\mu_{fut} = 0)$. Assuming returns follow a normal distribution $N(\mu_{fut}, \sigma_{fut})$, three probability distributions of futures returns are generated: $N_1(0,0.1)$, $N_2(0,0.2)$, and $N_3(0,0.3)$, which are used to simulate futures price trajectories in each hedging horizon. For each probability distribution 5,000 futures price trajectories are simulated for each hedging horizon. The starting price in each trajectory is the same (R$90.00 per 15 kilograms), based on the average price observed in the six maturities used as reference for this study. Each trajectory starts with $F_0 = 90$ and the second daily price is generated by randomly picking a daily return from the probability distribution and multiplying it by the initial price. The subsequent prices are also generated by randomly picking daily returns from the probability distribution and multiplying them by the price in the previous day. This process continues for 42 days in the 2-month hedging horizon and 84 days in the 4-month hedging horizon, and is repeated 5,000 times for each probability distribution. At the end, there will be six sets of 5,000 simulated futures price trajectories: 2-month hedging horizon with $N_1(0,0.1)$, 2-month hedging horizon with $N_2(0,0.2)$, 2-month hedging horizon with $N_3(0,0.3)$, 4-month hedging horizon with $N_1(0,0.1)$, 4-month hedging horizon with $N_2(0,0.2)$, and 4-month hedging horizon with $N_3(0,0.3)$.

The simulated price trajectories are used to calculate returns on spot and futures positions and transactions costs in each hedging horizon. It is assumed that spot and futures prices are the same on the last day of the hedging horizon $(S_1 = F_1)$ and spot and futures returns are calculated as $r_{spot} = (S_1 - CP)/CP$ and $r_{fut} = (F_0 - F_1)/F_0$, respectively. Cost of production (CP) used to calculate spot returns are based on average values between 2009 and 2011 obtained from the Center for Advanced Studies on Applied Economics (CEPEA). The set of spot and futures returns calculated from the 5,000 trajectories are used to generate the

[2] Calculated volatilities for each contract series are 22.3% for October 2008, 12.5% for May 2009, 11.9% for October 2009, 10.6% for May 2010, 10.7% for October 2010, and 8.6% for May 2011.

covariance between spot and futures returns which is used to calculate the hedge ratio in (8). Transaction costs in futures trading (as previously discussed) are also based on the price trajectories. Income tax on gains in futures markets and margin costs related to daily mark-to-market are calculated for each price trajectory and, in addition to the fixed exchange fees, are used to generate a probability distribution of transaction costs. Based on these distributions, means (μ_{tc}) and variances (σ_{tc}^2) for transaction costs are calculated and used to find the optimal hedge ratio in (8). Finally, covariance between futures returns and transaction costs $(\sigma_{fut,tc})$ needed to calculate the hedge ratio in (8) is obtained from the simulated price trajectories.

RESULTS

Results are initially discussed without transaction costs in futures trading, so that it is possible to get a sense of the magnitude of hedge ratios without hedging costs. First standard minimum-variance hedge ratios are calculated following equation (8) and considering no costs either in the spot or futures positions $(tax = 0, \mu_{tc} = 0 = \sigma_{tc}^2, \sigma_{fut,tc} = 0)$. Calculated ratios are presented in Table 1 and values are close to 1 for both hedging horizons and all three scenarios for the volatility of futures prices. Income tax on spot positions is then introduced $(tax = 0.275)$, but there are still no transaction costs in futures trading. Hedge ratios drop to values between 0.71 and 0.79 as income tax is introduced for spot positions (Table 1). This finding is expected because income tax affects the covariance between spot and futures returns, while there is no change in the variance of futures returns (these are the only two variables considered in the calculation of hedge ratios at this point). It can be shown that $\sigma_{spot,fut}^{tax} = (1 - tax)\sigma_{spot,fut}^{no\ tax}$, thus the covariance becomes smaller when the tax rate of 0.275 is considered. Intuitively, it implies that changes in spot prices are not matched with changes in futures prices as closely as they would be without taxes on the spot position.

Table 1: Hedge ratios without any costs and only with income tax on spot position

	Volatility of simulated price trajectories		
	10%	20%	30%
No costs (standard minimum-variance hedge)			
2-month hedge	0.976	0.992	0.992
4-month hedge	0.995	1.000	1.000
Income tax on spot position; no futures costs in futures trading			
2-month hedge	0.721	0.727	0.770
4-month hedge	0.710	0.759	0.791

The next step is to calculate hedge ratios considering transaction costs in futures trading. At first these costs are included in a deterministic manner, i.e. there is a positive cost to trade futures contracts but no uncertainty about the value of this cost $(\mu_{tc} > 0, \sigma_{tc}^2 = 0, \sigma_{fut,tc} = 0)$. Consistent with previous studies (Lence 1995, Mattos et al., 2008), the introduction of deterministic transaction costs in futures trading decreases the optimal hedge ratio. In the 2-month horizon hedge ratios vary between 0 and 0.761 depending on the volatility scenario, while in the 4-month horizon they vary between 0.276 and 0.841 (Table 2). The following step is to allow for income tax on the spot positions in addition to deterministic transaction costs in futures trading, in which case there is a larger drop in optimal hedge ratios (Table 2). In the scenario with lower volatility, optimal hedge ratios turn out to be zero for both hedging horizons when deterministic costs are considered for spot and futures positions.

Table 2: Hedge ratios with deterministic transaction costs in futures trading

	Volatility of simulated price trajectories		
	10%	20%	30%
Deterministic transaction costs in futures trading			
2-month hedge	0.000	0.596	0.761
4-month hedge	0.276	0.717	0.841
Deterministic transaction costs in futures trading and income tax on spot position			
2-month hedge	0.000	0.332	0.539
4-month hedge	0.000	0.473	0.619

Finally, uncertainty about transaction costs in futures trading is introduced. Now, in addition to a positive cost to trade futures contracts, producers also face uncertainty about the total value of these costs, which can only be known at the end of the hedge $\left(\mu_{tc} > 0, \sigma_{tc}^2 > 0, \sigma_{fut,tc} \neq 0\right)$. In line with findings discussed above and with previous studies (Lence 1995, Mattos et al., 2008), optimal hedge ratios when transaction costs in futures trading are introduced are smaller than minimum-variance hedge ratios. If costs related to income tax on the spot position are also considered, the reduction in hedge ratios is amplified (Table 3).

Table 3: Hedge ratios with stochastic transaction costs in futures trading

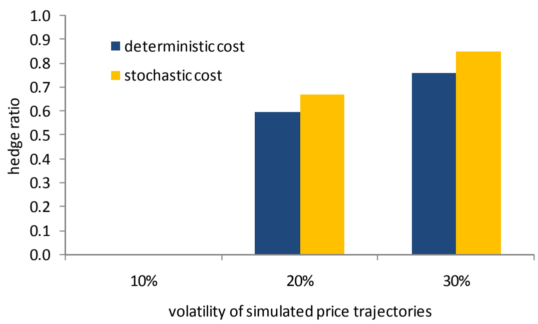
	Volatility of simulated price trajectories		
	10%	20%	30%
Stochastic transaction costs in futures trading			
2-month hedge	0.000	0.671	0.848
4-month hedge	0.305	0.784	0.907
Stochastic transaction costs in futures trading and income tax on spot position			
2-month hedge	0.000	0.373	0.601
4-month hedge	0.000	0.518	0.668

Previous results essentially show that hedge ratios become smaller as the magnitude of transaction costs (either on spot or futures positions) increases. A clearer comparison of how uncertainty in transaction costs affects hedge ratios is presented in Figure 1, which shows the same optimal hedge ratios as in the tables above, but now focusing on the differences between hedge ratios in the presence of deterministic transaction costs and the ones in the presence of stochastic transaction costs. As can be seen, optimal hedge ratios increase when stochastic transaction costs are introduced compared to the cases with deterministic costs. This finding suggests that producers would trade a larger quantity of futures contracts when they are uncertain about the value of transaction costs, and a smaller quantity of futures contracts when they can determine the exact amount of transaction costs involved in their hedge.

Figure 1: Hedge ratios with deterministic and stochastic transaction costs in futures trading

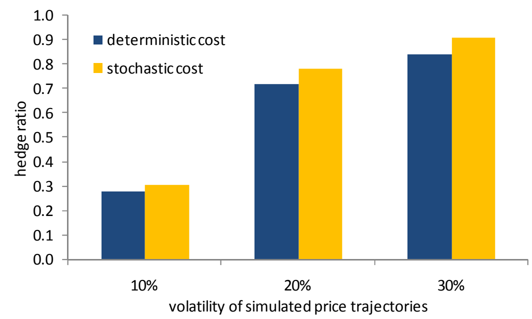
2-month hedge

no income tax on spot position



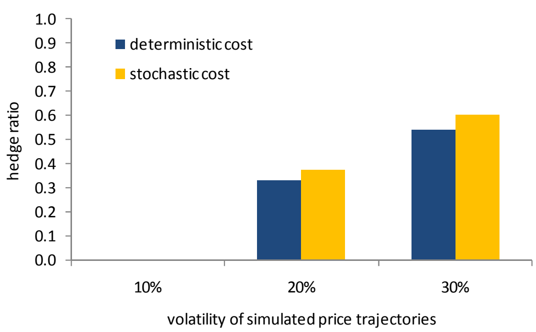
4-month hedge

no income tax on spot position



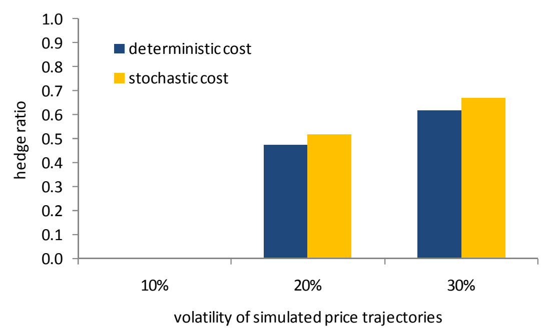
2-month hedge

with income tax on spot position



4-month hedge

with income tax on spot position



At this point it should be useful to go back to equation (8) and explore how the hedge ratio can increase in the presence of more uncertainty. When deterministic costs are considered, $\mu_{tc} > 0$, $\sigma_{tc}^2 = 0$, and $\sigma_{fut,tc} = 0$. Thus the optimal hedge ratio is given by (9). When stochastic costs are considered, $\mu_{tc} > 0, \sigma_{tc}^2 > 0, \sigma_{fut,tc} \neq 0$, and the optimal hedge ratio is given by (10). The two expressions diverge is in their denominators, specifically in the difference between variance of transaction costs and covariance between futures returns and transaction costs $\left(\sigma_{tc}^2 - 2\sigma_{fut,tc}\right)$ which appears in (10) but not in (9).

$$h = \frac{\mu_{fut} - \mu_{tc} - \theta\sigma_{fut,spot}}{\theta z\left(\sigma_{fut}^2\right)} \tag{9}$$

$$h = \frac{\mu_{fut} - \mu_{tc} - \theta\sigma_{fut,spot}}{\theta z\left(\sigma_{fut}^2 + \sigma_{tc}^2 - 2\sigma_{fut,tc}\right)} \tag{10}$$

Since the optimal hedge ratios increases in the presence of stochastic transaction costs, it can be inferred that $\left(\sigma_{tc}^2 - 2\sigma_{fut,tc}\right) < 0$, which is indeed observed in the simulated data. A future step for this research is to explore in more detail how this relationship between σ_{tc}^2 and $\sigma_{fut,tc}$ affect hedge ratios, mathematically and intuitively.

CONCLUSION

Two main results emerge from this study. First, consistent with previous research, introduction of transaction costs in futures trading leads to smaller hedge ratios. In the current study it was also considered that hedgers have to pay income tax on their spot position, in which case a larger reduction in optimal hedge ratios happened. Second, allowing for uncertainty in transaction costs does not seem to have a larger impact on hedge ratios. In fact, the introduction of stochastic transaction costs in the hedging model causes optimal hedge ratios to increase relative to the case with deterministic costs.

The impact of uncertainty in transaction costs on the optimal hedge ratio seems to depend on the difference between the variance of transaction costs and the covariance between futures returns and transaction costs. In the current simulation this difference is negative, which reduces hedge ratios when stochastic costs are considered. However, the covariance between futures returns and transaction costs depends on how transaction costs on futures trading are determined. Thus it is possible that distinct results could be found in markets with different procedures to calculate transaction costs. Further, the uncertainty in costs also affects the covariance between spot and futures returns. There are differences in income tax rates for the spot and futures markets, which imply that actual gains and losses in each market might not match as closely as it is usually considered in hedging studies. Therefore the covariance between spot and futures returns would also be smaller than it is typically seen in hedging models.

Finally, two points remain to be investigated more carefully. One is the relationship between the variance of transaction costs and the covariance between futures returns and transaction costs, which appears to make hedge ratios increase in the presence of stochastic transaction costs. Another issue is how distinct income tax rates on the spot and futures positions impact the optimal hedge ratio. In the present simulation tax rates on spot and futures positions are 27.5% and 15%, respectively. The cost with income tax represents 50% to 70% of the total cost in futures markets and is responsible for almost all the variability in transaction costs (Table 4, Appendix). It should be interesting to explore different types of tax structures with spot and futures positions that could potentially reduce transaction costs for hedgers.

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APPENDIX

Table 4: Mean and standard deviation of transaction costs in futures trading based on simulated price trajectories [a]

	Annual volatility of simulated price trajectories					
	10%		20%		30%	
	mean (%)	std. dev. (%)	mean (%)	std. dev. (%)	mean (%)	std. dev. (%)
2-month hedge						
income tax	0.278	0.345	0.551	0.662	0.809	0.942
margins cost	0.019	0.023	0.038	0.048	0.059	0.076
exchange fees	0.300	0.000	0.300	0.000	0.300	0.000
total	0.597	0.333	0.889	0.636	1.168	0.904
4-month hedge						
income tax	0.453	0.478	0.872	0.896	1.261	1.298
margins cost	0.055	0.068	0.111	0.140	0.175	0.220
exchange fees	0.300	0.000	0.300	0.000	0.300	0.000
total	0.808	0.441	1.284	0.819	1.737	1.178

(a) transaction costs are expressed as a percentage of the initial futures price