Chapter 2
Backwardation and Optimal Hedging Demand in an Expected Utility Hedging Model

"A theory of speculative markets under ideal conditions of certainty is Hamlet without the Prince."

Samuelson (1957, p. 205).

2.1 Introduction

Most recent models on optimal hedging deal with exporting firms facing price or exchange rate risk. In order to hedge the spot commitment, firms go short in futures contracts.[1] This hedging literature, dealing with exporting firms hedging short, unequivocally suggests a negative relation between backwardation and the size of the optimal short hedging position.[2] In sum, the literature suggests that if the

[1] See e.g., Briys, Crouhy, and Schlesinger (1993), Briys and de Varenne (1998), Briys and Schlesinger (1993), Friberg (1998), Adam-Müller (1997, 2000) and Lien and Wang (2002). For more information on the role of unbiasedness in futures markets and hedging see e.g., Benninga, Eldor, and Zilcha (1984, 1985), Broll and Eckwert (1996, 2000), Broll, Wahl, and Zilcha (1995) and Zilcha and Broll (1992).

[2] In the literature, the term backwardation is used in a variety of ways relating current and expected spot prices to futures and forward prices. Following Holthausen (1979), Briys and Schlesinger (1993) and Adam-Müller (2000), in this study, backwardation is defined as the futures price being less than the expected spot price. Explanations of backwardation include the existence of a risk premium, cost of carry, convenience yield, and capacity constraints. Note that, investigating the explanations of backwardation in more detail is beyond the scope of this chapter. Interested readers are referred to Litzenberger and Rabinowitz (1995), Frechette and Fackler (1999), Pindyck (2001), Inci and Lu (2007) and Larson (2007). In contrast to backwardation, the futures market is said to exhibit contango if the futures price exceeds the expected spot price. The literature on backwardation and contango dates back to Keynes (1930), Hicks (1939) and Kaldor (1940). There is a large literature dealing with the controversy about the Keynesian "normal backwardation" hypothesis. Some studies find backwardation to be normal while others reject the hypothesis. For a survey on the controversy, see e.g., Ehrhardt, Jordan, and Walkling (1987), Kolb (1992) and Miffre (2000). This study does not add to this controversy but rather investigates the impact of backwardation on hedgers' demand for currency futures contracts.

A. Röthig, *Microeconomic Risk Management and Macroeconomic Stability*, Lecture Notes in Economics and Mathematical Systems,
DOI 10.1007/978-3-642-01565-6_2,

futures market is characterized by backwardation (contango), it is optimal for the short hedger to underhedge (overhedge), where underhedging (overhedging) means choosing a futures position smaller (larger) than the initial spot commitment. In the absence of backwardation or contango, the firm hedges fully, and therefore chooses the futures position to be the same size as the spot position.[3] Hence, an increase in backwardation should, ceteris paribus, reduce the trading volume of hedgers in short futures contracts.

This chapter studies the impact of backwardation on hedging activity in short and long currency futures contracts.[4] First, the optimal hedging strategy of a representative importer is derived. The importing firm expects delivery of a certain amount of a good at a futures date at the then prevailing random exchange rate. To hedge the spot exposure the importer can go long in currency futures markets. Second, hedging costs are introduced into the model. Third, the impact of backwardation on long and short hedging activity in six currency futures markets is investigated empirically. To the best of our knowledge, there is rarely any literature dealing with importers hedging long. Among the few exceptions are Haigh and Holt (2000) and Jin and Koo (2006). Haigh and Holt (2000) use a model in which hedgers are simultaneously long and short in different futures markets. Jin and Koo (2006) examine the hedging problem of a Japanese grain importer facing multiple risks. However, Haigh and Holt (2000) and Jin and Koo (2006) do not investigate the role of backwardation and contango on optimal hedging. In addition the model in this chapter is related to the expected utility framework laid out by Holthausen (1979) and Briys and Schlesinger (1993), whereas Haigh and Holt (2000) and Jin and Koo (2006), both employ the mean-variance concept. Holthausen (1979) and Briys and Schlesinger (1993) investigate the impact of backwardation on the optimal hedging decisions of exporting firms. The model presented in this chapter extends these investigations to importers. In addition, the impact of hedging costs on the importer's optimal hedging strategy are investigated.

The model of the importer's hedging problem introduced in this chapter leads to the conclusion that it is optimal for long hedgers to overhedge (underhedge) if the futures market is characterized by backwardation (contango). The firm hedges fully in the absence of backwardation or contango. However, this result is altered by introducing hedging costs. In fact, the existence of hedging costs provides a rationale for backwardation to be normal. In the presence of hedging costs, the importing firm hedges fully if, and only if, the futures market exhibits backwardation. The firm tends to overhedge if the amount of backwardation exceeds hedging costs. The firm hedges fully if the extent of backwardation equals hedging costs. If hedging costs exceed the amount of backwardation, or if the futures market is unbiased or exhibits contango, the optimal hedge is a partial hedge. However, irrespective of the existence of hedging costs, an increase in backwardation should, ceteris paribus, increase the trading volume of hedgers in long futures contracts.

[3] See e.g., Briys, Crouhy and Schlesinger (1990, 1993), Briys and de Varenne (1998) and Broll and Wong (2002).

[4] A previous version of this chapter has been published as Röthig (2008).

Although there is a large literature dealing with backwardation and firms' optimal hedging strategies in the theory of the firm, few attempts have been made to approach the impact of backwardation on hedgers' demand for futures contracts empirically. The empirical part of this study analyzes the impact of backwardation on hedgers' demand for short and long currency futures contracts in six currency futures markets. Following Litzenberger and Rabinowitz (1995) and Pindyck (2001), two measures of backwardation (i.e., weak and strong backwardation) are employed. Using vector autoregressive (VAR) and vector error correction (VECM) models, the results of this study show that backwardation has a significant impact on hedgers' trading volume in currency futures markets. However, the sign of the impact does not correspond to economic theory for all currencies. The results therefore offer little support for the hypothesis that short (long) hedging activity depends negatively (positively) on backwardation.

In Sect. 2.2 the model is presented and the firm's optimal hedging strategy is derived. The impact of backwardation and contango on the optimal hedge are analyzed and hedging costs are introduced into the model. Section 2.3 presents the empirical results based on VAR and VECM models. Section 2.4 concludes.

2.2 The Expected Utility Hedging Model

2.2.1 Optimal Long Hedging

Suppose there is a representative importer in country A who is obliged to buy a known quantity x of a good from country B at period $t = 1$ at a certain price level p.[5] Having made the decision to import the quantity x, the firm faces exchange rate risk between the period the decision is made (i.e., $t = 0$) and the spot commitment date $t = 1$. The expected return of the spot position depends on the random exchange rate $\tilde{e}_1$ as follows:

$$E(R_S) = -\tilde{e}_1 px. \tag{2.1}$$

Since the price level p is non-stochastic and known at period $t = 0$, p is set equal to one for simplicity. In addition to the spot commitment, the importer can trade long futures contracts in the currency futures market. Let f_0 be the futures price

[5] It is important to stress that the quantity x of imports is given. Since the firm in this model is not deciding about the optimal production level, and therefore not choosing the optimal amount of imports, this model can be interpreted as concerned with the short run. Moreover, the price level p is fixed, also pointing to a short run model. According to Sandmo (1971) this approach may be considered a weakness but also a strength. The weakness concerns the separation of production policy and strategies for financing and investment. A strength of dealing with short run profits is that the model stays relatively simple and is not based on too many assumptions. Moreover it is more realistic and applicable since hedging is generally concerned with single cash flows and hedging vehicles like futures are generally available only for the short run.

at time $t = 0$ for delivery of a certain amount of foreign currency in $t = 1$. In this model the importer holds the futures position until delivery at period $t = 1$, that is, until the spot commitment date. At futures delivery date, the random futures delivery price is $\tilde{f}_1$. Suppose that, due to arbitrage relations, the random spot price and the random futures price coincide at spot commitment date (futures delivery date, respectively). Then, since basis risk is absent, the expected return of the long futures position $\tilde{f}_1 - f_0$ equals $\tilde{e}_1 - f_0$ per contract h.[6] If the term $\tilde{e}_1 - f_0$ is zero (not zero), the futures market is said to be unbiased (biased). If the futures price is less than the expected spot price (i.e., $\tilde{e}_1 - f_0 > 0$), the futures market exhibits backwardation. The futures market exhibits contango if the futures price exceeds the expected spot price (i.e., $\tilde{e}_1 - f_0 < 0$). The expected profit of the hedged portfolio is the sum of the expected return of the spot position plus the long futures position:

$$E(\Pi) = -\tilde{e}_1 x + (\tilde{e}_1 - f_0)h. \tag{2.2}$$

It can easily be seen that the long futures position can be used to offset (i.e., to hedge) the existing spot exchange rate exposure. If the importer chooses the amount of futures contracts traded h to equal the spot commitment x, then the expected profit of the hedged portfolio is non-stochastic. This hedging strategy is widely known as the "equal and opposite" or "one to one" hedge. However, although potential losses in the spot position are offset by the futures position, potential gains in the spot position due to a decrease in the exchange rate are offset as well by losses in the futures position.

The importer's decision problem is to choose a futures position h to maximize expected utility. The importing firm maximizes its expected utility of profit at date $t = 1$ where U is a concave, continuous and differentiable utility function defined over profit Π.

$$\underset{h}{Max} EU[\Pi] = U[-\tilde{e}_1 x + (\tilde{e}_1 - f_0)h]. \tag{2.3}$$

The firm is assumed to be risk averse, so that $U'[\Pi] > 0$, $U''[\Pi] < 0$.[7] Following Briys and Schlesinger (1993) the first-order condition is calculated:

$$\frac{\delta EU[\Pi]}{\delta h} = EU'[-\tilde{e}_1 x + (\tilde{e}_1 - f_0)h](\tilde{e}_1 - f_0) = 0. \tag{2.4}$$

Using the representation of profit presented in (2.2) the first-order condition can be rewritten as

$$\frac{\delta EU[\Pi]}{\delta h} = EU'[\Pi](\tilde{e}_1 - f_0) = 0. \tag{2.5}$$

[6] The difference between the random variables $\tilde{e}_1$ and $\tilde{f}_1$ in the delivery period is known as the basis (or, basis risk, respectively). See e.g., Peck (1975) and Lapan and Moschini (1994).

[7] For more information on similar utility functions and risk aversion see e.g., Pratt (1964), Baron (1970), Rothschild and Stiglitz (1970), Sandmo (1971), Diamond and Stiglitz (1974), Ishii (1977) and Kimball (1990, 1993).

The second-order condition for a maximum is assumed to hold given risk aversion.[8] Using the covariance operator *Cov*, (2.5) can be written as[9]

$$\frac{dEU[\Pi]}{dh} = EU'[\Pi]E(\tilde{e}_1 - f_0) + Cov[U'[\Pi], \tilde{e}_1] = 0. \tag{2.6}$$

The covariance term $Cov[U'[\Pi], \tilde{e}_1]$ is crucial in the subsequent analysis of the relationship between hedging activity and backwardation. Equation (2.6) can be used to determine the conditions under which the risk-averse firm hedges fully (i.e., $h = x$), hedges partially (i.e., $0 < h < x$), or overhedges (i.e., $h > x$). Note that (2.6) consists of three terms. $U'[\Pi]$ is positive for any Π by definition. The second term, $E(\tilde{e}_1 - f_0)$, is zero if the futures market is unbiased (i.e., $\tilde{e}_1 = f_0$). Suppose the second term is zero, then (2.6) reduces to $Cov[U'[\Pi], \tilde{e}_1] = 0$.

In order to analyze the covariance term in more detail, recall that profit at date 1 is given by $E(\Pi) = -\tilde{e}_1 x + (\tilde{e}_1 - f_0)h$. As previously mentioned, profit is independent of the exchange rate if $h = x$, and hence the covariance is zero. If the firm hedges less than full (i.e., $h < x$) the covariance is positive and if the firm overhedges (i.e., $h > x$) the covariance is negative.[10]

[8] The second partial derivative of the utility function with respect to h is

$$\frac{\delta^2 EU[\Pi]}{\delta h^2} = EU''[\Pi](\tilde{e}_1 - f_0)^2.$$

The equation is negative since $U'[\Pi] > 0$, $U''[\Pi] < 0$ by definition. Therefore a maximum exists. However, as Holthausen (1979, p. 989) points out, this is not the case for risk-neutral ($U''[\Pi] = 0$) or risk-loving firms ($U''[\Pi] > 0$).

[9] To see this, recall that $E(XY) = E(X)E(Y) + Cov(X,Y)$ (see e.g., Cochrane, 2001, p. 15). Equation (2.5) can therefore be rewritten as

$$EU'[\Pi](\tilde{e}_1 - f_0) = EU'[\Pi]E(\tilde{e}_1 - f_0) + Cov[U'[\Pi], (\tilde{e}_1 - f_0)] = 0,$$

which in turn, using $Cov(X+Y,Z) = Cov(X,Z) + Cov(Y,Z)$, can be formulated as

$$EU'[\Pi]E(\tilde{e}_1 - f_0) + Cov[U'[\Pi], \tilde{e}_1] + Cov[U'[\Pi], -f_0] = 0.$$

Since f_0 is non-stochastic, and using $Cov(1,X) = 0$, the equation can be simplified to

$$EU'[\Pi]E(\tilde{e}_1 - f_0) + Cov[U'[\Pi], \tilde{e}_1] = 0.$$

[10] Note that the covariance is defined as

$$Cov(X,Y) = E((X - E(X))(Y - E(Y)).$$

Suppose that $X = U'[\Pi]$ and $Y = \tilde{e}_1$. If the firm underhedges (i.e., $h < x$), the futures position is smaller than the spot position and profit therefore depends negatively on the random exchange rate. An increase in $\tilde{e}_1$ decreases Π and, due to concavity, increases $U'[\Pi]$. Hence, $(X - E(X)) > 0$. In addition, an increase in $\tilde{e}_1$ leads to $(Y - E(Y)) > 0$. The covariance is therefore positive.

However, if the firm overhedges (i.e., $h > x$), the futures position is larger than the spot position. Since the futures position yields profits when $\tilde{e}_1$ increases, profit depends positively on the exchange rate. Hence, an increase in $\tilde{e}_1$ increases Π and decreases $U'[\Pi]$, again, due to concavity. Therefore $(X - E(X)) < 0$. Since, everything else is equal, the covariance is negative.

Now, if the futures market is unbiased, the term $\tilde{e}_1 - f_0$ in (2.6) is zero. Therefore, the covariance must be zero as well for (2.6) to hold. For the covariance to be zero, which is achieved if profit is independent of exchange rate changes, the firm must hedge fully. Hence, firms hedge fully when the futures market is unbiased. If the futures market exhibits backwardation (i.e., $\tilde{e}_1 > f_0$), the second term in (2.6) is positive. The covariance in (2.6) must therefore be negative for the condition that the first-order-condition equals zero to hold. This implies that $h > x$. The resulting futures position is an overhedge. Now suppose that the futures market exhibits contango (i.e. $\tilde{e}_1 < f_0$). In this case, the covariance in (2.6) must be positive, since the first term in the equation is negative, for the condition that the first-order-condition equals zero to hold. This implies that $h < x$. The resulting futures position is a partial hedge.

2.2.2 *Hedging Costs and Optimal Hedging*

In this section hedging costs are introduced into the model. The expected utility of profit with hedging costs is

$$EU[\Pi] = U[-\tilde{e}_1 x + (\tilde{e}_1 - f_0 - c)h]. \tag{2.7}$$

Again, profit is independent of the exchange rate if the firm hedges fully (i.e., $h = x$). In this case, spot exposure is completely offset and therefore perfectly hedged by the futures position. Maximizing expected utility of profit with respect to h yields

$$\frac{dEU[\Pi]}{dh} = EU'[-\tilde{e}_1 x + (\tilde{e}_1 - f_0 - c)h](\tilde{e}_1 - f_0 - c) = 0. \tag{2.8}$$

Using covariances, the first-order condition can be rewritten as

$$\frac{dEU[\Pi]}{dh} = EU'[\Pi]E(\tilde{e}_1 - f_0 - c) + Cov[U'[\Pi], \tilde{e}_1] = 0. \tag{2.9}$$

Equation (2.9) consists of three terms. Again, $U'[\Pi]$ is positive for any Π by definition. The second term $E(\tilde{e}_1 - f_0 - c)$ is zero if hedging costs equal the amount of backwardation (i.e., $c = \tilde{e}_1 - f_0$). Suppose the second term is zero, then (2.9) reduces to $Cov[U'[\Pi], \tilde{e}_1] = 0$, which holds true if firms hedge fully. If $c > 0$, the term $E(\tilde{e}_1 - f_0 - c)$ in (2.9) is zero if $E(\tilde{e}_1 - f_0) > 0$, or more precisely if $E(\tilde{e}_1 - f_0) = c$. Hence, firms hedge fully if, and only if, futures markets are biased, i.e., exhibit backwardation ($E(\tilde{e}_1) > f_0$). If the amount of backwardation exceeds trading costs c (i.e., $E(\tilde{e}_1 - f_0) > c$), the second term in (2.9) is positive. The covariance in (2.9) must therefore be negative for the condition that the first-order-condition equals zero to hold. This implies that $h > x$. The resulting futures position is an overhedge. In the case of an unbiased futures market (i.e., $E(\tilde{e}_1) = f_0$), or if the futures market exhibits contango (i.e., $E(\tilde{e}_1) < f_0$), the covariance in (2.9) therefore must be positive for the condition that the first-order-condition equals zero to hold. This implies that $h < x$. The resulting futures position is a partial hedge.

2.3 Empirical Investigation

In this section the impact of backwardation on short and long hedging activity is empirically investigated. Regarding short hedging, again, the literature suggests that in the case of backwardation (contango) it is optimal to underhedge (overhedge). The theoretical model in this study dealing with a representative importer's long hedging problem suggests that it is optimal to overhedge (underhedge) if the futures market is characterized by backwardation (contango). Hence, ceteris paribus, the hedging models predict a negative effect of backwardation on short hedging activity as well as a positive effect on long hedging activity.

2.3.1 Data and Summary Statistics

The empirical investigation uses weekly data on spot and futures prices and hedgers' positions for six currency futures contracts traded at the Chicago Mercantile Exchange. Australian Dollar (AUD), Canadian Dollar (CAD), Swiss Francs (CHF), Euro (EUR), Japanese Yen (JPY), and Mexican Peso (MXP) futures contracts are investigated. The hedgers' position data come from the Commodity Futures Trading Commission's (CFTC) Commitments of Traders (COT) report and the price data come from Datastream.[11]

Following Litzenberger and Rabinowitz (1995) and Pindyck (2001), two measures of backwardation are employed. Futures markets exhibit strong backwardation if futures prices are below spot prices (i.e., $\tilde{e}_t > \tilde{f}_t$). Weak backwardation is defined as a situation where discounted futures prices are below spot prices (i.e., $\tilde{e}_t > exp(-r_t * (3/12))\tilde{f}_t$ where r_t is the three month LIBOR rate).

The summary statistics are presented in Table 2.1. With regard to the measure of weak backwardation, backwardation appears to be normal as proposed by Keynes (1930). All currency futures markets investigated exhibit weak backwardation at least 95% of the time. The results for strong backwardation are mixed. While some currency futures prices were on average strongly backwarded (i.e., the AUD and MXP series over 90% of the time), some exhibit backwardation and contango from time to time (i.e., CAD and EUR), and some exhibit contango most of the time (i.e., CHF and JPY).

[11] For more information on the COT report, see e.g., Ederington and Lee (2002), Chatrath et al. (2003) and Röthig and Chiarella (2007).

Table 2.1 Summary statistics for backwardation and hedging activity

Futures contract	AUD		CAD		CHF		EUR		JPY		MXP	
Sample	02 Jan 2001 to 31 Jan 2006		06 Oct 1992 to 31 Jan 2006		06 Oct 1992 to 31 Jan 2006		12 Jan 1999 to 31 Jan 2006		06 Oct 1992 to 31 Jan 2006		26 Mar 1996 31 Jan 2006	
Observations	252		696		694		369		696		515	
Panel A: Weak and strong backwardation												
	BW	BS	BW	BS	BW	BS	BW	BS	BW	BS	BW	BS
Mean	0.0101	0.0030	0.0101	0.0001	0.0075	−0.0023	0.0121	−0.0004	0.0000	−0.0000	0.0032	0.0018
Minimum	0.0027	−0.0040	0.0048	−0.0056	−0.0004	−0.0094	−0.0039	−0.0180	−0.0000	−0.0001	−0.0017	−0.0028
Maximum	0.0178	0.0106	0.0245	0.0091	0.0230	0.0129	0.0224	0.0115	0.0002	0.0000	0.0119	0.0101
Standard error	0.0028	0.0024	0.0026	0.0019	0.0030	0.0030	0.0030	0.0037	0.0000	0.0000	0.0023	0.0020
% in backwardation	100	92.46	100	53.01	99.85	21.32	99.72	50.13	96.40	6.75	99.61	98.83
Panel B: Short hedging activity												
	Short		Short		Short		Short		Short		Short	
Mean	35,539.88		39,196.21		22,124.58		65,122.91		47,972.39		27,602.20	
Minimum	4,910.00		4,945.00		1,932.00		2,984.00		7,440.00		1,306.00	
Maximum	114,073.00		111,552.00		86,565.00		148,495.00		184,367.00		127,620.00	
Standard error	19,312.65		21,500.59		14,244.79		28,653.69		30,963.11		23,741.40	
Panel C: Long hedging activity												
	Long		Long		Long		Long		Long		Long	
Mean	12,569.76		27,201.43		28,371.87		39,115.23		62,162.80		17,977.66	
Minimum	1,294.00		1,360.00		1,558.00		1,647.00		10,111.00		1,752.00	
Maximum	51,749.00		63,398.00		87,271.00		125,244.00		188,591.00		54,741.00	
Standard error	9,973.88		13,125.70		17,377.14		20,266.04		28,854.10		9,804.78	

Note: The summary statistics are computed using weekly data. The price data are obtained from Datastream. Strong backwardation is defined by $BS_t = \tilde{e}_t - \tilde{f}_t$ where $\tilde{e}_t$ is the spot price and $\tilde{f}_t$ is the futures price in t. Weak backwardation is defined by $BW_t = \tilde{e}_t - exp(-r_t * (3/12))\tilde{f}_t$ where r_t is the three month LIBOR rate. Data on hedging activity are obtained by the Commodity Futures Trading Commission's (CFTC) Commitments of Traders (COT) report. Short hedging activity is defined by $Short_t = Comm\_Positions\_Short\_All_t$, and long hedging activity is defined by $Long_t = Comm\_Positions\_Long\_All_t$

Interestingly, with regard to the measure of strong backwardation, in the markets where futures prices exhibit contango, hedgers are on average net long (i.e., the mean of long hedging activity exceeds the mean of short hedging activity in Table 2.1). Miffre (2000) points out that the idea that backwardation and contango depend on hedgers' net positions is consistent with the Keynesian hypothesis. According to this hypothesis, futures prices should be backwarded if hedgers are net short, and futures prices should exhibit contango if hedgers are net long. The inequality between hedgers' long and short positions requires the existence of speculators to fill the gap and restore equilibrium.[12] Since backwardation and contango can be regarded as a risk premium earned by speculators, backwardation (contango) attracts speculators to go long (short).[13] However, with regard to the hedging literature and in line with the model in the previous section, in addition to speculators, hedgers are motivated to hedge long (short) if futures prices exhibit backwardation (contango), as well. Hence, the causality may not run in one, but in both directions: Backwardation influences hedging activity, which in turn has an impact on backwardation. If the causality runs in both directions, the assumption underlying the ordinary least squares (OLS) method, that the explanatory variables (i.e., backwardation) are non-stochastic, does not hold. In fact, this assumption is likely to be violated since hedgers and speculators, as the main traders in futures markets, jointly determine the degree of backwardation. The simplest way to circumvent this problem, associated with OLS, is to employ a dynamic model where all variables are endogenous. In this study, vector autoregressive (VAR) and vector error correction (VECM) models are chosen for the empirical analysis. The flexible VAR and VECM models are dynamic in nature, and allow for a simple interpretation of the results. Applying VAR and VECM models to the analysis at hand may provide insights into the dynamics of hedgers' demand for futures contracts. Further reasons to employ dynamic models that allow for lagged values include the following. First, backwardation may not affect hedgers' demand immediately. It may take several time periods to adjust risk management strategies to a change in backwardation. It is reasonable to assume that trading activity reacts more slowly to changes in prices than prices react to changes in trading activity. The speed and extent of traders' reactions to price changes may depend on psychological, technological, and institutional factors. Second, hedging demand might initially overreact to changes in backwardation. The VAR and VECM models are able to capture these dynamics.

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[12] Samuelson (1957, p. 194) points out that "(...) the total long position (of hedgers and speculators) must be exactly matched, at the equilibrium pattern, by the total short position (of hedgers and speculators)." See also Danthine (1978), Anderson and Danthine (1983) and Fort and Quirk (1988) for more information on backwardation and speculation.

[13] Note that, in addition of representing a risk premium, there are several alternative explanations of backwardation including the cost of carry, convenience yield, and capacity constraints. In fact, while the "(...) risk premium is unobserved (...)" (Inci and Lu, 2007, p. 181; see also Longstaff, 2000), "backwardation is an observable statistic (...)" (Frechette and Fackler, 1999, p. 761). Therefore it may be misleading to use the terms backwardation and risk premium interchangeably.

2.3.2 Vector Autoregression and Vector Error Correction Analysis

In order to check the stationarity properties of the series, augmented Dickey Fuller (ADF) tests with one lag and Kwiatowski, Phillips, Schmidt and Shin (KPSS) tests are carried out. The results indicate that several series, especially $AUD-Short$, $AUD-BW$, $EUR-Short$, $EUR-BW$, and $MXP-Short$ are integrated of order one (i.e., $I(1)$). Table 2.2 presents the results of the ADF and KPSS tests for the levels of the series and for the corresponding first differences (i.e., ADF-$I(1)$ and KPSS-$I(1)$). The levels of at least some of the variables are non-stationary, while taking first differences of the variables induces stationarity. The ADF-$I(1)$ and KPSS-$I(1)$ tests clearly suggest that all series are stationary.

Because at least some of the variables are integrated of order one, the next step in the analysis is to determine the cointegration properties of the variables. Table 2.3 presents the results of Johansen trace tests. The number of cointegrating ranks is determined sequentially. If the hypothesis that there are no cointegrating ranks ($r=0$) is rejected, the analysis proceeds by testing for a cointegrating rank of one ($r=1$). According to Lütkepohl (2004), the following decision rules apply: Choose a VAR model in first differences if the first null hypothesis ($r=0$) cannot be

Table 2.2 Unit root tests

	ADF	KPSS	ADF-$I(1)$	KPSS-$I(1)$		ADF	KPSS	ADF-$I(1)$	KPSS-$I(1)$
					AUD				
Short	−0.9648	5.8098	−5.8886	0.0179	*BW*	−1.0887	5.8227	−15.2805	0.0089
Long	−1.8793	4.5654	−13.6720	0.0200	*BS*	−3.2506	2.0713	−15.4664	0.0109
					CAD				
Short	−1.7217	15.8062	−21.2685	0.0103	*BW*	−2.1031	14.9800	−23.7622	0.0735
Long	−2.9445	5.2036	−20.4193	0.0056	*BS*	−6.7597	3.2904	−24.7462	0.0195
					CHF				
Short	−3.7598	3.4793	−21.2730	0.0054	*BW*	−3.1524	13.1601	−24.2683	0.0308
Long	−2.9107	1.3423	−20.6706	0.0080	*BS*	−5.4092	3.5265	−24.3232	0.0118
					EUR				
Short	−1.4393	8.8683	−16.0090	0.0151	*BW*	−1.5966	3.0126	−20.7061	0.0063
Long	−1.9690	8.4793	−15.5425	0.0175	*BS*	−5.6774	4.0669	−20.9346	0.0099
					JPY				
Short	−2.6556	15.8938	−20.7894	0.0062	*BW*	−4.2248	9.1204	−22.8943	0.0120
Long	−1.9274	8.2294	−21.4288	0.0096	*BS*	−4.8501	3.1897	−22.8242	0.0081
					MXP				
Short	−1.1841	8.1529	−15.2272	0.0724	*BW*	−3.3479	18.8028	−19.0308	0.0284
Long	−1.7611	2.7243	−18.7324	0.0213	*BS*	−4.7321	15.8992	−18.9982	0.0273

Note: ADF and KPSS are the test statistics of the augmented Dickey Fuller and the Kwiatowski, Phillips, Schmidt and Shin test. The ADF test rejects the null hypothesis of nonstationarity if the test statistic is negative and the absolute value of the test statistic exceeds the critical value of the respective significance level: 1%: −2.56; 5%: −1.94; 10%: −1.62. The KPSS test rejects the null hypothesis of stationarity if the test statistic exceeds the critical value of the respective significance level: 1%: 0.739; 5%: 0.463; 10%: 0.347. For more information on the test statistics, see Lütkepohl and Krätzig (2004)

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Table 2.3 Tests for cointegrating rank

		Short						*Long*					
		Lags	H0	LR	pval	90%	95%	Lags	H0	LR	pval	90%	95%
AUD	*BW*	2	0	35.73	0.0001	17.98	20.16	3	0	27.20	0.0038	17.98	20.16
			1	7.41	0.1085	7.60	9.14		1	8.08	0.0810	7.60	9.14
	BS	2	0	42.39	0.0000	17.98	20.16	2	0	56.57	0.0000	17.98	20.16
			1	7.42	0.1084	7.60	9.14		1	9.49	0.0426	7.60	9.14
CAD	*BW*	2	0	71.67	0.0000	17.98	20.16	2	0	97.99	0.0000	17.98	20.16
			1	20.01	0.0002	7.60	9.14		1	34.77	0.0000	7.60	9.14
	BS	2	0	65.27	0.0000	17.98	20.16	2	0	105.25	0.0000	17.98	20.16
			1	19.82	0.0002	7.60	9.14		1	36.24	0.0000	7.60	9.14
CHF	*BW*	3	0	99.04	0.0000	17.98	20.16	3	0	85.04	0.0000	17.98	20.16
			1	41.14	0.0000	7.60	9.14		1	30.03	0.0000	7.60	9.14
	BS	3	0	92.56	0.0000	17.98	20.16	3	0	81.80	0.0000	17.98	20.16
			1	39.08	0.0000	7.60	9.14		1	25.51	0.0000	7.60	9.14
EUR	*BW*	2	0	91.58	0.0000	17.98	20.16	3	0	64.80	0.0000	17.98	20.16
			1	19.29	0.0003	7.60	9.14		1	21.52	0.0001	7.60	9.14
	BS	3	0	51.20	0.0000	17.98	20.16	3	0	43.53	0.0000	17.98	20.16
			1	12.61	0.0096	7.60	9.14		1	19.80	0.0002	7.60	9.14
JPY	*BW*	3	0	94.57	0.0000	17.98	20.16	3	0	109.54	0.0000	17.98	20.16
			1	23.01	0.0000	7.60	9.14		1	21.59	0.0001	7.60	9.14
	BS	3	0	88.39	0.0000	17.98	20.16	3	0	84.69	0.0000	17.98	20.16
			1	25.32	0.0000	7.60	9.14		1	22.33	0.0001	7.60	9.14
MXP	*BW*	1	0	43.77	0.0000	17.98	20.16	3	0	41.18	0.0000	17.98	20.16
			1	5.61	0.2310	7.60	9.14		1	15.26	0.0026	7.60	9.14
	BS	1	0	55.88	0.0000	17.98	20.16	3	0	50.38	0.0000	17.98	20.16
			1	5.57	0.2349	7.60	9.14		1	15.58	0.0022	7.60	9.14

Note: In each case the lag length is chosen using the Akaike, Hannan-Quinn, and Schwartz information criteria. H0 represents the null hypothesis that the cointegrating rank r is 0 or 1, respectively. LR is the test statistics and pval is the p-value. 90% and 95% are the corresponding critical values

rejected. If $r = 0$ can be rejected but $r = 1$ cannot, a VECM model should be considered. If, however, all null hypothesis can be rejected, choose a VAR model in levels. Regarding the test results for the AUD and the $MXP - Short$ series, the Johansen trace tests reject the first null hypothesis ($r = 0$) of no cointegration whereas the null of $r = 1$ cannot be rejected. Therefore, following the decision rules, VECM models are chosen for the AUD and the $MXP - Short$ series. For the remaining series, VAR models in levels are chosen since all null hypotheses are rejected.

Table 2.4 presents the selected models, lag order, and Granger causality test results. The results of the Granger causality tests point to a significant impact of both weak and strong backwardation on short and long hedging activity. Most of the p-values are smaller than 0.05, indicating causal relations between backwardation and hedging activity. For 18 out of the total of 24 investigations, using a 5% significance level, the noncausality null hypothesis can be rejected. The next step in the analysis is to check whether the empirical results are consistent with economic theory.

Table 2.4 Lags and Granger causality test

		Short				*Long*			
		Model	Lags	Test value	p-value	Model	Lags	Test value	p-value
AUD	*BW*	VECM	1	1.9156	0.1484	VECM	3	8.0633	0.0000
	BS	VECM	1	2.3132	0.1000	VECM	1	13.9600	0.0000
CAD	*BW*	VAR	2	4.2170	0.0149	VAR	2	12.4582	0.0000
	BS	VAR	2	0.0112	0.9889	VAR	2	0.0812	0.9220
CHF	*BW*	VAR	3	21.3415	0.0000	VAR	3	21.6060	0.0000
	BS	VAR	3	13.3164	0.0000	VAR	3	16.0179	0.0000
EUR	*BW*	VAR	2	12.4326	0.0000	VAR	3	8.4114	0.0000
	BS	VAR	2	0.8242	0.4390	VAR	2	0.7981	0.4506
JPY	*BW*	VAR	3	36.8745	0.0000	VAR	3	45.7324	0.0000
	BS	VAR	3	32.2219	0.0000	VAR	3	41.7792	0.0000
MXP	*BW*	VECM	10	1.9845	0.0269	VAR	3	13.1686	0.0000
	BS	VECM	10	1.9911	0.0263	VAR	3	12.7187	0.0000

Note: In each case the lag length is chosen using the Akaike, Hannan-Quinn, and Schwartz information criteria

Figures 2.1 and 2.2 present the responses of short and long hedging activity to shocks in weak and strong backwardation. Again, economic theory suggests that, with growing backwardation, hedgers' demand for short futures contracts should be reduced and hedgers' demand for long futures contracts should increase. The impulse response functions reveal whether changes in weak and strong backwardation have a positive or negative effect on short and long hedging activity.

Considering the signs of the responses presented in Figs. 2.1 and 2.2, the empirical results do not unambiguously support the negative relation between backwardation and the trading volume of hedgers in short futures contracts as discussed in the theoretical hedging literature. Regarding the impact of weak backwardation on short hedging activity, the AUD, CAD, CHF, and EUR series show a positive response. The response of the JPY series reveals positive overshooting before turning negative after about 12 periods. Only the MXP series shows a negative effect of weak backwardation on short hedging activity, after an initial small positive reaction.

In contrast, the results for strong backwardation and short hedging activity are more significant. Here, four out of six responses (AUD, CHF, JPY, and MXP) indicate a negative impact of strong backwardation on short hedging activity after an initial overshooting. Moreover, for the remaining two series (CAD and EUR) the null hypothesis of no Granger causality cannot be rejected.

The results for long hedging activity and weak backwardation undoubtedly indicate a positive influence and, therefore, support the relation suggested by economic theory, even though two series (AUD and MXP) reveal initial negative overshooting. However, the results concerning strong backwardation and long hedging activity cannot support these findings. Only the EUR and MXP series show a positive response in the long run.

Summing up, six out of 12 responses of short hedging and eight out of 12 responses of long hedging are consistent with economic theory. Although the

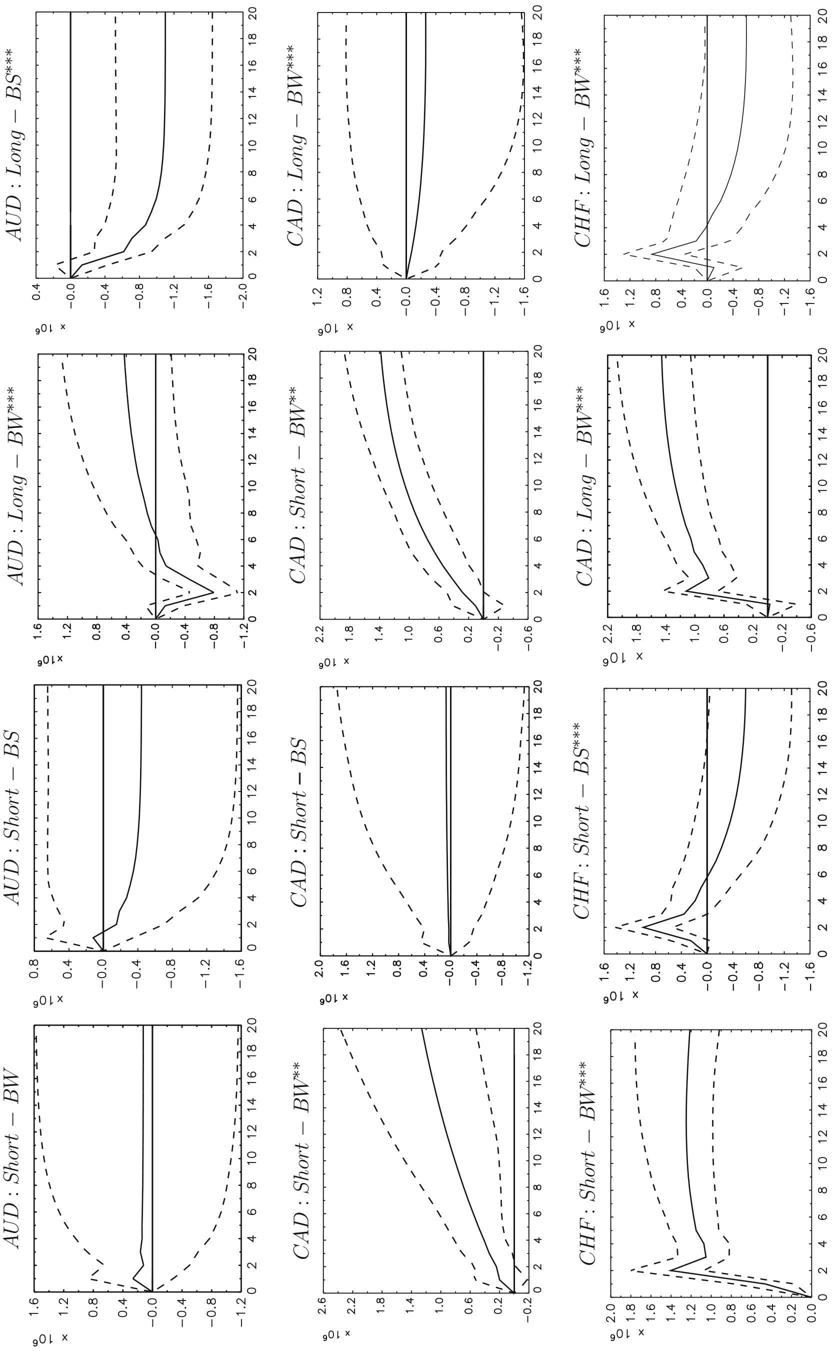

Fig. 2.1 Impulse response functions: Effects of weak (*BW*) and strong (*BS*) backwardation on short (*Short*) and long (*Long*) hedging activity. *Asterisks* *, **, and *** indicate that the null hypothesis of no Granger causality can be rejected on the 10%, 5%, and 1% levels, respectively

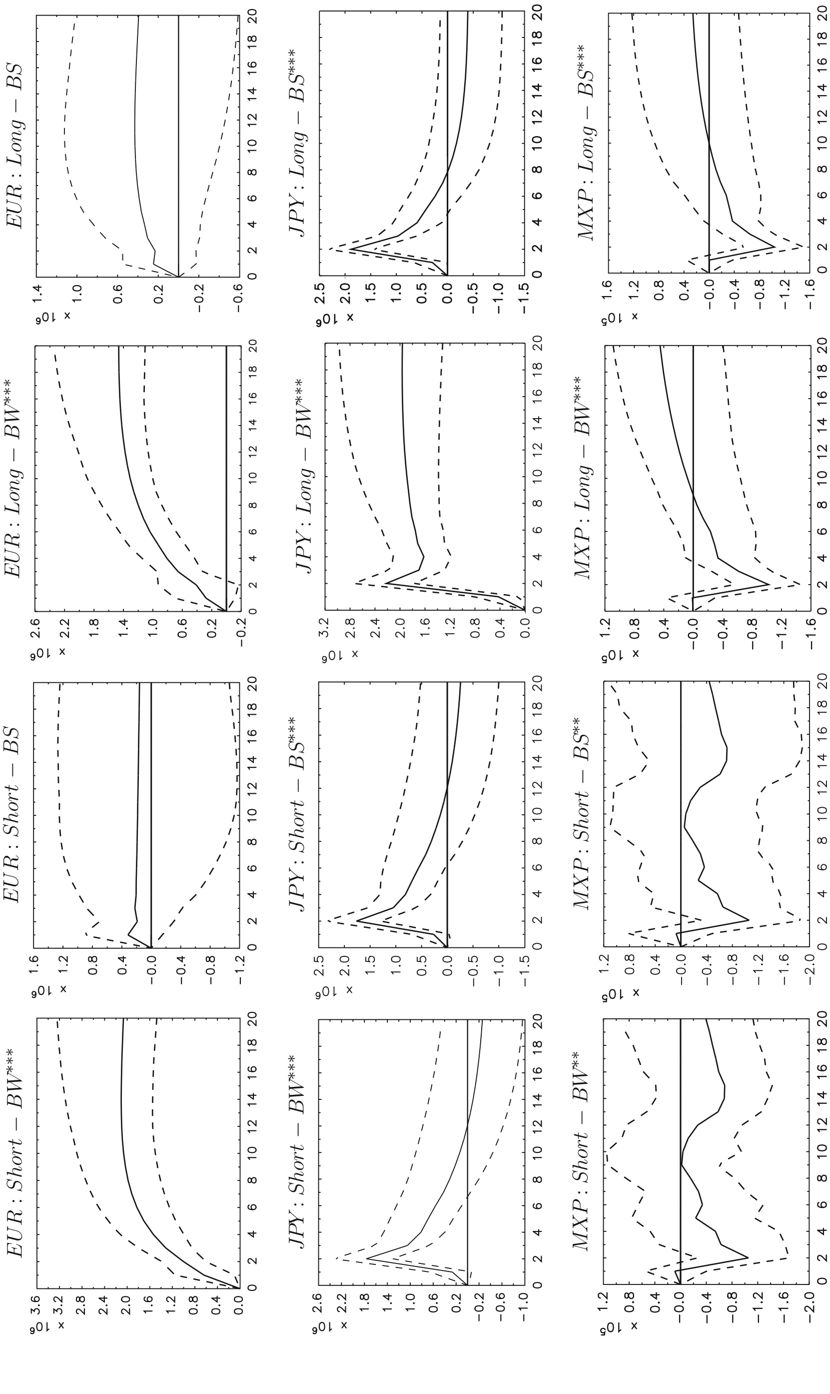

Fig. 2.2 Impulse response functions (continued): Effects of weak (*BW*) and strong (*BS*) backwardation on short (*Short*) and long (*Long*) hedging activity. *Asterisks* *, **, and *** indicate that the null hypothesis of no Granger causality can be rejected on the 10%, 5%, and 1% levels, respectively

Table 2.5 Diagnostic tests

		Short				*Long*			
		Port	LM	ARCH-LM	LJB	Port	LM	ARCH-LM	LJB
AUD	*BW*	0.3609	0.3767	0.2188	0.0000	0.1714	0.2105	0.1330	0.0000
	BS	0.2680	0.5542	0.5880	0.0000	0.0000	0.0035	0.0280	0.0000
CAD	*BW*	0.0001	0.0000	0.0000	0.0000	0.0008	0.0011	0.0429	0.0000
	BS	0.0336	0.0002	0.0000	0.0000	0.0131	0.0002	0.0350	0.0000
CHF	*BW*	0.0001	0.2331	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	BS	0.0416	0.4304	0.0000	0.0000	0.0155	0.0066	0.0000	0.0000
EUR	*BW*	0.0524	0.0001	0.7007	0.0000	0.0700	0.0000	0.4392	0.0000
	BS	0.0349	0.0003	0.6213	0.0000	0.0578	0.0035	0.6277	0.0000
JPY	*BW*	0.0000	0.0465	0.0000	0.0000	0.0000	0.0077	0.0000	0.0000
	BS	0.0021	0.0158	0.0001	0.0000	0.0043	0.0013	0.0226	0.0000
MXP	*BW*	0.0000	0.0000	0.0020	0.0000	0.1972	0.3772	0.0524	0.0000
	BS	0.0000	0.0000	0.0028	0.0000	0.6040	0.5719	0.0639	0.0000

Note: Port and LM are the Portmanteau (10 lags) and Breusch–Godfrey Lagrange Multiplier tests (2 lags) for autocorrelation. ARCH-LM is the multivariate ARCH-LM test (5 lags). LJB is the Lomnicki–Jarque–Bera test for nonnormality

empirical results for long hedging are better than the results for short hedging, this empirical investigation offers little support for the hypotheses suggested by economic theory.

A series of diagnostic tests for autocorrelation, nonnormality, and ARCH effects in the residuals are conducted and the p-values of the tests are presented in Table 2.5. The results of the diagnostic tests are not all fully satisfactory. For example, the results for $CAD - Short$, $CAD - Long$, $CHF - Long$, $JPY - Short$, $JPY - Long$, and $MXP - Short$, all reject the respective null hypotheses of no autocorrelation, no ARCH and normality. The problem of autocorrelation in the residuals might be solved by using a model in first differences rather than in levels. However, this would contradict the decision rules applied in the context of the Johansen trace test. A second potential solution is to include more lags into the analysis. This, however, may result in imprecise coefficient estimates if the lag order is chosen too large.[14] Moreover, the lag structure is chosen by employing the Akaike, Hannan-Quinn, and Schwartz information criteria and should therefore not be altered.[15] According to Lütkepohl (2004, p. 131), the remaining ARCH found in several residuals may not be a big problem "(...) if the linear dependencies are of major concern (...)". The rejection of normality may be caused by few very extreme residuals. Because of the large sample sizes in this study the violation of the normality assumption should

[14] See e.g., Lütkepohl (1990).

[15] Note that a number of specifications of VAR and VECM models have been applied to the data, yielding results similar to the ones presented in the text. For more information on residual autocorrelation, VARs, and VECMs, see e.g., Brüggemann (2006) and Brüggemann, Lütkepohl, and Saikkonen (2006).

be inconsequential due to a central limit theorem.[16] Since the main purpose of this chapter is to investigate the sign of the impact of backwardation on hedging activity, the empirical results are still sufficient. With respect to diagnostic tests, Ericsson (1999, p. 42) argues that the "(...) rejection of the null does not imply the alternative. Even so, test rejections are informative by demonstrating that the model can be improved." However, finding potential directions of improvement will be left for future research.

2.4 Discussion

This chapter investigates the impact of backwardation on long and short hedging activity in currency futures markets. First, the optimal long hedging strategy of an importer exposed to currency risk is derived in an expected utility framework with and without hedging costs. The model suggests that it is optimal for the long hedging importer to overhedge (underhedge) if the futures market exhibits backwardation (contango). The importing firm hedges fully if the futures market is unbiased. However, in the presence of hedging costs, the firm hedges fully if the futures market is characterized by backwardation. Therefore, hedging costs provide a rationale for backwardation to exist. Irrespective of whether hedging costs are introduced into the model, backwardation has a positive impact on the size of the firm's optimal long hedging position.

The empirical part of this chapter investigates the relationship between backwardation and hedgers' demand for six currency futures contracts, using vector autoregressive and vector error correction models. The summary statistics suggest that backwardation and contango are indeed normal in currency futures markets, as proposed by Keynes (1930). However, the hypothesis of a negative (positive) impact of backwardation on short (long) hedging activity cannot be supported.

The contribution of this chapter is threefold. First, the hedging problem of the representative exporter, examined by Holthausen (1979) and Briys and Schlesinger (1993), is extended to the hedging problem of an importer. Second, hedging costs are found to provide a rationale for backwardation to be normal. Finally, the impact of backwardation on long and short hedgers' trading volume in currency futures markets is investigated empirically. To the best of our knowledge, this is the first study to directly regress hedgers' position data from the Commitments of Traders (COT) report on two measures of backwardation. However, the results offer little support for the hypotheses suggested by economic theory.

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[16] See e.g., Brooks (2002) for a detailed discussion on how to deal with autocorrelation, heteroscedasticity, and nonnormality.

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Microeconomic Risk Management and Macroeconomic Stability
Röthig, A.
2009, XVI, 144 p. 49 illus., 5 illus. in color., Softcover
ISBN: 978-3-642-01564-9