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Commodity futures markets: a survey[†]

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This review article describes the main contributions in the literature on commodity futures markets. It is argued that modern studies have focused primarily on technical questions, with insufficient economic content. More research needs to be directed towards understanding fundamental economic issues such as why so few farmers hedge, the impacts of government farm programs on commodity futures, and the market impacts of commodity pools. The literature has failed to explain the prevalence of inverted markets in grains and oilseeds, and there is unexplainable price volatility in markets such as hogs and orange juice.

1. Introduction

This survey will confine itself primarily to the literature on commodity futures, with only brief mention of the large literature on two related topics, financial futures and options on futures. In a well-known literature survey on commodity futures research, Gray and Rutledge observed that, ‘Anyone who undertakes a survey of the literature on futures trading is confronted with an amorphous and rather disjointed list of publications’ (1971, p. 57). Their observation was made almost thirty years ago and it is even more valid today. Therefore, I begin with the caveat that a literature review of the sort attempted here is necessarily incomplete. Futures trading volume in the United States alone has increased about twentyfold since the early 1970s and the trade volume growth has been even more rapid in the rest of the world combined. It seems that the volume of academic literature has increased proportionately to futures trade volume, if not more rapidly.

As testimony to the large literature base that now exists, the *Journal of Futures Markets* was initiated in 1981 and has since published over 700 articles. However, the following editorial comment by Mark Powers, which

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recently appeared in the *Journal of Futures Markets*, implies that many of these 700 articles have failed to further our basic understanding of futures markets.

> A recently completed review by the Editor suggests that many of the submissions to *The Journal of Futures Markets* are on narrow topics which neither reflect the breadth of interests of the readers of the Journal nor address the most important problems facing the futures and derivatives industry. Perhaps some authors have interpreted the historical record of published articles as implying that the Journal is interested only in such narrowly focused topics. This comment is intended to encourage submissions on a broader range of topics.
>
> The work done by some of the pioneers in futures research, like Holbrook Working, Roger Gray, Tom Hieronymus, Allen Paul, and Henry Bakken, was based on an in-depth understanding of economic institutions (sometimes using case studies), an appreciation of the major problems facing the industry, and a careful analysis of relevant data. Their work provided a rich literature that found its way into classroom lectures, agricultural extension efforts and public policy debates.
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> Today, similar efforts are needed to address a broad range of issues related to finance, law, accounting, exchange management, and regulation in futures (and related derivative) markets. These markets are increasingly international and growing steadily more complex. Deeper insights are needed into the structure, conduct, and performance of the industry; the purpose, relevance, costs, and benefits of the regulatory structures; the implications of legal decisions and tax and accounting rules on market efficiency; market usage, and risk management; the internationalization of futures and derivative products; and many other issues.
>
> (Powers 1994)

This quote suggests that much of the recent literature on futures markets fails to address fundamental broad-based issues in the industry. It is a pretty harsh criticism coming from the editor of a journal devoted to the study of futures markets. While his comments may not apply to published work on futures markets in other journals, his observation is relevant to the bulk of the recent published literature on futures markets. In other journals, obvious exceptions to this critique include outstanding papers such as those by Fama and French (1987) and Hartzmark (1987).

Gray and Rutledge (1971) provide the most comprehensive survey on futures markets ever published. Topics covered in their review include evolutionary aspects of futures markets, inter-temporal price relationships, concepts of hedging, price variability, and the stochastic nature of price fluctuations. Goss and Yamey (1978), Tomek and Robinson (1977), Kamara

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(1982), Blank (1989), and Malliaris (1997) have subsequently written other surveys. Leuthold and Tomek (1980) surveyed papers on livestock futures. Subsequent to Gray and Rutledge, the most comprehensive survey is that by Kamara.

Gray and Rutledge began with a discussion of the evolutionary aspects of futures markets, and the latest development in the industry at the time was trading in non-storable commodities (e.g., livestock futures). Gray and Rutledge outlined the most important questions addressed by the literature surveyed, and they defined remaining unanswered academic questions. At the time of their survey, futures trading was mostly confined to agricultural products and a few contracts in metals.

The Keynesian theory of *normal backwardation* was one of the earliest theories of inter-temporal futures prices and it postulated that futures prices are biased estimates of forthcoming cash prices because hedgers must compensate speculators for assuming the price risk of holding futures contracts. Subsequently, Working (1949) developed the idea that the primary function of commodity futures markets was the provision of returns for storage services, and he viewed inter-temporal prices as the jointly determined price of storage. Gray and Rutledge suggested that Working's theory was the most important contribution to the theoretical understanding of futures markets, and I believe this remains true even today. Gray and Rutledge also argued that the theory of normal backwardation had received far too much attention in the literature. On this point, they quote Gray as follows: 'Understanding futures markets, with all due respect to the masters, is more important than supporting or refuting the Keynesian hypothesis of normal backwardation' (1971, p. 75). Subsequent researchers did not accept Gray and Rutledge's advice on this point, as the backwardation question has been countlessly revisited in the literature. More on this later.

Gray and Rutledge clarified the modern view of hedging developed by Working. In essence, this view rejected risk reduction as the sole motive for hedging and emphasised hedging with a motive of earning returns. In the 1950s, Holbrook Working (1953) categorised alternative motives for commercial hedging in commodity futures and these categories continue to be valid today. The three broad categories are arbitrage hedging, operational hedging, and anticipatory hedging. An *arbitrage* hedge is sometimes referred to as a *carrying-charge hedge*. Since the futures and cash price converge in the delivery month, a commercial firm can 'arbitrage' the two markets and earn a risk-free return from the predictable change in the *basis* — the mathematical difference between the futures and cash price. *Operational* hedging facilitates commercial business by allowing firms to buy and sell on the futures markets as temporary substitutes for subsequent cash market

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transactions. This use of futures markets provides firms with an avenue for being flexible in day-to-day operations and reducing price risk. Profiting from a change in the basis does not figure as prominently as an objective with this type of hedge. *Anticipatory* hedges involve buying or selling futures contracts by commercial firms in 'anticipation' of forthcoming cash market transactions. Price expectations play an important role with this type of hedge.

At the time the Gray and Rutledge paper was written, the portfolio explanation of hedging was relatively new. Gray and Rutledge indicated the portfolio approach had some promise, but they were careful to withhold judgement as to its usefulness, given the lack of empirical studies available at the time. Later on, Gray (1984) criticised studies that used the portfolio approach to estimate optimal hedge ratios.

Gray and Rutledge suggested that 'a persistent question in the literature on futures trading is, what is its effect on price variability?' (1971, p. 85). They found that insufficient work had been done on this question, in particular with regard to the futures contracts for non-storable commodities, introduced in the 1960s. However, for storable commodities they found the evidence, on balance, suggested that futures have a stabilising effect on cash prices, suggesting that seasonal variation in cash prices tends to be dampened with a futures market.

Gray and Rutledge identified the following questions that had only been 'touched upon' in the literature at the time of their survey:

- direct usefulness of futures markets for primary producers;
- usefulness of futures trading for less developed countries;
- price relationships for non-storable commodities;
- the significance of alternative approaches to speculation; and
- the usefulness of the portfolio approach to hedging.

Since the Gray and Rutledge paper, the first two questions have not received the same attention in the literature as the last three questions on their list.

Leuthold and Tomek (1980) explained that semi-perishables (e.g., butter, eggs, onions, potatoes) were traded at the turn of the century but the introduction of trading in nonstorables such as live hogs and live cattle in the 1960s was a watershed for the industry. They surveyed research on the following questions in the livestock futures literature:

- futures price behaviour; effect of futures on cash and basis relationships;
- hedging use of livestock futures; and
- miscellaneous questions such as who uses futures.

Leuthold and Tomek argued that since futures prices for nonstorables are not being used to allocate inventories, forward pricing is an important

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economic justification for these markets. They pointed out that some farmers remain concerned about the alleged adverse influence of futures trading.[1]

After surveying the literature in 1982, Kamara came up with the following conclusions:

- The behaviour of the basis for storable commodities is well understood, unlike for nonstorables.
- Futures prices for some storable commodities provide reliable forecasts of cash prices, but for nonstorable commodities futures prices are mostly inaccurate as forecasts.
- Statistical analysis of futures price behaviour has found weak evidence of serial correlation.
- The distribution of futures prices is best described as a mixture of two normal distributions.
- Empirical estimates of equilibrium pricing models have found that futures prices are biased estimates of spot prices.
- Futures markets tend to stabilise cash prices; and
- There is only weak evidence of the existence of normal backwardation, and therefore hedgers are able to transfer price risk to speculators with little cost.

In this article, the classic pieces surveyed by Gray and Rutledge (1971) are not discussed in depth. Instead, the key findings in the literature since the time of Gray and Rutledge (1971) are summarised. The focus is on issues that have been settled in the literature since the 1970s and questions that are still open. In section 2, evolutionary aspects *post* Gray and Rutledge are highlighted. In sections 3 through 5, important questions confronted by the literature are outlined. Section 3 reports on both theoretical and empirical developments in the hedging literature. Commodity futures price behaviour is the topic attended to in section 4. The efficiency of futures markets and the

[1] This observation by Leuthold and Tomek was indeed accurate. A certain amount of scepticism remains among farm groups regarding the merits of futures trading. This is perhaps most prevalent in livestock, where the processing industry is highly concentrated (in the United States). For instance, there was a sharp decline in cattle prices in 1996 and some producers blamed the futures market. The United States General Accounting Office studied the issue and completed a report in November 1997. See the US GAO *Commodity Futures Trading: Purpose, Use, Impact, and Regulation of Cattle Futures Markets*, GAO/RCED-88-30, Washington, DC, November 1997. Contrary to the producer claims, the GAO found the cattle futures market was 'working fairly well and serving the traditional economic purpose of enhancing price discovery and facilitating risk shifting' (p. 3). The issue is not confined to livestock futures. For instance, in November 1979, the Coffee, Sugar, and Cocoa Exchange in New York perceived a cornering of its coffee futures market and it banned new positions for December delivery. See Barnhart, Kahl and Barnhart (1996).

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provision of price information are covered in section 5. In section 6, studies of futures pools, a relatively recent phenomenon, are considered.

2. Ongoing evolution of futures trading

The futures industry has grown by staggering proportions in the past three decades. As recently as the early 1970s, only about 30 million futures contracts were traded annually in the United States. By 1997, over 440 million contracts were traded — a thirteenfold increase.[2] Both inside and outside the United States, the increase in the trading of financial futures contracts has been particularly striking. For instance, the Sydney futures exchange was originally established in 1960 as a greasy wool futures exchange but today agricultural futures (wool and wheat) account for less than 1 per cent of trade volume on that exchange. Worldwide, agricultural commodities now account for less than 10 per cent of total futures and options trading volume.

Not only has the overall volume of trading increased steadily, but many innovative contracts, such as futures and options on Eurodollars and Treasury bonds, have also been developed. Today, the Eurodollar (on the Chicago Mercantile Exchange) has the largest share of trading volume on US exchanges, at 23 per cent. Treasury bonds contracts, traded on the Chicago Board of Trade, rank second in terms of total volume of all US futures and options contracts traded in 1997. The Eurodollar and T-Bond contract combined account for close to 45 per cent of trading volume. The number of different futures contracts traded in North America and worldwide continues to expand each year. Trade volume on US futures markets is now less than 40 per cent of total world trade volume, compared to about 80 per cent ten years ago.

Recently, equity index futures have also increased in importance, accounting for about 20 per cent of futures and options trading volume worldwide. Trading volume in equity indexes now exceeds trading volume in agricultural commodities. For instance, the Standard and Poor's (S&P) 500 stock index (traded on the Chicago Mercantile Exchange) is the fifth most active US futures contract. In 1997, the Chicago Board of Trade started trading the Dow Jones Industrial Average (DJIA) futures index, in competition with the S&P 500 index.

Some of the latest innovations in agricultural futures contracts include the Chicago Mercantile Exchange's cheddar cheese futures, which started

[2] In the bimonthly magazine *Futures Industry*, the Futures Industry Association (http://www.fiafii.org/) in Washington, DC, publishes volume and open interest data for worldwide futures and options contracts.

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trading in 1997. The cheese contract is cash-settled, so actual delivery or taking of delivery is not possible. Although no longer controversial, the issue of cash settlement was contentious at one time when the Chicago live cattle futures contract was converted to cash settlement (Kahl, Hudson and Ward 1989).

Most of the US futures markets, with the exception of the Philadelphia Board of Trade, also trade options on futures contracts. Like futures markets, options have a long history, albeit a more tattered one. Options (or privileges) traded in grains from about the 1840s until the 1930s. Options were blamed for the excessive volatility of grain prices before the Great Depression and the eventual collapse of prices in the early 1930s. The futures exchanges did not have strict control over options trading, which was often conducted away from the futures trading floor. As a result, the US Congress banned options trading on agricultural commodities in 1936. It wasn't until 1981 that the Commodity Futures Trading Commission (CFTC) approved options for a very limited number of futures contracts, including gold, sugar, and Treasury bonds. In 1984 several more agricultural options were introduced under a three-year pilot-trading project. This program included options on futures for corn, soybeans, live hogs, live cattle, wheat, and cotton. In January 1987, the CFTC judged the pilot trading successful, and it approved options trading on futures contracts. By 1997, options volume on US futures exchanges represented about 20 per cent of total US futures and options contract volume. The relative importance of options as a share of global futures and options volume was around 25 per cent in 1997.

The CFTC was introduced in 1974 and regulation of the futures industry was revamped at that time to cover the growing futures trading in non-agricultural contracts. Prior to 1974, US futures trading was regulated by the 1936 Commodity Exchange Act, which was administered by the US Department of Agriculture (Peck 1985). The National Futures Association is a self-regulatory industry organization that was established in 1981. The National Futures Association assumes some regulatory responsibility, on behalf of the CFTC.

Anderson (1986) discusses futures industry regulation in the United States and the United Kingdom. Pirrong (1993, 1995) has also written on various aspects of regulation of futures and options trading. For instance, he challenges the notion that government regulation of manipulative practices in futures markets is unnecessary (Pirrong 1995). He shows that the theoretical arguments underlying the efficiency of self-regulation are weak, and he finds that self-regulation is an inefficient means to reduce monopoly power in financial markets. Pirrong's conclusions are based on an examination of the history of self-regulation at ten different exchanges. Earlier, Pirrong (1993) specified both necessary and sufficient conditions for

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traders to manipulate futures prices at contract expiration, and he derives the welfare implications of manipulation. Pirrong describes markets where manipulation is most likely to occur, but his analysis is theoretical. Its empirical relevance remains an unanswered question.

3. Hedging

According to the theoretical literature, primary commodity producers (or even marketing boards or entire countries) stand to derive considerable price risk reduction benefit from hedging with either futures contracts or forward cash contracts (Johnson 1960; Stein 1961; McKinnon 1967; Danthine 1978; Holthausen 1979; Feder, Just and Schmitz 1980; Anderson and Danthine 1983). This theory is corroborated with considerable empirical literature which has estimated either minimum variance hedge ratios or optimal hedge ratios (i.e., percentage of output to be hedged) and has found large potential risk reduction benefits from hedging (Heifner 1972; Peck 1975; Ederington 1979; Grant and Eaker 1989; Castelino 1992; Lence, Kimle, and Hayenga 1993).

However, both the theoretical and empirical literature appears to contradict reality because very few primary producers actually hedge (Helmuth 1977; Berck 1981; Brorsen, 1995). For example, a 1977 survey by the Commodity Futures Trading Commission (CFTC 1978) found that only about 7 per cent of US grain farmers use futures, and many of these farmers were speculating rather than hedging. Only 20 per cent of the farmers surveyed by the CFTC had ever used forward contracting. In a 1993 survey of California farmers, Blank, Carter and McDonald (1997), studied commodities for which either futures or forward contracts were available. They found that only about 23 per cent of the surveyed farmers price their commodities through forward contracts and only 6 per cent hedge with futures contracts. Why do so few farmers hedge against price risk with either futures or forward contracts? This question has not been explicitly confronted in the literature. Brorsen and Irwin (1996) have argued that more work needs to be done using primary data on hedging activity for a better understanding of hedging issues.

3.1 Hedging theory

Hedging can be viewed quite simply as the process of simultaneously choosing futures positions and underlying cash positions in order to construct a portfolio of assets. Stein (1961) and Johnson (1960), who used the foundations of portfolio management, first rigorously presented a portfolio explanation of hedging. With this approach, a hedger is viewed as

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being able to hold several different cash and futures assets in a portfolio and is assumed to maximise the expected value of his utility function by choosing among the alternative portfolios on the basis of their means and variances. In a theoretical paper, McKinnon (1967) extended this concept and used a mean-variance objective function for the producer. In this framework, the objective function is: $\Theta = EU(\Pi) - (\lambda/2)V(\Pi)$, where, $EU(\Pi)$ is expected utility of profit (Π), $V(\Pi)$ is the variance of profit, and λ is the absolute risk aversion coefficient. McKinnon (1967) focused on the hedge decision (rather than the production decision) and calculated the optimal hedge ratio assuming minimum risk hedging.

Using an expected utility maximisation framework, but focusing on the production decision (rather than the hedge decision), Danthine (1978) incorporated the possibility of buying and selling futures contracts into the model of the competitive firm under price uncertainty. Holthausen (1979), and Feder, Just and Schmitz (1980), derived essentially the same results as Danthine. In the Danthine model, production is not risky and it is assumed there is no basis risk. He demonstrated that planned production responds positively to the current futures contract price and that changes in the subjective distribution of futures or spot prices do not lead to changes in production decisions. The firm copes with price uncertainty by participating in the futures market, where a certain price is substituted for an uncertain one, while optimal production is unaltered. The futures price is the driving force affecting producer production decisions. With a futures market, production decisions are shown to be independent both of the producer's degree of risk aversion and price expectations, and they are separable from the producer's 'portfolio problem' (i.e., just as under the Markowitz separation theorem). The optimal hedge in the Danthine-type model depends on the degree of risk aversion and the probability distribution of the forward price.

Anderson and Danthine (1983), and later Batlin (1983), showed that the 'separation' result in Danthine (1978), Holthausen (1979), and Feder, Just and Schmitz (1980) does not hold when either output or the basis is random. For example, when basis risk is present, changes in the subjective distribution of the forthcoming spot price lead to changes in the production decision.

Anderson and Danthine (1983) modified the McKinnon (1967) model to allow the simultaneous determination of hedging and production decisions. In a mean-variance framework, and with price, yield and basis risk, the Anderson-Danthine optimal hedge result is:

$$\frac{h^*}{E(q)} = \frac{\rho(s,f)\sigma(s)}{\sigma(f)} + \frac{\rho(q,f)\sigma(q)/E(q)}{\sigma(f)/E(s)} + \frac{F - E(f)}{\lambda E(q)\sigma^2(f)} \tag{1}$$

where h^* is the number of futures contracts ($h^* > 0$ indicates a short hedge);

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s, f, and q are random variables representing the spot price at harvest, harvest time futures price, and quantity produced, respectively; ρ is the correlation coefficient; σ is the standard deviation; F is the planting time futures price; and E is the expectation operator. The first term on the right-hand-side in equation 1 represents the effect of basis risk on the optimal hedge. From the first term, the higher the correlation between the spot price and futures price at harvest, the larger the optimal hedge, *ceteris paribus*. The impact of yield risk is captured by the second term, where we find the higher the correlation between harvest time futures price and production, the higher the optimal hedge. The numerator in the third term represents the extent to which futures prices are thought to be biased estimates of forthcoming spot prices. If there is no perceived bias, then this speculative component of the hedge ratio is zero.

Survey results have found that farmers prefer forward contracting to direct hedging with futures contracts (Blank, Carter and McDonald 1997). Forward contracts are a substitute for futures contracts, as both provide an opportunity to reduce price risk. However, from the producer's perspective, neither financial tool dominates the other as there are pros and cons of using one versus the other. Perhaps the one key distinguishing feature is the absence of basis risk with forward contracting (Miller 1986). As above, using the mean-variance framework, the first order conditions for forward contracting are:

$$\frac{q^*}{E(q)} = 1 + \frac{\rho(q,f)\sigma(q)/E(q)}{\sigma(s)/E(s)} + \frac{G - E(s)}{\lambda E(q)\sigma^2(s)} \tag{2}$$

where q^* is the quantity contracted and G is the cash forward contract price. Miller concluded that the absence of basis risk does not necessarily lead to higher levels of forward contracting relative to direct hedging with futures. This is true both theoretically and empirically.

3.2 Empirical results on hedging

There is an extensive empirical literature on hedging. This literature has focused on estimating two summary statistics: the optimal hedge ratio (i.e., the optimal futures position relative to the cash position) and the percentage reduction in price risk attainable from hedging. Results have varied widely but most studies find significant benefits associated with hedging. However, for some producers in some countries, the empirical evidence suggests hedging has limited benefits.

There are two standard formulas that have been developed for computing the optimal hedge ratio. Ederington (1979) and others have drawn on McKinnon (1967) and utilised the minimum risk hedge ratio. Alternatively

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there is the utility-maximising optimal ratio developed by Johnson (1960), and Heifner (1972). If the expected profit from holding futures contracts is zero, the utility-maximising optimal hedge then becomes equivalent to the risk-minimising hedge ratio (Heifner 1972; Kahl 1983).[3]

Empirical estimates of the optimal hedge ratios for commodities are often less than 100 per cent of the cash position. For example, Ederington (1979) has estimated that a hedger in the wheat market, who maintained 78 per cent of their wheat inventory hedged, would have reduced price risk by 84 per cent. Grant and Eaker's (1989) estimate shows a similar opportunity to reduce price risk for wheat, but their data covers a different time period and they calculate a hedge ratio closer to 1.0. Heifner (1972) found that one-third to one-half of the price risk in cattle feeding could be eliminated through hedging, with optimal hedge ratios ranging from 56 per cent to 88 per cent of production. Miller (1986) studied the soybean market and found the optimal forward contracting and optimal hedge ratios to lie between 50 per cent and 60 per cent of output. Carter and Loyns (1985) found that due to a high basis risk, there was little incentive for Canadian feedlots to hedge cattle on the Chicago futures market.

Hedging studies by Rolfo (1980) and Grant and Eaker (1989) were more comprehensive in that they examined optimal anticipatory hedges, by incorporating production risk into their model. Rolfo (1980) estimates a smaller optimal hedge for Brazil as a cocoa producer (45 per cent hedge ratio), but he studies national risk, rather than individual producer risk. Generalising from the cocoa example, Rolfo suggested production risk (and the negative covariance between production and price) as an explanation for the lack of hedging interest in the real world.

In the case of Australia, two papers have investigated whether or not there are potential benefits resulting from the Australian Wheat Board (AWB) hedging on the Chicago wheat market (Bond, Thompson and Geldard 1985; Sheales and Tomek 1987). The AWB began this hedging practice in 1982. It was an innovative step on the part of the Board as few marketing boards around the world hedged at that time, or even today. Bond *et al.* estimated that the high (offshore) basis risk faced by the AWB implied an optimal hedge ratio of only about 20 per cent, with presumably little benefit from hedging. Sheales and Tomek also found that the scope for reducing the AWB's variability of returns was very small through offshore hedging, but

[3] Heifner (1972) was the first to point out that the minimum-risk hedging ratio is equivalent to the optimal hedge ratio if the expected profit from holding a futures position is zero (i.e., futures prices are unbiased). Kahl (1983) elaborated on this finding. Twelve years after Heifner's paper was published, Benninga, Eldor and Zilcha (1984) claimed to discover this result, without any reference to either Heifner or Kahl.

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hedging on Chicago could give the Board additional flexibility in the timing of sales.

In 1996 the Sydney futures exchange introduced a new wheat futures contract. Simmons and Rambaldi (1997) estimated the optimal hedge ratio for Australian farmers using this new contract. They found the optimal hedge ratio to be near zero. Even though wheat farmers may not be too interested in hedging on the Sydney exchange, a study on wool futures predicts more interest on behalf of wool producers (ABARE 1997). The ABARE report suggests that about 45 per cent of wool producers could reduce their underlying price risk by 80 per cent if they hedge on the Sydney exchange.

In one of his books on futures markets, Jeffrey Williams (1986) points out that the portfolio theory of hedging has become a spectacular growth industry. Williams' comment is 'tongue-in-cheek' as he goes on to cast considerable doubt on the portfolio (mean-variance) approach to estimating optimal hedge ratios. Roger Gray (1984) has raised similar concerns. However, several authors have ignored the warnings from Gray and Williams, for instance see Liu and Rausser (1993). They add a small twist to the standard portfolio hedging model by considering the potential use of futures markets as an instrument of food security in a developing country. They set up a utility maximisation problem and derive the optimal hedging strategy using the portfolio approach. Basis risk and transactions costs are incorporated in the theoretical model. Liu and Rausser estimate optimal hedge ratios for the People's Republic of China and they conclude that China can reduce its risk of participating in the international grain and cotton markets by hedging on the futures market. Kawai and Zilcha (1986) have incorporated exchange rate uncertainty into the standard Danthine (1978) hedging model, but exchange rate risk is a moot point for developing countries, such as China, whose currency is non-convertible.

Hartzmark (1988) empirically tested the portfolio theory of hedging using CFTC weekly data on cash and futures positions held by large commercial hedgers. He specifically tested for risk-minimising behaviour in wheat and oats by comparing cash and futures positions with risk-minimising positions. Hartzmark found that the firms he studied adjusted their cash and futures positions in accordance with one another and that they did not adapt their expectations to changing market conditions. He therefore concluded the firms acted as though they were risk minimisers. In a related paper, Peck and Nahmias (1989) obtained different results. They analysed quarterly cash and futures market positions for a number of US flour mills combined. They calculated the recommended hedging strategies from portfolio theory (optimal and minimum risk hedges) and compared it to actual behaviour. Their results show little statistical relationship between either the optimal or

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the minimum risk ratios and actual hedge ratios. From this, Peck and Nahmias conclude the portfolio model has little practical relevance. Peck and Nahmias use more aggregate data than Hartzmark, and they analyse small long hedgers, compared to Hartzmark's sample of large short hedgers.

In an empirical study of soybean hedging, Miller and Kahl (1987) found negative correlation (−0.3 to −0.8) between yield and price for a sample of farms in Illinois. This suggests anticipatory hedges for Illinois soybean producers could involve simultaneous losses on both farm revenue and futures positions.

Sakong, Hayes and Hallam (1993) compare hedging with options versus futures. They set up a standard hedging model with both price and production uncertainty, and they find that the introduction of production uncertainty alters the optimal futures and options position and almost always makes it optimal for the producing firm to purchase put options. This result was already well known. Event risk has long been one of the standard reasons for hedging with options rather than futures (see Feiger and Jacquillat 1979). Stoll and Whaley explain:

> options not only provide insurance against price risk that is conditional on an event (receiving the bid, having a successful harvest, making the loan, making the stock offering) but also avoid any penalty if the event does not occur (the bid is rejected, the harvest is poor, the loan is not taken down, or the stock issue is not sold). It is in this sense that options provide protection against both price and quantity risk and are, therefore, a better hedging tool than futures contracts in some cases.
>
> (1985, p. 229)

Lapan, Moschini, and Hanson (1991) compare hedging with options versus futures with nonstochastic production. First, they show the well-known result that if futures prices and options premiums are unbiased, options are a redundant hedging device.[4] Then they go on to demonstrate that if prices are symmetrically distributed and if futures prices are biased, then options may be useful. Vercammen (1995) has generalised this result for the case of skewed price distributions.

Sephton (1993) estimated the optimal canola hedge ratio for simultaneous positions in futures and Winnipeg Commodity Exchange (WCE) cash markets. However, his empirical results are meaningless because Vancouver cash prices reported by the WCE do not reflect actual market transactions.

[4] Moschini and Lapan (1992) showed this result does not hold if some input decisions are made after the output price is realised.

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Sephton (1993) displays an unfamiliarity with the workings of the Winnipeg Commodity Exchange feed wheat and feed barley contracts. For instance, he argues that WCE feed wheat and barley prices are closely tied to international conditions, which is not true because these contracts are for domestic feed usage only and the Canadian Wheat Board export monopoly results in weak arbitrage between the world market and the domestic feed market.

3.3 Dynamic hedging models

Anderson and Danthine (1983), Marcus and Modest (1984), Ho (1984), and Hey (1987) first developed dynamic hedging models, which assume that producers can revise their hedge positions during the growing season. Anderson and Danthine assumed the size of the hedge is adjusted at discrete points in time, whereas Ho allowed for hedge positions to be continuously adjusted over time. Karp (1987) extended Anderson and Danthine's model by adding stochastic production. Karp (1988) subsequently developed a continuous model similar to Ho's. Myers and Hanson (1996) revert to assuming non-stochastic production but they studied the problem under more general assumptions on the utility function. They provide an alternative to Karp's optimal dynamic hedging rule. Anderson and Danthine's model assumed a single production cycle and this was extended by Lence, Sakong and Hayes (1994) who developed a two period dynamic hedging model and added options on futures.

Conceptually these dynamic models are more appealing than static hedging models. This is especially true for field crops with a long lag between planting and harvest, and considerable opportunity for updating hedging decisions. However, Martinez and Zering (1992) applied a dynamic hedging model (similar to Karp's 1987 model) to a hypothetical US corn producer and found the economic gains from a dynamic hedging strategy were small, compared to the old-fashioned fixed hedge position. This result is somewhat surprising.

Most futures contracts expire in less than two years. Therefore, in an attempt to hedge against long-term risk, firms sometimes choose to enter into sequential short-term hedges — rollover hedging. Rollover hedging is therefore a financial transaction where a firm attempts to use futures markets to hedge price risk far into the future (e.g. 3–10 years). The firm buys/sells futures contracts that are actively trading and then 'rolls over' these hedges in the most distant futures contracts as the old contracts mature. There is considerable controversy over this hedging procedure. Some argue that rollover hedging is not a sound financial strategy because it is too risky.

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The question is: does sequential short-term hedging, or rollover hedging, serve as a beneficial mechanism for long-term hedging in commodity markets? Presently, there are several international companies that use roll-over hedging. The German-based firm Metallgesellschaft used this technique in the oil market, but encountered huge financial losses. Why those losses accumulated is still a subject of debate (Edwards and Canter 1995). Alternatively, using simulation analysis, Gardner (1989) has found that rollover hedging can reduce risk for commodity firms in the case of cotton, soybeans and corn.

4. Price behaviour

The theory of price of storage (Kaldor 1939–40; Hawtrey 1939–40; Working 1948, 1949) and the theory of normal backwardation (Keynes 1923, 1930; Hicks 1946; Dusak 1973) have been embraced as the two most important theories of commodity price behaviour (Fama and French 1987). However, it should be noted that the theory of price of storage and the theory of normal backwardation are not necessarily mutually exclusive as the former can incorporate Keynes' notion of a risk premium as one component of the cost of holding stocks. However, in the literature, the relative importance of the risk premium is almost totally ignored by the theory of price of storage.

4.1 The theory of normal backwardation

An essay in the *Manchester Guardian Commercial* in 1923 by John M. Keynes initiated the concept of the theory of normal backwardation. In his view, futures prices are unreliable estimates of the cash or spot price prevailing on the date of expiry of the futures contract. He believed it 'normal' for the futures price to be a downward biased estimate of the forthcoming spot price. This theory, in effect, argues that speculators sell 'insurance' to hedgers and that the market is 'normally' inefficient because the futures price is a biased estimate of the subsequent spot price.

The theory of normal backwardation has been very controversial over the many years it has been debated in the literature. For instance Telser (1958) and Cootner (1960) both tested their interpretation of the theory of normal backwardation and obtained conflicting results even though they used the same data. Cootner found evidence to support the theory of normal backwardation, while Telser's conclusions were contrary. Several other writers have also tested the validity of the theory of normal backwardation. Rockwell (1967) and Kamara (1982) give a summary of the findings. The long-standing conclusion has been that the theory of normal backwardation

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may be valid for particular markets under special conditions, but it is not adequate as a general explanation of commodity price behaviour.

Dusak (1973) tested for the existence of a risk premium within the context of the capital asset pricing model. Following Cootner (1960), she viewed the futures price as comprising two components: an expected risk premium and a forecast of a forthcoming spot price. With this approach, she argues the Keynesian notion of a risk premium takes on a new interpretation, namely, the risk premium required on a futures contract should depend on the extent to which the variations in prices are systematically related to variations in the return on total wealth. If the capital asset pricing model applies, and if the risk of a futures contract is independent of the risk of changes in the value of all assets taken together, then investors will not have to be paid for that risk since they can diversify it away. The Keynesian 'insurance' interpretation, on the other hand, identifies the risk of a futures asset solely with its own price variability. Dusak tested for both types of risk in the futures market, and her results suggest that wheat, corn, and soybeans futures contracts are not risky assets whether they are held independently or as part of a larger portfolio of assets.

Carter, Rausser and Schmitz (1983) extended Dusak's approach to account for seasonal changes in net hedging pressure and to include commodities in the investor's well-diversified portfolio. They estimated non-market and systematic risk as time-varying parameters to evaluate the importance of seasonal changes in investors' positions. Carter *et al.* found some evidence of systematic risk. More importantly, they found evidence of non-market risk that varies seasonally. Marcus (1984) criticised Carter *et al.* for over-weighting commodities in the well-diversified portfolio and showed that with a reduced weighting the hypothesis of zero systematic risk cannot be rejected. This is not surprising because it is essentially a restatement of the Dusak result. The Carter *et al.* finding of seasonality of non-market risk was independent of the debate over how much weight to give commodities in the investor's portfolio. Their finding of time-varying non-market risk encouraged subsequent work to apply more general non-static models of the pricing of futures contracts. For instance, Fama and French (1987) also test for a time-varying risk premium in futures prices.

Hartzmark (1987) analysed actual profit and loss data and found little empirical support for the theory of normal backwardation. His study showed that large commercial agricultural firms (hedgers) earn substantial profits from futures trading in some markets, which suggests that they do not pay a risk premium to speculators. However, he did find that some individual speculators do earn profits on a regular basis. This is an interesting and valuable paper, largely because it used actual trading histories of individual futures traders. In a follow-up study, Hartzmark (1991) attempted to answer

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the question as to why certain futures traders earn positive profits and others sustain losses. Hartzmark found that it is inherent luck that largely determines trader performance. This result seems less plausible than his 1987 finding.

Modern financial theory has been used widely to examine the question of the Keynes–Hicks risk premia in futures market contracts, explained by the theory of normal backwardation. Ehrhardt, Jordan and Walking (1987) and Park, Wei and Frecka (1988) used arbitrage pricing models with the factors approximated through factor analysis from a range of commodity futures returns data. They conclude that there are no risk-premia, though Park *et al.* find an unsystematic influence on expected returns. Two more recent studies use multi-beta asset pricing models with pre-specified economic factor state variables similar to those used by Chen, Roll and Ross's (1986) study of capital market assets: Young (1991) finds evidence that the unexpected change in the term structure of interest rates and unexpected inflation entails some systematic risk in corn, though not in wheat and soybeans. Young does not reject the zero intercept condition that expected returns are unrelated to unsystematic risk. Bessembinder (1992) finds some evidence of risk premia in live cattle, soybeans, and cotton, yet far less than in nonagricultural financial futures returns such as Treasury bills. As an alternative to asset pricing models, Chang (1985) used nonparametric tests and found the existence of a risk premium for wheat, corn and soybeans. Fama and French (1987) studied monthly returns for 21 commodities and found weak statistical evidence of an average risk premium. They conclude:

> When commodities are combined into portfolios, statistical power is increased and marginal evidence of normal backwardation is obtained. But the evidence is not strong enough to resolve the long-standing controversy about the existence of nonzero expected premiums.
>
> (1987, p. 72)

Kolb (1992) used a similar methodology to study daily returns for 29 commodities and he found that most commodities do not exhibit a risk premium. Prior research results are therefore mixed about whether there is low systematic risk or none, and whether there is normal backwardation. However, these studies analyse whether unconditional average returns are consistent with unconditional average risk premia and required returns.

Bessembinder and Chan (1992) take a new approach and study commodity futures returns in a conditional latent variable model with time-varying risk premia. Their study stems from a large body of evidence that expected bond and equity returns vary in relation to risk premia that vary with changing economic conditions (e.g., Fama and French 1989; Ferson and Harvey 1991). This is consistent with efficient markets and with asset pricing theory, which does not impose constant risk premia or betas. Bessembinder and

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Chan (1992) use a latent variable model which allows risk premia to vary and does not require the market portfolio to be observed, but which also imposes beta stationarity. They find that expected commodity futures returns are time-varying in relation to time-varying risk premia, conditioned on predetermined economic variables that also have forecast power in equity and bond markets. Further, they find commodity futures returns to be consistent with a two-latent-factor asset pricing model, though the two factors are not equivalent to those priced in equity markets.

Bjornson and Carter (1997) build on the work of Bessembinder and Chan (1992) and use a conditional asset pricing model to evaluate time-varying expected returns to holding commodity stocks under varying economic conditions. Bjornson and Carter examine seven commodities: corn, soybeans, soymeal, soyoil, wheat, hogs, and pork bellies. This study builds on the existing literature in three ways. First, it examines the impact of a broader range of economic conditioning variables than has been used in prior studies of conditional expected commodity returns. Second, it interprets the sensitivity of the commodities to the conditioning economic information variables, as they relate to surrounding economic conditions. Third, it estimates expected returns under a single-beta conditional asset pricing model with both the risk premium and the beta allowed to vary with time, conditioned on the economic information implicit in a common set of instrumental variables.

4.2 The theory of price of storage

H. Working (1948, 1949) presented an important critique of the theory of normal backwardation, extending work by Kaldor (1939–40). His theory was critical of the view that futures markets existed solely for the purpose of transferring risk from the hedger to the speculator and critical of the view that the cash and futures markets are autonomous. The concept was supported and refined by Brennan (1958), Cootner (1967), Telser (1958) and Weymar (1966). The theory of the price of storage hypothesised that inter-temporal price relationships are determined by the net cost of carrying stocks. For example, the theory argued that in the presence of adequate supplies, the price of a futures contract for December delivery tends to be the price for October delivery plus the net (positive or negative) cost of storing the commodity from October to December. Alternatively, the futures price for any delivery month is equal to the current spot price plus the cost of storage.

According to the theory of the price of storage, the equilibrium relationship between the futures price and the spot price is as follows:

$$F_{t,T} = S_t(1 + r_{t,T}) + w_{t,T} + c_{t,T} \tag{2}$$

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where $F_{t,T}$ is the futures price at time t for delivery at time T, S_t is the spot price at time t, $r_{t,T}$ is the opportunity cost of tying up funds in inventory from time t through time T (i.e., the financing cost), $w_{t,T}$ is the total cost of carrying the inventory (i.e., warehouse costs, insurance, spoilage, etc.), and $c_{t,T}$ is the convenience yield over the time interval t through T. If the equality in equation 2 is not satisfied (i.e., if $F_{t,T} \geq S_t(1 + r_{t,T}) + w_{t,T} + c_{t,T}$), then an arbitrage opportunity exists.

If a situation arises where $F_{t,T} < S_t(1 + r_{t,T}) + w_{t,T}$, then the theory suggests that the futures price contains an implicit convenience yield ($c_{t,T}$). Rewriting equation 2 provides a definition of convenience yield: $c_{t,T} = S_t(1 + r_{t,T}) + w_{t,T} - F_{t,T}$.

A convenience yield is a negative cost, hence the term 'yield' which implies a return to the owner of inventory derived from the flow of services yielded by a unit of inventory over a given time period. An analogy often made is that cash in the pocketbook yields a flow of services not obtainable from money sitting in a bank account, hence a liquidity premium for holding money. Working's theory predicts that the marginal convenience yield is decreasing in aggregate inventory and approaches zero for high inventory levels.

Fama and French (1987) find that marginal convenience yield varies seasonally for most agricultural commodities but not for metals. Brennan (1991) studies precious metals, oil, lumber and plywood futures and he provides evidence that the convenience yield is inversely related to the level of inventories.

Fama and French argue that:

> there are two popular views of commodity futures prices. The theory of storage explains the difference between contemporaneous spot and futures prices in terms of foregone interest in storing a commodity, warehousing costs, and a convenience yield in inventory. The alternative view splits a futures price into an expected risk premium and a forecast of a future spot price. The theory of storage is not controversial.
>
> (1987, p. 55)

However, they failed to anticipate the controversy surrounding convenience yield. Without reference to convenience yield, Khoury and Martel (1989) developed a model that offers an explanation as to why inventories would be held with negative expected spot price changes. Wright and Williams (1989) point out that studies which have found evidence of convenience yield have always used aggregate storage data and correlated these data with intertemporal prices measured at a terminal market. They argue that any apparent convenience yield could be illusionary and due to spatial aggregation of stocks and attribution of intertemporal incentives at one

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locality to at all locations. In addition, they suggest that variations over time in the marginal cost of transformation from one subaggregate to another could explain why some researchers have claimed to have found support for the notion of convenience yield. Brennan, Williams, and Wright (1997) extend this line of inquiry and examine convenience yield from the perspective of an individual firm. They develop a mathematical programming model of shipments and storage in the wheat marketing system of Western Australia. Brennan *et al.* find that, if intertemporal price spreads are properly measured (at the local level), stocks are not held at a monetary loss. This result questions previous empirical work that has supported the convenience yield argument.

Ng and Pirrong (1994) study the dynamics of industrial metals prices and find that price behaviour in those markets is consistent with the theory of storage. Building on the work of Fama and French (1987), Ng and Pirrong use the theory of storage to derive fundamental relations between the storage-adjusted forward-spot price spread and the variances and correlations of spot and forward prices. Ng and Pirrong conclude that spot-and-forward return dynamics are strongly related to fundamental factors in the market, rather than to speculative trading.

5. Provision of price information and efficiency

Some of the literature on futures markets has emphasised the informational role that the markets perform. The price information they yield facilitates both production and storage decisions. For example, see Cox (1976); Peck (1976); Turnovsky (1979); Danthine (1978); and Grossman (1989). Assuming the futures market is efficient, Cox finds empirical evidence to indicate that futures trading increased the information incorporated in a commodity's spot price. That is, he finds that a spot market is more efficient in the sense that prices more fully reflect available market information when there is futures trading. Cox argues that futures trading can alter the amount of information reflected in expected prices because speculators aided by futures trading may be more informed about future conditions and because the information incorporated in a futures price can be acquired cheaply by individuals who do not trade in futures markets. Cox's empirical results are drawn from the onion, potato, pork belly, cattle, and frozen orange juice markets.

The forward pricing role of futures markets became important when trading in contracts for non-storable commodities was initiated. Peck (1976) revives the notion of the forward pricing role and argues that futures markets provide forward prices that could be used by a producer in formulating the production decision. Her paper consists of an examination of the effects a

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forward price might have on the stability of commodity prices. The conclusions are that futures markets dampen price fluctuations by facilitating the storage decision and that producer use of the futures price in production decisions creates converging price fluctuations. These results are similar to those given in a much earlier discussion by D.G. Johnson (1947) who argues that if producers made their production decisions in relation to forward prices, greater individual and industry stability could be achieved.

Turnovsky (1979) suggests that Peck's paper suffers from several limitations. Turnovsky considers the implications of an efficient futures market for commodity price stabilisation. Theoretically, he shows the introduction of an efficient futures market will tend to stabilise spot prices. This result is similar to Samuelson's (1971) demonstration that competitive speculation stabilises prices to the optimal extent — speculators buy low and sell high. The allocation of welfare gains or losses from the introduction of a commodity futures market is also considered by Turnovsky. It is found in general that the allocation of the benefits from a futures market to the various groups in the economy tends to be an intractable exercise. However, in the case where no private storage exists, it is found that the futures market yields net gains to producers, and losses to consumers.

Turnovsky (1979) and McKinnon (1967) both conclude that the introduction of an efficient futures market will almost certainly tend to stabilise spot prices and that its main benefits occur through its effects on production decisions. It is also suggested that the introduction of futures markets may be an effective and cheaper alternative to buffer stock stabilisation. These results may suffer from the fact that the price information provided by futures markets does not have a large enough time horizon to yield all of the benefits alluded to by McKinnon and Turnovsky.

Grossman (1989) argues the private and social incentives for the operation of a futures market are a function of how much information spot prices alone can convey from 'informed' to 'uninformed' traders in the market. He reasons that the trading activity of informed firms in the present spot market makes the spot price a function of their information, and uninformed traders can use the spot price as a statistic which reveals all of the informed traders' information. However, he argues, the spot price will not reveal all of the informed traders' information because there are many other random factors which determine the price. With the introduction of a futures market, the uninformed firms will have the futures price as well as the spot price transmitting the informed firms' information to them, and this is the informational role of futures markets. He seems to ignore the influence of random factors in determining the futures price and the fact that spot and futures prices are likely determined simultaneously.

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Jeremy Stein (1987) shows that it is theoretically possible for price destabilisation to arise with the introduction of more speculators. The new speculators change the informational content of prices and affect the reaction of incumbent traders. The entry of new speculators lowers the informational content of prices to existing traders.

Crain and Lee (1996) find a high degree of correlation between changing US farm programs and changing spot and futures price variability. Some farm programs raise price volatility while other programs tend to lower volatility. The effect is so strong that they find the seasonality effects of volatility do not seem to be as important as the impact of farm programs.

5.1 Efficiency of futures markets

A very broad definition of an efficient futures market is one in which prices fully reflect available information at any point in time (Fama 1970). Alternatively, if information is costly, an efficient market is one which reflects information up to the point where the marginal benefits from trading (futures contracts) based on this information do not exceed the marginal costs of collecting the information (Fama 1991). Empirical testing for efficiency is difficult because these definitions are so general.

Empirical work on the efficiency of futures markets typically measures the adjustment of futures prices to a particular information set. In his early review of this work in security markets, Fama (1970) classified efficient market tests into three groups: weak, semi-strong, and strong form.[5] The information set for weak-form tests is confined to historical market prices. Semi-strong form tests measure the market's adjustment to historical prices plus all other relevant public information and strong-form tests measure its adjustment to 'inside' information not available to the public. However, any test of market efficiency is necessarily a joint test of efficiency and a model of asset pricing, which means that market efficiency *per se* is not strictly testable (Fama 1991).

Figlewski (1978) has questioned the efficiency assumption in its most general form. He develops a model of a speculative market in which the redistribution of wealth among traders with different information is studied and theoretically demonstrates that in neither the short nor the long run is

[5] Fama's concept of efficient markets is different from (but not necessarily inconsistent with) the traditional welfare concept of efficiency in economic theory. Fama measures market efficiency by the speed at which prices reflect changes in supply and demand information, whereas the welfare concept of efficiency is concerned with maximising the size of the economic pie.

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full efficiency (in Fama's strong-form sense) likely in a financial market if the participants are risk-averse.

Some of the early tests for efficiency in futures markets assumed that prices (and returns) in an efficient market should follow a martingale[6] stochastic process throughout time. However, Danthine (1978) and Lucas (1978) have both shown theoretically that periodical failure of the martingale property to hold is not evidence of market inefficiency. Danthine first criticised as too casual Samuelson's (1965) argument that spot commodity prices may not follow a sub-martingale if they vary with such factors as the weather, which may be serially correlated. He went on to develop possible reasons why the link between a martingale process and efficiency in commodity markets could be problematic.

Structured as Fama weak-form tests, the early studies of efficiency applied mechanical filters to futures prices to determine the success profit-wise of various trading systems. For instance, see Leuthold (1972), Stevenson and Bear (1970), and Praetz (1975). Cargill and Rausser (1975) compare and contrast the use of mechanical filters to determine whether profits can be generated and the use of statistical tests to determine whether systematic price behaviour is present. They find filter tests are not a substitute for statistical analysis, and using statistical analysis, they reject the simple random walk model as an explanation of commodity market behaviour.

Brinegar (1970) statistically tested the degree to which wheat, corn, and rye futures prices departed from behaviour expected in a random (martingale) series of prices. The test consisted of an application of Working's 'H' statistic. Loosely defined, the 'H' statistic is an index of continuity in a time series, where continuity is measured by price changes that are gradual or sluggish. For the three commodities he studied, he found varying evidence of continuity, concentrated between four- and sixteen-week intervals. That is, he found that prices reacted to exogenous 'shocks' in a gradual fashion and consequently concluded that the behaviour of the markets studied was less than 'ideal'.

Tomek and Gray (1970), and later Kofi (1973), were the first to test the forecasting ability of the futures market within the context of market efficiency. They challenged Working's reluctance to view futures price quotations for storable commodities as forecasts, and they argued that inventories of storable commodities provide a link between the springtime prices of the post-harvest futures and the subsequent harvest-time prices,

[6] A martingale is a stochastic sequence of variables and its major characteristic is that the conditional expected value of the random variable for time $t + 1$ equals the value for time t. A sub-martingale admits a trend in prices. The martingale hypothesis does not require successive random variables to be drawn from the same distribution.

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which helps to make the futures price a self-fulfilling forecast. Using OLS, they estimated the coefficients of the following linear regression equation:

$$P_h = \alpha + \beta P_{fh} + e_h \tag{3}$$

where P_h = cash price at harvest time, P_{fh} = planting time futures quotation for the harvest time contract, and e_h = error term. A 'perfect forecast' was one for which α and β were estimated to be zero and unity, respectively.

Both studies found that the forward pricing function of futures markets was more reliable for continuous than for discontinuous inventory markets. For potatoes, coffee, wheat, corn, soybeans, and cocoa, Kofi's (1973) results from 1953–69 data clearly show that the further away from the contract expiration date, the worse the futures market performs as a predictor of spot prices. Leuthold (1972) estimated equation 3 for corn and cattle and similarly found the futures market to be an efficient predictor of spot prices for only near maturity dates. His results for cattle show that, up until the fifteenth week prior to delivery, the cash price was a more accurate indicator of realised cash prices than was the futures price. This phenomenon was also confirmed for Maine potatoes by Gray (1972), and for live beef cattle, corn and Maine potatoes by Stein (1981). The estimated coefficients of the equivalent of equation 3 led Stein to conclude that the futures price, earlier than four months to delivery, is a biased and useless forecast of the closing price.

Kenyon, Jones and McGuirk (1993) examined the forward pricing performance of soybeans and corn and how this may have changed over time. For the 1952–72 period, they found both soybeans and corn futures to be unbiased forecasts of forthcoming spot prices. However, for the more recent 1974–91 period, they found both soybeans and corn futures to be biased estimates of forthcoming spot prices. Kenyon *et al.* reasoned this decline in forecasting ability was due to the reduced role of the government in the marketplace and greater production uncertainty.

However, Maberly (1985) and Elam and Dixon (1988) argue that running OLS on equation 3 could give misleading results with regard to pricing efficiency. They have different reasons for making the same claim. Maberly argues that studies may have erroneously found inefficiency due to biased OLS estimates resulting from ex-post 'censored' data. The spot price is censored from above by the value of the futures price and the futures price is censored from below by the value of the spot price, which means the forecast error (e_h) and the forecast (P_{fh}), are negatively correlated in equation 3. Elam and Dixon agree with Maberly's conclusion but they argue that his reasoning is flawed. Elam and Dixon suggest the OLS bias is due to the fact that the regressor in equation 3 is the lagged value of the dependent variable. More recently, Brenner and Kroner (1995) take a different tack and argue that a test for price bias with equation 3 is inappropriate for commodity markets

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due the fact that spot and futures prices may not be cointegrated, because the cost of carry has a stochastic trend.

Tomek (1997) stresses that futures prices can provide poor price forecasts but still be efficient, as long as their forecasts are better than any alternative such as an econometric model. If the futures market is efficient, then it should be able to out-forecast an econometric model.

Elam (1978) developed a semi-strong test of efficiency and he considered the question of whether or not profits can be earned by fundamentally trading the hog futures market. An econometric model of the US hog market was estimated and used to generate price forecasts. These forecasts were in turn used in a fundamental trading strategy. His basic trading rule was: sell one hog futures contract if the futures contract price is x per cent above the price level forecast, and buy one contract if the futures contract price is x per cent below. This rule yielded profits over the period studied and led Elam to conclude that the hog futures market is not efficient.

Leuthold and Hartmann (1979) have tested the efficiency of the same market by estimating a simple two-equation, demand-supply model to forecast hog prices. Their results indicate that the model is periodically a more efficient indicator of subsequent spot prices than is the hog futures market. Hence, they conclude that the live-hog futures market does not reflect all publicly available information and is inefficient.

Just and Rausser (1981) found that the futures market does just as well as publicly available econometric models, in terms of forecasting commodity prices. Roll (1984) found that price movements in the orange juice futures market could predict freezing temperatures in Florida better than the US national weather service could. In other words, the futures market was found to be efficient in terms of incorporating available weather information. However, Roll indicates that a 'puzzle' remains in the orange juice futures market because there is a large amount of inexplicable price volatility.

Using a semi-strong form test, Rausser and Carter (1983) examined the efficiency of the soybean complex. The relative accuracy of the soybean, soybean oil, and soybean meal futures markets was examined via structurally based ARIMA models. In some cases, the models out-performed the futures market for both long- and short-range forecasts. However, Rausser and Carter stressed that unless the forecast information from the models is sufficient to provide profitable trades, then superior forecasting performance in a statistical sense has no economic significance.

Fama and French (1987) tested for evidence of whether or not commodity futures prices provided forecast information superior to the information contained in spot prices. They found that futures markets for seasonal commodities contain superior forecast power relative to spot prices. However, this was not the case for nonseasonal commodities.

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5.2 Event studies and efficiency implications

Papers by Gorham (1978), Hoffman (1980), Miller (1979), Sumner and Mueller (1989), Colling and Irwin (1990), and Grunewald, McNulty and Biere (1993), have demonstrated that futures prices react quickly to the release of USDA livestock and crop reports. Sumner and Mueller (1989) investigated the informational content of USDA corn and soybean harvest forecasts. They developed a statistical test to determine whether the mean and variance of day-to-day futures price changes are influenced by releases of corn and soybean crop reports. They found that USDA harvest forecasts affect market price movements but concluded that significant information content does not mean that crop reports are worth the price to taxpayers. In a follow-up study, Fortenbery and Sumner (1993) found that after 1984, corn and soybean futures prices did not react to the release of USDA reports. Garcia *et al.* (1997) found that the unanticipated component of USDA corn and soybean reports affects futures prices but the informational value of the reports has declined since the mid-1980s.

Colling and Irwin (1990) use the release of the government's *Hogs and Pigs Report* (*HPR*s) to test the efficiency of the live hog futures market and find the futures market to be efficient. They use survey data of market expectations to distinguish between anticipated and unanticipated information in the *HPR*s. Their results indicate the market is quick to adjust to the new unanticipated information, and does not react to anticipated information. Therefore, Colling and Irwin conclude the market is efficient.

Grunewald *et al.* (1993) examined the futures market's reaction to unanticipated information contained in USDA *Cattle on Feed* reports. They found that futures prices respond immediately to unanticipated information in the government reports and that the live cattle futures market is efficient. In a related paper, Baur and Orazem (1994) studied the orange juice futures market and found that USDA crop reports explain less than one-half of the price variation occurring after the release of the reports.

Most of these 'event studies' have argued that because the market reacts to USDA reports, the reports might have economic value. Carter and Galopin (1993) took this one step further by hypothesising that the sufficient condition for having economic value is that a futures trader ought to be willing to pay for advance access to the reports. Their main finding was that significant profits cannot be earned by a futures trader who has advance possession of the government's *Hogs and Pigs Report* (*HPR*). Therefore, the futures market is efficient because it has already discounted a significant amount of the *HPR* information.

The Carter and Galopin finding was somewhat surprising because the hog futures price reacted whenever the *HPR*s were released. During the first

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day following the *HPR* releases, the futures market moved up or down by the 'limit' amount of 1.5 cents/lb. about 40 per cent of the time. In about 2 out of 3 cases, the futures price move exceeded 1 cent/lb. Such price jumps represent a 3.0 per cent to 4.0 per cent price change over a 1 or 2 day period and are unusually large price swings inasmuch as the mean daily price change of hog futures has been estimated to be only 0.04 per cent (Fama and French 1987). Clearly, the necessary condition is met in the case of the USDA *HPR*s, namely that futures prices react to the reports. However, the Carter and Galopin result showed the sufficient condition was not met. This implies that any explanation of why the market reacts to the reports must be due to something other than the fact the *HPR*s contain valuable information. There is considerable variation in hog futures prices after release of the reports that cannot be explained by the reports. This is consistent with the findings by Roll (1984) and Baur and Orazem (1994) for orange juice futures prices.

Mann and Heifner (1976) examined futures price changes for serial independence using two non-parametric tests. Both tests refute the hypothesis of serial independence, and indicate that commodity futures prices do not adjust efficiently to new information in the short run. They suggest the lack of serial independence is due to deliberate price manipulation by certain traders and/or the tendency for groups of traders to use charting procedures. No explanation is offered for these suggestions.

Mean reverting behaviour in commodity prices is inconsistent with a random walk model and it has been used to test for efficiency (Pindyck 1993). Pindyck found that for copper, lumber, and gold, the cash and futures markets are inefficient because prices can temporarily drift away from fundamentals — supporting the mean reversion hypothesis that commodity prices are not pure random walks. Evidence of mean reverting behaviour in agricultural spot prices was also found by Allen, Ma and Pace (1994) and by Walburger and Foster (1997). However, Irwin, Zulauf and Jackson (1996) argue that the mean reversion results in these studies could be biased due to small sample properties. Using Monte Carlo regression analysis, they do not find support for the existence of mean reversion in commodity futures prices. The implication of their finding is that the efficient market hypothesis is a better description of commodity futures prices than the noise trader model.

6. Futures pools

A futures pool (or commodity fund) is a managed speculative futures fund similar to a mutual fund in either the stock or bond market. It pools investors' money and then trades futures and options contracts using these

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funds. Any profits from the fund's trading are returned to the investors, net of management fees. An estimated US$35 billion[7] is currently invested in managed futures globally. The pools are controversial participants in the futures market because in aggregate they control significant speculative funds.

Because most pools use technical analysis exclusively (Irwin and Brorsen 1985), the theoretical literature that deals with the price effects of technical traders applies to futures pools. Beja and Goldman (1980) developed a dynamic model of the equilibrium process in the equities market, and show that if technicians on average correctly forecast price trends, then prices may be forced to an equilibrium more quickly than without technicians. They also show that too much technical trading can cause price swings unrelated to the fundamentals of the market, even if the technical traders correctly forecast price trends. Frankel and Froot (1993) showed that self-sustaining dynamics can result from a model with two types of traders. This literature suggests that technical analysis may either increase or decrease volatility. Brorsen and Irwin (1987) point out that the market impacts of increased technical trading (through large pools) is an empirical issue.

The literature on futures pools *per se* is undeveloped. Most of the literature on these pools considers the risk and returns to investing in pools. Irwin and Brorsen (1985) studied the role of public commodity pools in a portfolio of financial assets and they found a beneficial diversification effect. Elton, Gruber and Rentzler (1987, 1989) evaluated commodity funds' performance and found that less than one-half of the funds they studied produced returns greater than Treasury bills, and the management fees and transactions costs of the funds were found to be high. Overall, they question the use of funds as an investment vehicle because they are a high risk and low return investment. Schneeweis, Savanayana and McCarthy (1991) found that commodity pools may be rational investments as stand-alone investments, as additions to existing stock and bond portfolios, or as part of an optimal portfolio. Edwards and Ma (1988) found that a superior commodity fund could not be selected on the basis of historical performance. The research in this area is mixed on the value of funds to speculators, but nevertheless futures pools remain a popular investment option.

There has been very little work investigating the effect of futures pools on volatility. Brorsen and Irwin (1987) attempt to measure the effect of technical analysis by using futures funds' share of open interest as a proxy

[7] This figure was reported by the Managed Funds Association (MFA), a US-based association of managed funds professionals, with more than 690 members that represents the managed futures, hedge funds, and related futures funds industry throughout the world see (http://www.mfainfo.org/).

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for the prevalence of technicians in the market. Using a survey of fund managers they estimate the share of the total open interest controlled by futures funds. In addition, they test whether technical trading of futures funds affects volatility by regressing a measure of volatility on open interest, and find that technical trading and futures funds either reduce or do not affect volatility. Brorsen and Irwin's results are handicapped by a weak data set: a survey of 32 fund managers and then regressions based on quarterly data over six years. Quarterly observations are too infrequent to capture important short-term volatility effects. Their measure of the open interest held by funds is also questionable. They estimate total equity held by the funds, and they have survey data that reveal in which markets funds hold positions. They then convert total equity to estimated positions held in each market, using an arbitrary formula that assumes the equity in the funds is allocated to each market as a constant share.

A recent paper by Irwin and Yoshimaru (1996) was the first to use a good data set to study the issue of futures funds and volatility. They had data on the trading volume of large commodity pools operating in 36 different futures markets from the first of December 1988 to the end of March 1989. This data set reveals several interesting insights into the trading behaviour of commodity pools: the pools trade primarily in large markets; pools trade frequently (in some markets the pools make trades on more than 90 per cent of the days the market is open); pools tend to trade when other market participants are trading (pools trading volume is correlated with total market volume); and pools use similar trend-following methods when making trading decisions. In general, pool trading is a small percentage (2 per cent over the whole sample) of the total trading volume, but on some days it constitutes a large share of the total volume (the highest value reported was over 45 per cent), but Irwin and Yoshimaru do not identify any characteristics of days that have particularly high fund activity.

Using the CFTC data, Irwin and Yoshimaru (1996) estimate a regression with an estimate of daily volatility as the dependent variable, and lagged volatility and pools' share of the total trading volume as explanatory variables Generally, they find the impact of the trading volume measure to be insignificant. One of the problems with the models of Irwin and Yoshimaru is that the fit is uniformly poor. They explain very little of their estimated volatility (the highest R^2 in 72 regressions is 0.17), and do not investigate why their models fit so poorly.

7. Conclusion

This article has presented a summary of the literature on commodity futures markets and has attempted to determine potential gaps in the literature.

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There are two leading theories of futures price formation — the theory of normal backwardation (i.e., the risk premium theory) and the theory of price of storage — both of which have been in existence for many years. The empirical literature continues to debate the relative importance of these two theories. More recent work has supported the theory of price of storage, although one of its main components — convenience yield — has become controversial.

It is ironic that perhaps the most successful literature is that which has focused on purely technical questions such as the distribution of futures prices or statistical analysis of futures price behaviour. These studies use highly advanced statistical techniques but quite often there is little economic content. The current state of the literature is still quite primitive in terms of understanding fundamental broad-based economic issues. Further work is clearly required on addressing the following questions:

- Why do so few producers hedge with futures contracts?
- What is the market impact of commodity funds and of the technical trading that is used increasingly by these funds?
- What is the theoretical explanation for the prevalence of inverted markets in Chicago grain and oilseed contracts?
- Why is there so much unexplainable price volatility in markets such as hogs or orange juice?

There is a wide gap in the theoretical versus empirical literature on hedging. The theory predicts that individual producers can benefit from hedging a relatively large share of expected production. However, in practice, hedging at the individual producer level is uncommon. While a portion of the lack of hedging can be explained by existing theory, most of it cannot be explained. Just because producers do not directly hedge does not mean that futures markets are of little relevance to them. In fact, if hedging is important down the food production chain as value is added and leverage rises, then futures markets may have a significant effect on the level of demand, marketing costs, and on producer welfare.

More research needs to be directed towards the impact of government farm programs on commodity futures markets, along the lines of Crain and Lee (1996). For instance, milk and cheese futures contracts have been growing recently in the United States, in part due to less government involvement (and more price instability) in the dairy sector. In addition, the recent legislative proposals to allow off-exchange agricultural options trading is an important issue that may need to be addressed. More structural issues include increased concentration in the agricultural and food sector and the effect on futures markets.

Speculative trading through managed commodity funds and computerised

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technical decision-making is playing a larger and larger role in the futures industry. This is particularly true with the globalisation of the industry and trading around the clock. Does this managed technical trading lead to more stable prices or does it crowd out the fundamentals and lead to greater inefficiency? Neither the theory nor the empirical understanding is well developed in this area. The issue creates a challenge for researchers. It is a relatively recent phenomenon and little data on the role of funds is presently available.

The theory of price of storage explains inverted markets by appealing to the concept of convenience yield. According to this theory, the futures price can be less than the spot price plus the cost of carry when the commodity generates convenience yield. Convenience yield is thought to arise when carryover stocks are below adequate or normal levels. However, casual empiricism suggests that old crop–new crop price inversions are becoming more common for the major agricultural commodities, wheat, corn, and soybeans. Over the past twenty years, the old crop–new crop price spreads have been inverted in about one-half of the years. The Chicago wheat market has been inverted in seven out of the last ten years. In many of these years, the risk of a stockout has not been a factor. So, the challenge is to explain these prevalent inversions. If there is no such thing as convenience yield, then what is an alternative explanation for these inversions? If there is convenience yield, why is it so large in so many years to the extent that it offsets the cost of carry, and results in a negative price spread between the old crop–new crop futures? Perhaps the ongoing debate regarding normal backwardation is not totally irrelevant in today's modern futures markets and perhaps it can help explain these inversions.

The primary economic function of futures markets is to determine inter-temporal (or contingent) prices. Inter-temporal prices should improve the conditions under which decentralised production and consumption decisions are made and should ensure that risk is more adequately taken into account. Futures markets serve as a vital tool for managing economic and financial risks. In the commodity markets, contingent markets will become more and more important in the coming years with government deregulation and liberalised international trade. It is therefore imperative that our understanding of the economics of futures markets continues to improve.

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