# PRICING BEHAVIOUR IN AUSTRALIAN FINANCIAL FUTURES MARKETS

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ABSTRACT

This paper identifies two major sets of issues which have been raised in the study of financial futures markets outside Australia. The first concerns the hypothesis of market efficiency, which asserts that futures prices fully reflect available information about subsequent prices in the physical markets. Secondly, there is the question of whether or not futures trading has a detectable influence on the short-term variability of spot prices. A weekly data set, covering each of the three main SFE contracts over the period from December 1984 to February 1988, is used to investigate the two sets of hypotheses. Statistical results generally support the efficiency hypothesis, the one clear exception being the case of the pre-crash sample for the SPI contract; a significant average discount was found in this case, indicating that the futures market may have anticipated the subsequent crash.

In investigating potential causal links from futures markets to physical markets, two main findings are obtained. First, no link is detected from futures trading volumes to spot price volatility; and secondly, the data suggest that futures price movements have tended to lead spot price movements during the sample period by between one and two weeks. It is argued that this result is consistent with conventional theory, which suggests that prices will react to new information most quickly in those markets where transactions costs are lowest.

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## 1. Introduction

The rapid growth of trading in financial futures markets has raised important questions about the effect of futures trading on prices in the associated spot markets. One view is that futures markets tend to improve efficiency and price stability in the spot markets by making those markets more liquid. This occurs because the distinctive features of futures markets, namely their highly standardised contracts and the fact that they are relatively unregulated, generally enable them to operate with very low transactions costs. On the other hand, it has been suggested that these very features of low cost and lack of regulation may actually exacerbate spot price volatility by encouraging excessive speculative activity. Concerns of this kind have recently been highlighted by the October sharemarket crash, when it was noted that sharp falls in the price of share index futures preceded major price movements on the New York Stock Exchange. This paper aims to review the theory and evidence on the role and performance of financial futures markets, and to present comparable evidence on recent performance of the Australian markets. Three futures contracts are specifically studied: these are the share price index contract and the 90-day and 10-year interest rate contracts, which together have accounted for the bulk of trading on the Sydney Futures Exchange during the last four years.

To provide a broad perspective on the issues, section 2 of the paper begins by briefly reviewing theories on the economic role of futures markets and the possible consequences of futures trading. This is followed in Sections 3 and 4 by a preliminary discussion of data on the recent behaviour of futures markets in Australia, and a review of relevant empirical work, undertaken mainly in the U.S. The remainder of the paper, in sections 5 and 6, sets out a framework for empirical testing with the Australian data, and presents the results.

## 2. Review of Theories of Futures Markets

### 2.1 Economic Functions of Futures Markets

There are two main theoretical approaches to explaining the economic function of futures markets - the cost of storage theory, and the risk allocation theory. The cost of storage theory is usually traced back to Working (1949) and Telser (1958), and was originally developed with specific reference to commodity futures. The theory views the futures premium (difference between futures and spot prices) as a risk free return paid to holders of a commodity. For existing stocks to be willingly held, this premium must be equal to the implicit net cost of holding that commodity. Net cost in this context means the sum of interest opportunity and storage costs, less the value of the service yielded by the commodity when held as inventory. This condition is required to ensure that the riskless activity of holding an additional unit of the commodity, for delivery at the futures price, earns a zero profit. In applications of the Working model, it is generally assumed that storage costs and inventory service yields are dependent on the quantities of stocks held. Thus the futures premium is uniquely determined by the supply of stocks and the risk free interest rate.

An important feature of the cost of storage theory is its recognition that futures markets are redundant when short selling of the physical commodities is possible and transactions costs are negligible. For example, a sold futures position could be replicated by selling short in the spot market, investing the proceeds at interest, and buying back at the future date. Since short selling is generally not possible in commodity markets, or is expensive, it has been argued that futures markets perform the economically useful role of facilitating optimal allocation of inventories by permitting short selling at low cost. In particular, Williams (1987) suggests that some producers will generally wish to be short in futures during the production process because in doing so, they are "borrowing" inventories which have a positive convenience yield as an adjunct to production.

The second main theoretical approach views futures contracts as being primarily instruments of risk management. This view generally interprets futures prices as representing expectations of future spot prices, possibly including some premium for risk. Keynes is often regarded as having anticipated the theory in his hypothesis that commodity futures should generally be at a discount to spot prices, in order to compensate speculators for the risk involved in providing price insurance to producers. This is the so-called "backwardation" hypothesis. Once again, however, the essential redundancy of futures markets must be noted. Futures offer an independent risk management service only to the extent that transactions costs or short selling constraints prevent the underlying assets or commodities from being used for the same purpose.

The two theories of futures markets should probably be seen as complementary: one describes the difference between spot and futures prices on the basis of inter-market arbitrage, while the other describes the influence of expectations and risk on the level of those prices. In practice, the relative applicability of the two theories probably depends on the cost of inter-market arbitrage. When spot transactions costs are high and short selling constraints are present, the arbitrage relationship implied in the storage costs theory will tend to break down. In this case, futures prices might be expected to be determined primarily by expectations, so that these markets would play an enhanced role in reflecting the effects of new information in prices. With low or negligible transactions costs in the physical markets, futures would tend to have much less of an independent role. Interest rate and currency futures probably fall much closer to this extreme than do commodity or share index futures.

## 2.2 Effect of futures on volatility

A number of theoretical arguments have been put forward to justify a link between futures trading and price volatility. In the first place, there is the frequently expressed view that speculation in general can destabilise prices. Such a position has been argued in detail in classic texts such as J.S. Mill's Principles and Keynes' General Theory, as well as by numerous other authors. The idea of destabilising speculation has, however, proved difficult to reconcile in theory with individually rational behaviour by investors. Recent attempts to provide formal examples of rational but destabilising speculation by Hart (1977) and Hart and Kreps (1987) for example, give the impression of being rather contrived. The opposing case, that rational speculation is always stabilising, was forcefully made by Friedman (1953):

> "People who argue that speculation is generally destabilising seldom realise that this is largely equivalent to saying that speculators lose money, since speculation can be destabilising in general only if speculators on average sell when the [price] is low ... and buy when it is high."

Friedman's position appears common sense to many, but has been challenged empirically by a body of recent literature on the claimed "excessive volatility" of asset prices, sparked initially by Shiller (1981, 1984).

Shiller argued that medium-term speculative swings have made asset prices in the United States many times more volatile than could be justified by fundamentals alone. The issue remains a controversial one, and one which cannot be fully examined here.

The relevance of this debate for futures markets is that futures are among the markets which come closest to the textbook ideal of costless unconstrained trading. It is here therefore that proponents of both extreme views on the stability of speculative trading expect to see their views most clearly illustrated. Thus, Tobin (1976) proposed a tax on speculative transactions as a means of stabilising international financial markets, arguing that low transactions costs are harmful to price stability. Miller (1986) on the other hand sees futures markets as enhancing spot market efficiency by bypassing inefficient taxes and regulations. Ultimately, the relative merits of these views can only be judged on an empirical basis.

A second line of argument, in papers by Newbery (1987) and Weller and Yano (1987) addresses the issue of price stability in a general equilibrium framework. These papers suggest that even in fully efficient markets, futures trading can influence the volatility of spot prices by influencing the volatility of private wealth distribution (Weller and Yano) or by influencing the supply behaviour of risk averse producers (Newbery). This influence can be in either direction, depending on the parameters of the models. These ideas are relatively new and likely to be developed further, but their empirical relevance is perhaps limited by the fact that futures contracts are generally traded only at short maturities. It seems particularly unlikely that the channel by which futures influence the volatility of spot prices, should be via effects on production as suggested by Newbery.

As a final point, it should be noted that changes in price volatility have no necessary implications for welfare, although some such implications often seem to be assumed. On the contrary, it has been shown that improved informational efficiency may sometimes be associated with greater price volatility. Green (1986) for example has shown in a simple theoretical model that a removal of short selling constraints will generally increase the information content of prices, and that this may increase price volatility. There is no obvious reason to consider such an outcome undesirable.

## 3. Australian Futures Markets

Organised futures trading began in Australia with the opening of the Sydney Greasy Wool Futures Exchange (now the Sydney Futures Exchange, or SFE) in May 1960. After a relatively slow start, futures trading has grown rapidly, both in terms of turnover, and in the variety of contracts available for trade. The dramatic nature of this growth is illustrated in Table 1 on page 22, which shows total annual trading volumes for the main contracts.

As the table indicates, growth in futures trading has been particularly strong in the period since 1983, and the introduction of financial futures contracts has been largely responsible for this. The first financial futures contract, in 90 day bank bills, was introduced in October 1979; it was followed by contracts in the share price index (SPI) in February 1983, and in 10 year bonds (December 1984).[1] These financial contracts have now largely replaced the older commodity futures as the main focus of trading, together accounting for over 90 per cent of the value of turnover by 1987. To some extent, this reflects overseas trends. In the United States, for example, the financial contracts have certainly been the main area of growth in futures trading; but there has been no corresponding decline in commodity futures. One reason for the relative demise of commodity futures in Australia may lie in the growing internationalisation of these markets. Most commodity contracts are now traded on the major exchanges in the U.S. which, being more liquid, are likely to be more attractive than the non-U.S. exchanges; this may underlie a tendency for the non-U.S. exchanges to specialise in local products, particularly local financial products, in which they may have a comparative advantage.

The close relationship between spot and futures prices in Australia is illustrated in figures 1, 2 and 3, showing weekly price observations on the three major contracts since December 1984. Broadly speaking, this close relationship is what the theory of storage would lead us to expect: when adjusted for net holding costs (which are probably small), the difference between futures and spot prices for an asset should be limited by the cost of spot-futures arbitrage. Consistent with this theory, the proportionate

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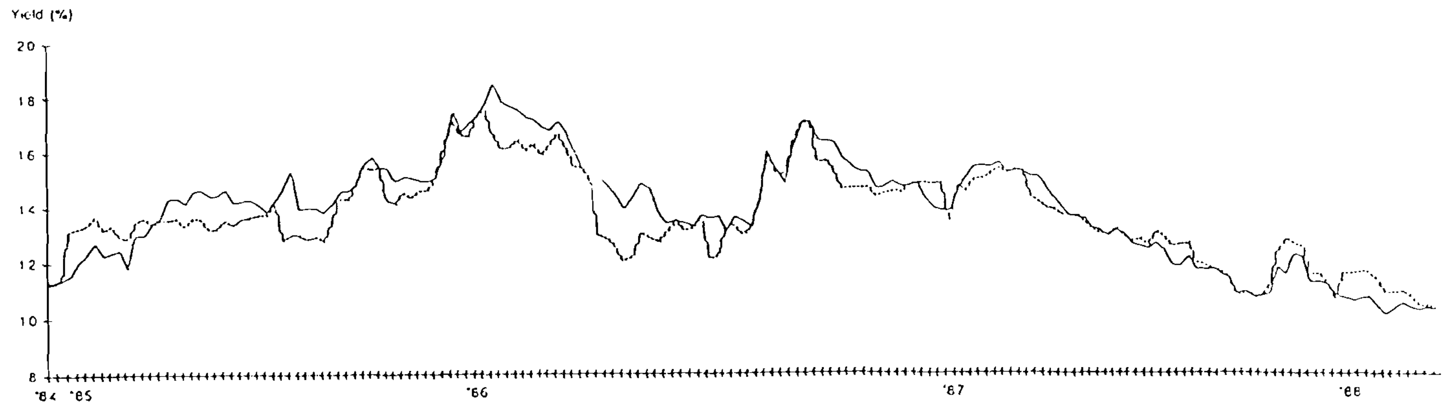
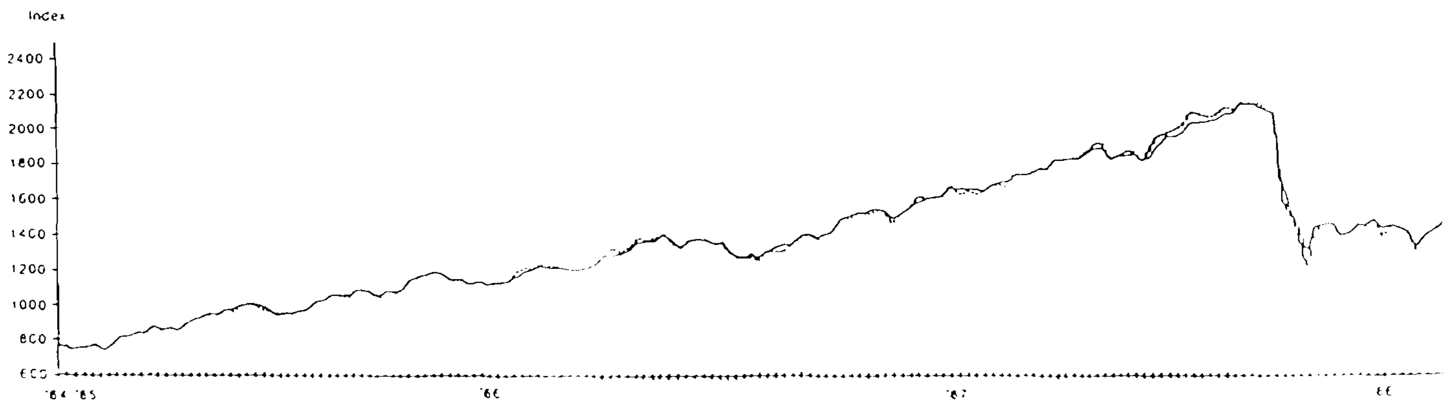
1. A two year bond contract was also introduced (in 1982) but was not a success. More recently, a three year contract was introduced in April 1988, and has been quite heavily traded during its first few weeks of being available.

# FUTURES PRICE vs SPOT PRICE

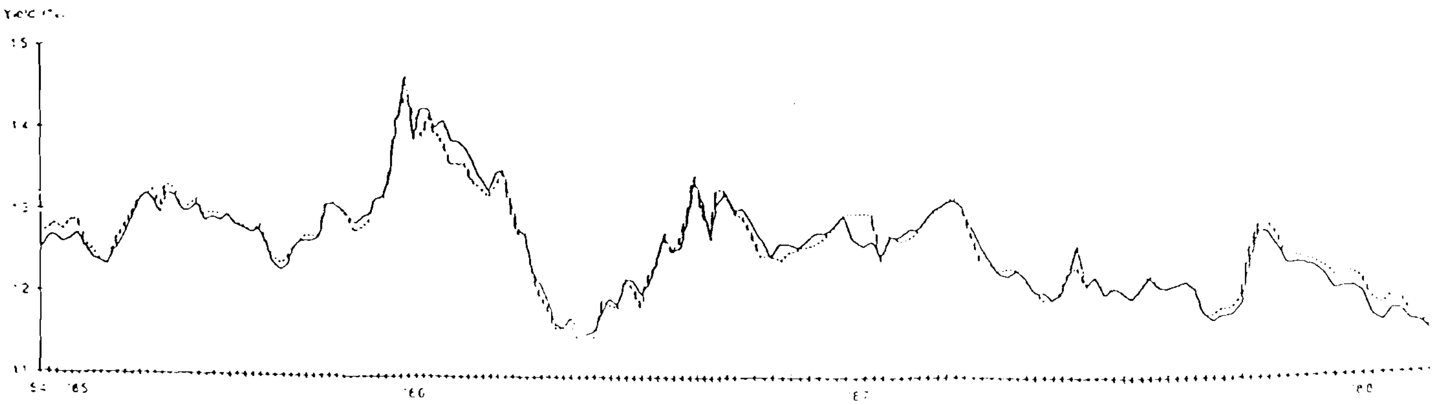
## 90 DAY BANK ACCEPTED BILLS futures price ····· — spot price




## ALL ORDINARIES SHARE PRICE INDEX futures price ····· — spot price




## 10 YEAR COMMONWEALTH TREASURY BOND futures price ····· — spot price



premium on SPI futures is generally larger and more variable than in the case of the bond contract. The 90-day bill market is less readily comparable to the other two at this level, because the cost of holding is related mainly to interest rate movements between the trading date and contract maturity date, which may at times be relatively large. Details of the three contracts are set out in the Appendix.

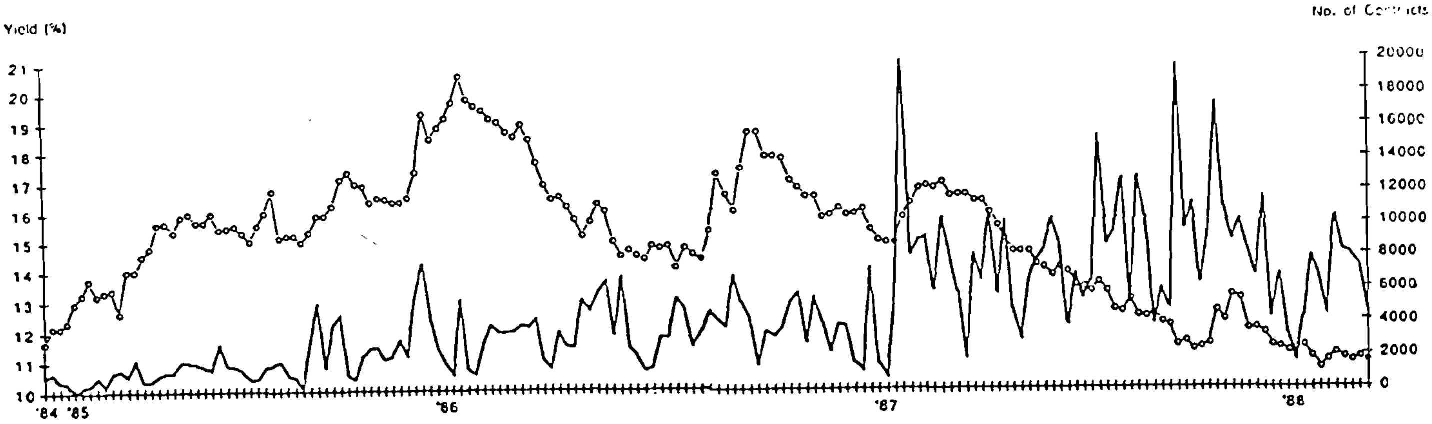
Based on casual inspection of the graphs, the predictive content of the futures prices in general does not appear to be large. A weak case can perhaps be made that the 10 year bond futures market anticipated the decline in bond yields which occurred in the early part of 1986 (though not the subsequent reversal of this trend). Generally, however, the two sets of prices move in parallel. An interesting exception concerns the period around the October share market crash. The premium on December SPI futures began to fall some three weeks prior to the crash, and was actually negative (a hitherto rare occurrence) for several days before hand. Immediately after the crash, the premium remained negative for some weeks, thus predicting further share price falls which subsequently occurred. Of course, this observation can be given more than one interpretation. Whether the futures market contributed causally to share price movements, or was merely forecasting them, is not easily determined from these data alone. However, if it is accepted that the initial impetus for lower share prices came from overseas, this would suggest that the main role of the futures markets lay in predicting, rather than instigating, the major share price movements, at least initially.

Figures 3 to 6 show the weekly trading volumes in the major futures contracts over the same sample period. Apart from their strong upward trend, the volume figures show little systematic behaviour in the pre-crash period, and appear to bear no obvious relation either to the level of prices, or to their volatility. In particular, there does not appear to have been any noticeable increase in the short-term variability of prices over the period while trading volumes were increasing.

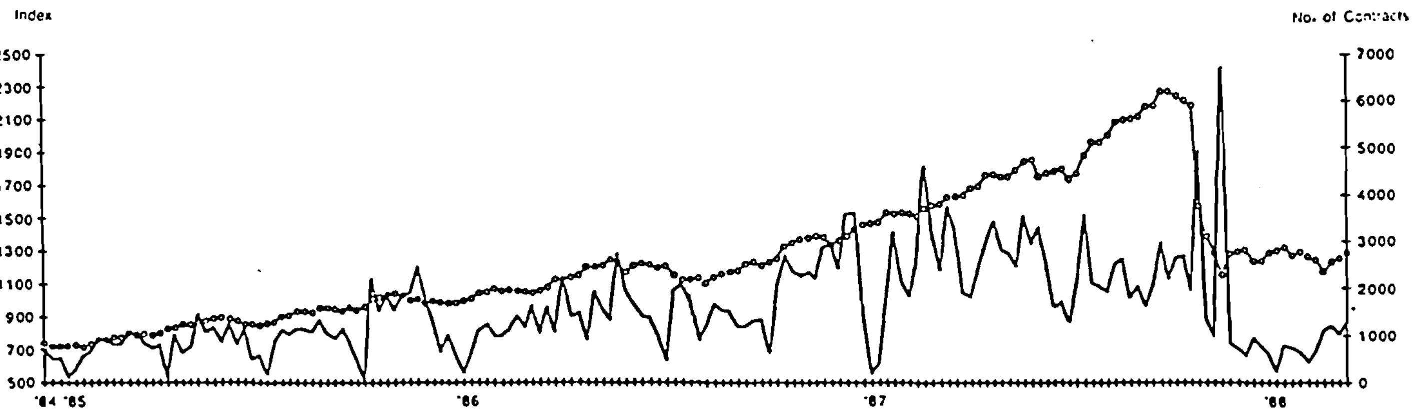
In the week of the crash, volumes reached a high peak, due mainly to widespread closing out of positions in reaction to the drop in share prices. Subsequently, average trading volumes declined in all three markets, and have remained relatively low ever since. The decline has been particularly severe in SPI contracts, with the value of daily turnover so far in 1988 down to around 10 per cent of pre-crash levels. No doubt, many investors have become

# VOLUME vs SPOT PRICE

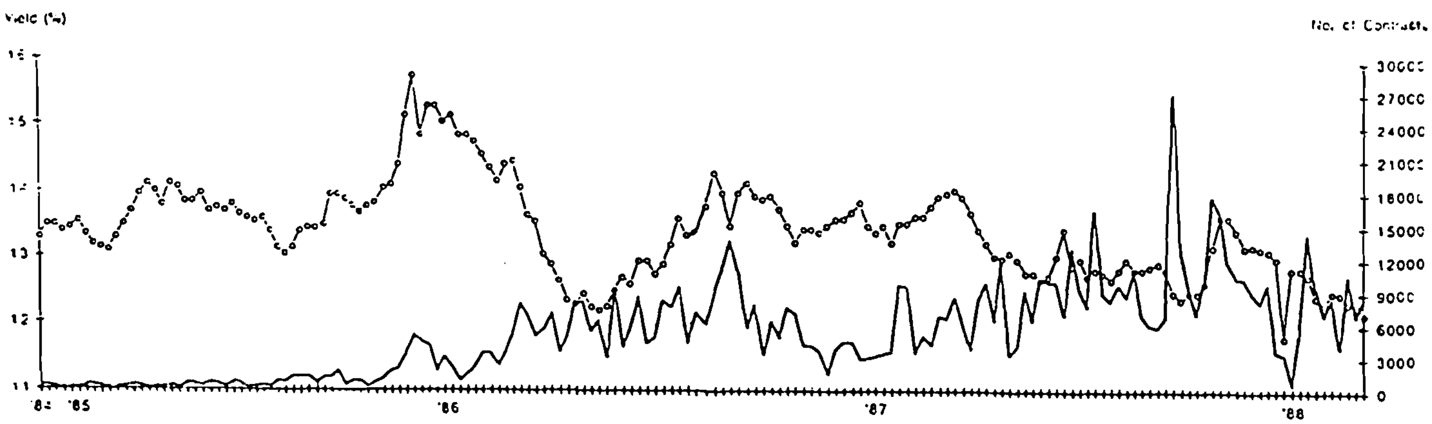
## 90 DAY BANK ACCEPTED BILLS (LHS) spot price -o- — volume (RHS)




## ALL ORDINARIES SHARE PRICE INDEX (LHS) spot price -o- — volume (RHS)




## 10 YEAR COMMONWEALTH TREASURY BOND (LHS) spot price -o- — volume (RHS)



more cautious in view of the large losses incurred in October, particularly with respect to SPI futures. Turnover on the Sydney stock exchange is also reported to be considerably reduced. These observations suggest a model in which price volatility is mostly fairly constant, but may influence turnover in exceptional periods. There seems no clear evidence of a causal link in the other direction, from volume to volatility, but this proposition will be tested more rigorously in the work reported in section 6.

## 4. Review of Empirical Evidence

Empirical evidence on the relationship between financial futures and spot markets has focussed on two main questions: first, are the futures markets efficient in the sense of fully reflecting information about expected future spot prices; and secondly, does futures trading tend to stabilise or to destabilise spot prices.

### 4.1 Efficiency

On the question of efficiency, interest rate futures markets in the United States have been tested fairly extensively for evidence of arbitrage profits or pricing biases, based on deviations between actual futures prices and the expected spot prices implied in the term structure. These are really tests of the joint efficiency of spot and futures markets. Results have been somewhat ambiguous, with studies on ten year bond futures (for example, Kolb, Gay and Jordan (1982) and Resnick and Henniger (1983)) generally offering no evidence against the efficient markets hypothesis, while comparable studies on ninety-day futures (Rendleman and Carabini (1979), Elton, Gruber and Rentaler (1984)) have found departures from jointly efficient pricing. These departures are however, claimed to be small compared with spot transaction costs.

As might be expected, much larger departures from joint efficiency have been found with respect to the share market, where transactions costs are higher. Cornell and French (1983) for example found the premium on Chicago share index futures could not be explained by an efficient arbitrage model, and a similar finding for Sydney SPI futures is reported by Bowers and Twite (1985). These results are consistent with the fact that arbitrage between spot and futures is much more costly in share indices than in interest rate contracts, reflecting the cost of assembling and trading a portfolio which is reasonably representative of the index. It should be noted however that the interpretation of these findings is not clear cut: a rejection of joint efficiency of the spot and futures markets, still leaves open the question as to where any inefficiency is located.

The main empirical evidence on the Australian interest rate futures markets is in papers by Sharpe (1984), Kearney, MacDonald and Hillier (1987) and Juttner, Tuckwell and Luedecke (1985). These studies use monthly data to perform standard tests for biases in bank bill futures prices as predictors of future spot prices. All three studies offer support for the hypothesis of no bias, implying at least a weak form of efficiency, although in some cases stronger forms of efficiency are rejected. A major criticism of these studies however is their use of data sets containing a high proportion of quoted prices at which no trades were actually made. This is a consequence of using monthly data points on contracts maturing three months ahead, when in practice only end-quarter maturing contracts have significant trading volumes. These data problems must cast doubt on the robustness of the reported results.

### 4.2 Volatility

The second main empirical question on futures markets concerns the stabilising or destabilising consequences of futures trading. Here the usual approach has been to test for significant changes in the variability of spot prices after the commencement of trading in a new futures contract, or to investigate correlations between spot price volatility and activity on futures markets. Early work on commodity futures showed, if anything, that futures trading tended to reduce variability of spot prices; much of this work is summarised by Power (1970). More recently, similar work has been carried out in financial futures markets (see for example Froewiss (1978), Simpson and Ireland (1982, 1985) and Rutledge (1986)); little or no relationship between futures trading and volatility has been detected, even with data sampled as frequently as daily. On a related issue, Kawaller, Koch and Koch (1987) investigated the lead-lag relationship between Chicago share index futures prices and the underlying index values. Their results suggested that the futures market slightly leads the spot on intra-day price movements. There appears to be no comparable Australian evidence on this point.

## 5. Specification of Empirical Tests

The limited aims of the empirical work reviewed above must be stressed. These papers make no attempt to relate the behaviour of spot and futures prices to market fundamentals, but rather look at specific issues of efficiency and price variability. In what follows, an empirical framework is specified with these same aims in mind.

### 5.1 Market Efficiency

As is well known, tests of market efficiency must be specified as joint tests of a hypothesis concerning expectations formation, and a hypothesis concerning market attitudes toward risk. Although in some recent work on forward exchange markets (eg. Domowitz and Hakkio (1985), Giovannini and Jorian (1987), Attanasio and Edey (1986)) various forms of risk aversion are allowed for, the more usual (and simpler) approach is to assume risk neutrality. Bilson (1981) has dubbed the joint hypothesis of risk neutrality and rational expectations the "speculative efficiency" hypothesis. The hypothesis asserts that the forward or futures price is an optimal unbiased predictor of the spot price for the contract maturity date.[2] This is written as:

$$f_t^T = E_t(s_T) \tag{1}$$

where $f_t^T$ is the futures price at time t on a contract maturing at T

$s_t$ is the spot price at time t

$E_t$ represents expectations conditional on information available at t.

It is usual for the prices to be measured in logs.

The form of the test used in this paper is dictated by the timing of maturities for the contracts that are normally traded. In the forward exchange markets, the convention is that contracts always mature a fixed period after the transaction date, eg. a one month forward rate is always for

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2. The terms "forward" and "futures" are used interchangeably here. Strictly speaking the two types of contract may have slightly different theoretical prices due to the effect of the deposit and margin system on the profitability of a futures contract.

delivery (roughly) 30 days after the spot date. This is particularly convenient from the point of view of econometric analysis, since one can define the unit of time to be the same as the contract length, and rewrite equation (1) as:

$$f_t^{t+1} = E_t(s_{t+1})$$

or, as is now familiar,

$$s_{t+1} = f_t^{t+1} + v_{t+1} \tag{2}$$

where $v_{t+1}$ represents the unanticipated component of the change in the spot exchange rate between t and t+1. Equation (2) can readily be made into a regression equation, since under the null hypothesis the error term has the classical properties.

In the futures markets, this pattern cannot be followed because the convention is for all contracts, at whatever time they are initiated, to mature at one of a small number of fixed end-quarter dates. On the SFE this means in practice the end of the current quarter. Prices for the off-months may be quoted on the exchange, but are rarely traded. This means that what is observed is a time series of observations of the form

$$\{f_t^{T(t)}, f_{t+1}^{T(t+1)}, \ldots\}$$

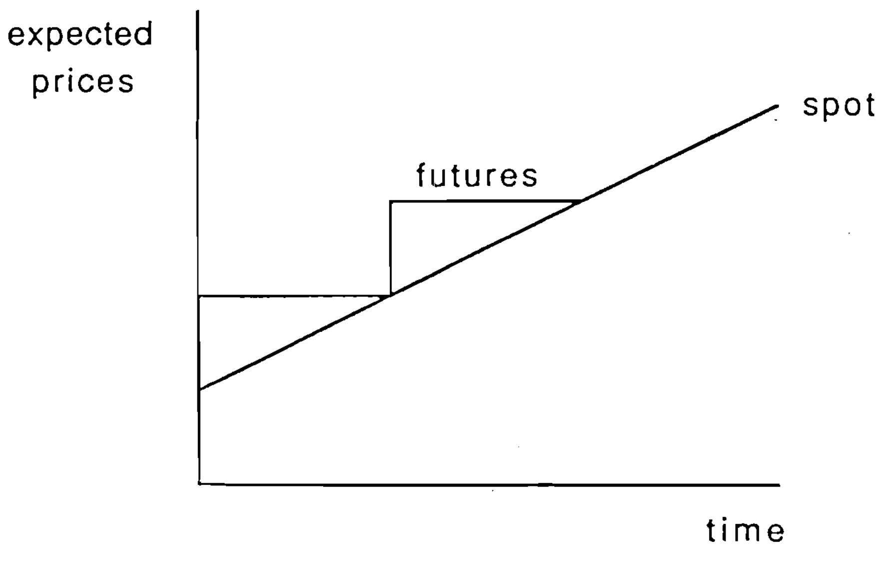
where T(t) is the standard maturity date for a contract traded at t (i.e. the end of the quarter in which the trade occurs), together with a time series on $s_t$.

From equation (1), a simple test of efficiency can be proposed based on first differences of the above time series:

$$\begin{aligned} f_{t+1}^{T(t+1)} - f_t^{T(t)} &= E_{t+1}(s_{T(t+1)}) - E_t(s_{T(t)}) \\ &= \{E_{t+1}(s_{T(t+1)}) - E_t(s_{T(t+1)})\} \\ &\quad + E_t\{s_{T(t+1)} - s_{T(t)}\} \end{aligned} \tag{3}$$

The first term on the right hand side of equation (3) represents a revision to expectations; if the market is efficient, this must be orthogonal to any information dated t or earlier. The second term will be identically zero whenever $T(t+1) = T(t)$, which is always true except when t+1 is the first observation of a new quarter. With weekly data, as is used in section 6, this occurs roughly every thirteenth observation. For those observations, the term represents expected capital growth in the spot price between the end of the current quarter and the end of the subsequent quarter. This need not necessarily be zero.

To illustrate this point, it might be expected that the share price index would show an upward drift, reflecting the capitalised reinvestment of earnings, in any sustained period in which the dividend payout ratio is lower than the interest rate. In this case we would expect the systematic component of the futures price to follow the spot price in a step function like that illustrated below, with the spot and futures prices converging at each maturity date.




Systematic changes in the futures price would be zero for observations on which there is no change of contract maturity date, but would jump to reflect the next quarter's expected capital growth each time a new contract is introduced.

In order to test the orthogonality condition given by equation (3), the variable $f_{t+1}^{T(t+1)} - f_{t}^{T(t)}$ is regressed on an arbitrary vector of information variables, which includes lagged values of the dependent variable, and current and lagged changes in spot prices. To account for the effects of new contracts, a separate new contract dummy is added for each contract. Thus the efficiency hypothesis is tested using regression equations of the form (deleting superscripts)

$$f_{t+1} - f_t = \alpha + \sum_i \delta_i d_{it} + \beta Z_t + u_{t+1} \tag{4}$$

where $Z_t$ is the arbitrary information vector

$d_{it}$ is the "new contract" dummy for the ith new contract

($d_{it}$ = 1 in the first week of the ith quarter

= 0 otherwise).

Under the null hypothesis of efficiency, $\alpha = 0$ and $\beta = 0$.

A special case of equation (4) is to include information about time to maturity in the information set $Z_t$. Specifically, since it is known that the futures premium must converge to zero at each maturity date, it might be hypothesised that this predicted convergence may help to predict movements in the futures price. To test this conjecture an AR(1) model of the premium scaled by time to maturity is specified as follows:

$$\frac{fp_{t+1}}{n_{t+1}} = \alpha + \sum_i \delta_i d_{it} + \frac{\beta fp_t}{n_t} + \varepsilon_{t+1} \tag{5}$$

where $fp_t$ is the proportionate futures premium (log futures price minus log spot price)

$n_t$ is the number of periods to maturity of a contract traded at t.

An estimate of equation (5) can be used to obtain an instrument for the predictable change in the premium $(\widehat{fp_{t+1} - fp_t})$, which can then be used in the information set $Z_t$ in tests of equation (4).

## 5.2 Volatility

For the purposes of this paper, volatility is defined using the average squared weekly price movement. This is roughly equivalent to the conditional variance of the price innovation in each period, since the time series evidence suggests that spot prices are approximately represented by random walks. Three hypotheses concerning the impact of futures trading on spot price volatility will be investigated.

(i) Futures trading volume "causes" spot price volatility, measured by $(s_{t+1} - s_t)^2$.

(ii) Futures price volatility $(f_t - f_{t-1})^2$ "causes" spot price volatility.

(iii) Futures price innovations (in levels) lead spot price innovations.

All three hypotheses are tested using Granger-causality methods. Granger (1969) proposed that causality be tested by estimation of the following pair of OLS regressions:

$$x_t + b_o y_t = \sum_{i=1}^{k} a_i x_{t-i} + \sum_{i=1}^{m} b_i y_{t-i} + u_t$$

$$y_t + c_o x_t = \sum_{i=1}^{k} c_i x_{t-i} + \sum_{i=1}^{m} d_i y_{t-i} + v_t$$

where $u_t$ and $v_t$ are white noise series and are uncorrelated. The variable $y_t$ is said to Granger cause $x_t$ if any of the b coefficients are statistically significant (causality is instantaneous if $b_o$ is significant). The reverse causality is tested in the second equation, using the c coefficients.

# 6. Empirical Results

## 6.1 Some Descriptive Statistics

Because of the potentially large impact of the share market crash on any statistical results, all tests are reported for both the complete sample available at the time of writing (the sample runs from December 1984 to

February 1988) and a "pre-crash" sample which ends at September 1987. As a preliminary to the main hypothesis tests, Tables 2 and 3 present some descriptive statistics on the properties of the first-differenced time series for spot and futures prices. For the purposes of this section, all variables are measured in logs. (Bill and bond yields are converted to log prices by taking the log of one plus the yield in each case.) To remove the "new contract" effects referred to in section 5.1, the futures data are pre-filtered by regressing the series on a full set of new contract dummies. Under the null hypothesis, the first differenced pre-filtered futures prices are white noise. This is not necessarily true for spot prices.

The autocorrelations and partial autocorrelations given in Tables 2 and 3 show that these series are clearly stationary in first differences, and suggest that they are generally close to being white noise, though there are some lag lengths at which correlations are marginally significant. There is, for example, significant first-order autocorrelation in futures prices in one case (that of 10 years bonds) but this appears to be sensitive to the length of the sample period chosen, and becomes insignificant when the crash period is removed from the sample. At longer lag lengths, the main feature of interest is a possible indication of fourth-order autocorrelation in spot interest rates, suggesting a weak within-month seasonal pattern.[3] This is not necessarily evidence of inefficiency, although there is weak evidence that this pattern may carry over into futures prices, which would be inconsistent with efficient markets. This proposition is more formally tested at a later point.

Table 4 presents tests of the hypothesis that innovations in futures prices are normally distributed (see Bera and Jarque (1986)). This is of only passing interest for the main questions in the present study, but is highly relevant in considerations of portfolio choice involving futures markets, and in the pricing of options on futures. Bera and Jarque specify a normality test which is a weighted combination of tests for skewness and kurtosis proposed by D'Agostino and Pearson (1973). The individual test statistics for skewness and kurtosis are given along with the combined test. The results reported in Table 4 suggest that interest rate futures prices come from distributions which have higher kurtosis (ie are more peaked) than the normal, but are not significantly skewed. Roughly speaking, this means that large

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3. This may be due to seasonality in government receipts and payments.

price changes occur with greater frequency than would be the case if the underlying distribution was normal. For SPI futures the results depend, not surprisingly, on whether or not the period around the share crash is included in the sample. The pre-crash data suggest consistency with the hypothesis of normality, but the October movements in share prices are sufficient to refute the hypothesis decisively, if included in the sample. A crash of the magnitude which actually occurred has virtually a zero probability of being drawn from a normal distribution.

## 6.2 Efficiency

Informational efficiency is tested using equation (4) as outlined in the previous section. The test involves specifying an arbitrary set of "Z" variables which are predetermined at time t, as possible predictors of the futures price movement ($f_{t+1}-f_t$). Two sets of tests are reported. The first uses lagged changes in spot and futures prices in the predetermined variable set; lags of up to 5 weeks are included, so as to make it possible to detect any inefficiency arising from within month seasonality. The estimated equations are reported in Tables 5 (for the pre-crash sample) and 6 (full sample). The results show little clear evidence of inefficient pricing, with only 3 out of 60 reported coefficients being significant at the 5 per cent level. Of these, the constant term in the SPI equation is highly significant and positive in the pre-crash sample, indicating positive drift in futures prices. This means that on average, an uncovered long position in SPI futures earned significant positive profits over the period, which is inconsistent with market efficiency.

One way of reconciling this result with investor rationality would be to hypothesise a speculative bubble of the form originally suggested by Blanchard (1979). Blanchard attempted to formalise the notion of a price which remains above market fundamentals for a sustained period because it is expected to grow further. In a process of this kind, it is assumed that the "bubble" is expected to grow at each point in time with some probability ($1-\pi$), but that the price returns to fundamentals with probability $\pi$. Expected capital growth must be just sufficient to ensure that investment in the market is a fair bet in each period. In the presence of this kind of bubble, the market would appear to be inefficient in any sub-period in which the bubble is still growing, because the return to a long position would contain a positive premium offsetting expected losses when the price returns to fundamentals. This hypothesis is not dissimilar to the "Peso problem" which arises in relation to forward exchange markets. In a loose sense, the hypothesis is supported by the result for the full sample, in which the constant term becomes insignificant; the crash was of roughly sufficient size to reduce the average excess returns on a long futures position to zero in the period taken as a whole.

Other significant coefficients in the above set of equations are fourth lags in the bill futures equation (pre-crash) and SPI futures equation (full sample), but these are only marginally significant and may well be spurious, given the large number of estimated coefficients.

The second set of efficiency tests uses expected premiums $(\widehat{fp_{t+1}} - fp_t)$ in the predetermined variable set. This test is specifically designed to test whether information about time to maturity (ie. the predicted rate of convergence between futures and spot prices) can be used to help predict the change in futures prices. The method of constructing an instrument for the expected change in the premium $(\widehat{fp_{t+1}} - fp_t)$ was outlined in Section 5. Results are shown in Table 7, and indicate no significant departures from efficiency, other than the positive constant term in the SPI equation which has already been discussed. An interesting consequence of these results is that spot prices must contain a predictable component which is offset by predictable movements in the premium. This is not necessarily evidence of spot market inefficiency. It simply indicates that future systematic behaviour of spot prices (whatever the cause) is rationally incorporated into current futures prices, whether or not the spot market itself is fully efficient.

### 6.3 Price Volatility

This section reports results on the three sets of hypothesis tests described in Section 5.2. The first two hypotheses concern changes in the variance of spot prices through time, and involve testing whether or not such changes are associated with lagged or contemporaneous activity on futures markets. The third concerns the related question of the lead-lag relationship between futures and spot prices in levels. Since the first two of these tests hypothesise the existence of conditional heteroskedasticity in the spot price data, a useful first step will be to test for this. A useful test in this regard is the ARCH test for conditional heteroskedasticity proposed by Engle (1982).

The ARCH test specifies conditional heteroskedasticity of the form

$$E(\varepsilon_{t+1}^2) = \alpha + \sum_{i=0}^{k} \beta_i \varepsilon_{t-i}^2 \tag{6}$$

where $\varepsilon_t$ is a zero mean error term; a $\chi^2$ test is applied for the joint significance of the $\beta$ coefficients. Thus, the ARCH method tests whether past variation in the error terms helps to predict the variance in the next period. Results are shown in Table 8. Lag lengths in each case were determined by testing down from a lag length of 6. The results show significant heteroskedasticity in two of the three cases, the exception being the share price index.

Results concerning the three main hypotheses on price volatility are reported in Tables 9 and 10. The first hypothesis is that futures trading volumes have a significant influence on the conditional variance of spot prices. As the results in Table 9 show, this hypothesis is rejected in the case of the two interest rate contracts: for these there appears to be no statistical relationship, either lagged or contemporaneous, between futures trading volumes and spot volatility, at least at the level of weekly data. One point to note on this issue is that the Wednesdays sample used here excludes certain days of high average volatility, such as balance of payments "news" days (which are generally Tuesdays), and it is possible that a correlation between price movements and volume could be detected on those days if both are similarly influenced by news. The result reported here does not rule out such correlation, but does appear to reject a causal link from volume to volatility.

In the case of the SPI, the results are ambiguous. There is an estimated negative contemporaneous relationship between volume and volatility, but this could easily be spurious, since the coefficient on the first lag is almost equal and opposite to the contemporaneous coefficient. No relationship is detected when the first lag is dropped from the regression.

The second and third hypotheses are closely related, asserting that futures markets lead spot markets in terms of price variability, and price levels, respectively. Test statistics for the two hypotheses are likely to yield similar results, since a lead-lag relationship established in terms of price movements is likely to carry over when measured in terms of the squared values of those price movements. This close relationship is born out by the results in Tables 9 and 10. There is quite strong evidence that futures prices lead spot prices (in both senses) for the two interest rate contracts. The lag lengths, at up to two weeks, are surprisingly long, although the strongest effects are contemporaneous or at the first lag. The evidence is much weaker for the SPI contract, with only the first lag in levels being significant, and only for the pre-crash sample. In the case of the bill contract, the interpretation of the empirical lead-lag relationship is somewhat ambiguous, since it may be evidence that the futures price innovation is predicting a movement in short-term interest rates which is outside the maturity period of the currently traded bills. This explanation may account for some part of the detected lead-lag relationship in this case.

## 7. Conclusions

The paper began by identifying two major sets of issues which have been raised in the study of financial futures markets outside Australia. The first of these concerns the hypothesis of market efficiency, which asserts that futures prices fully reflect available information about future spot prices. Efficiency in this sense is regarded as an important minimal requirement if futures markets are to fulfil their economic functions as instruments of inventory and risk management. The paper has assembled evidence on the efficiency of each of the three main futures markets in Australia, and in general the efficiency hypothesis is found to be supported by the data.

The one clear exception to this result concerns the pre-crash behaviour of share prices. SPI futures were found to have a significant positive drift, which is inconsistent with market efficiency because it indicates significant excess profits to holders of long positions prior to the crash. Conversely, short positions lost money on average. A possible means of reconciling this behaviour with investor rationality is the conjecture that the pre-crash period contained a speculative bubble in share prices, which investors expected would burst at some uncertain future date. Under this hypothesis, expected returns would be zero in an ex ante sense throughout the period, but would appear positive in sub-periods which exclude the crash. This conjecture has not yet been rigorously tested, but it appears a more promising approach for understanding the pre-crash period than explanations based on risk aversion or on mistaken expectations, which would be the main alternatives.

The second major issue concerned the question of whether or not futures trading has a statistically detectable influence on the short-term variability of spot prices. Here the results are quite clear in rejecting a causal link from futures trading volumes to spot price volatility. One easily verified aspect of this result is that there has been no trend increase in spot market volatility during the past three years, despite spectacular growth in futures trading.

This does not, however, mean that futures markets have no influence at all. There is strong evidence that futures price movements tend to lead movements in the corresponding spot prices, with the estimated lead time being possibly as long as one or two weeks.[4] It would be difficult to interpret this relationship as causal in the usual sense, but it could be argued that futures prices perform a signalling role, reacting relatively quickly to new information, which then becomes reflected in spot prices with a short lag. This interpretation is consistent with theory, which suggests that the signalling role is likely to be performed by the market with the lower transaction costs. In this sense, the futures markets could be seen as being more efficient than the spot.

As a final point, it should be reiterated that the paper has adopted a relatively limited working definition of market efficiency, based on the predictive content of futures prices over spot prices. Although the futures markets have been found to be generally efficient by this criterion, nothing in the paper can be taken as ruling out more deep-seated forms of inefficiency involving sustained departures of spot prices from market fundamentals.

4. In the case of bill futures, this result may in part be explained by the different time period covered by a futures bill as against a spot bill, since investors' views about the two periods may differ.

TABLE 1. ANNUAL TRADING VOLUMES OF MAIN SFE CONTRACTS
(thousands of contracts traded)

| | Wool | Bills | Bonds | SPI | Options | Other | Total |
|---|---|---|---|---|---|---|---|
| 1960-1978 (av.) | 75 | | | | | 2 | 77 |
| 1979 | 75 | 2 | | | | 189 | 266 |
| 1980 | 173 | 17 | | | | 421 | 611 |
| 1981 | 67 | 28 | | | | 359 | 454 |
| 1982 | 31 | 146 | | | | 233 | 410 |
| 1983 | 22 | 161 | | 180 | | 127 | 490 |
| 1984 | 9 | 173 | 2 | 237 | | 96 | 517 |
| 1985 | 7 | 594 | 242 | 282 | 22 | 76 | 1223 |
| 1986 | 2 | 1075 | 1432 | 466 | 242 | 64 | 3281 |
| 1987 | 1 | 2095 | 2064 | 625 | 568 | 16 | 5369 |

Notes

(i) The options column includes only options on the major contracts (bills, bonds and SPI).

(ii) "Other" consists mainly of commodity futures (cattle, gold, silver) and currency futures, together with options on these (after 1985).

Source: Sydney Futures Exchange, and Rutledge (1983).

TABLE 2. AUTOCORRELATION FUNCTIONS FOR FIRST DIFFERENCED PRICE SERIES

| Variable | Sample (short or long) | Lag Length 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| SPI spot | S | .09 | -.01 | .00 | .11 | -.15 | -.14 | -.07 | -.03 |
| | L | .20* | .19 | .09 | -.05 | -.05 | .03 | .06 | -.11 |
| SPI futures | S | -.04 | -.04 | -.01 | .14 | -.14 | -.17 | -.08 | .07 |
| | L | .12 | .14 | .12 | -.08 | -.06 | -.07 | .04 | -.05 |
| Bills spot | S | .08 | -.10 | .07 | .20* | .05 | -.11 | .00 | .05 |
| | L | .06 | -.09 | .07 | .16* | .02 | -.10 | -.03 | .05 |
| Bills futures | S | .04 | -.14 | .13 | .18* | -.01 | -.23* | -.16* | -.02 |
| | L | .05 | -.12 | .11 | .10 | -.04 | -.24* | -.15 | .01 |
| Bonds spot | S | .07 | -.10 | .12 | .16* | .04 | -.12 | -.05 | .09 |
| | L | -.02 | -.09 | .05 | .12 | .06 | -.11 | -.06 | .02 |
| Bonds futures | S | .12 | -.05 | .12 | .14 | -.01 | -.14 | -.09 | .05 |
| | L | .16* | -.05 | .04 | .11 | -.03 | -.16* | -.09 | .05 |

Note: 5% critical value is 0.155.

Asterisk denotes significance at 5% level.

TABLE 3. PARTIAL AUTOCORRELATION FUNCTIONS FOR FIRST DIFFERENCED PRICE SERIES

| Variable | Sample (short or long) | Lag Length 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| SPI spot | S | .09 | -.02 | .00 | .11 | -.18 | -.11 | -.05 | -.04 |
| | L | .20* | .16 | .03 | -.11 | -.04 | .01 | .10 | -.14 |
| SPI futures | S | -.04 | -.05 | -.01 | .14 | -.13 | -.17 | -.10 | .03 |
| | L | .12 | .12 | .09 | -.13 | -.07 | -.05 | .09 | -.05 |
| Bills spot | S | .08 | -.11 | .08 | .18* | .03 | -.08 | -.01 | -.01 |
| | L | .06 | -.10 | .08 | .15 | .01 | -.08 | -.04 | .01 |
| Bills futures | S | .04 | -.14 | .15 | .15 | .02 | -.22* | -.20 | -.10 |
| | L | .05 | -.12 | .13 | .07 | -.03 | -.23* | -.16 | -.04 |
| Bonds spot | S | .07 | -.10 | .14 | .14 | .05 | -.11 | -.07 | .04 |
| | L | -.02 | -.09 | .05 | .11 | .08 | -.11 | -.07 | -.02 |
| Bonds futures | S | .12 | -.07 | .14 | .11 | -.02 | -.14 | -.10 | .04 |
| | L | .16* | -.07 | .11 | .07 | -.05 | -.15 | -.07 | .06 |

Note: 5% critical value is 0.155.
Asterisk denotes significance at 5% level.

TABLE 4: JARQUE-BERA TESTS FOR NORMALITY

| | Skewness ($\sqrt{b_1}$) | Kurtosis ($b_2$) | Joint LM |
|---|---|---|---|
| Pre-Crash Sample: | | | |
| SPI | 0.00 | 3.63 | 2.44 |
| Bills | 1.05 | 6.39* | 97.60* |
| Bonds | 0.08 | 4.15* | 8.20* |
| Full Sample: | | | |
| SPI | -4.48* | 38.34* | 9137.12* |
| Bills | 0.83 | 5.62* | 66.00* |
| Bonds | -0.20 | 7.88* | 164.55* |

Notes: (i) The measure of skewness ($\sqrt{b_1}$) is defined by $b_1 = \frac{m_3}{(m_2)^{3/2}}$ where $m_i$ is the ith central moment. The theoretical value of $b_1$ is zero for the normal distribution. Positive skewness indicates a long right-hand tail.

(ii) Kurtosis is measured by $b_2 = \frac{m_4}{m_2^2}$ (= 3 for the normal). High kurtosis indicates that extreme values have a high probability of occurring, relative to the normal.

(iii) LM is a joint test for skewness and kurtosis as specified by Bera and Jarque (1986).

The critical values for the measure of skewness ($\sqrt{b_1}$) and kurtosis ($b_2$) are given in White and MacDonald (1980). The LM test specified by Bera and Jarque (1986) is distributed as a chi-square with two degrees of freedom. Asterisk denotes significance at the 5% level.

TABLE 5. EFFICIENCY TESTS BASED ON LAGGED PRICES
(PRE-CRASH SAMPLE)

| Market | Constant | Lagged Futures 1 | 2 | 3 | 4 | 5 | Lagged Spot 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SPI | $.84\times10^{-2}$* | .10 | -.01 | .07 | .44 | .28 | -.17 | .02 | -.12 | -.35 | -.34 |
| | $(.28\times10^{-2})$ | (.23) | (.25) | (.27) | (.27) | (.23) | (.29) | (.30) | (.31) | (.31) | (.26) |
| Bills | $.64\times10^{-3}$ | .08 | .00 | .12 | .18* | .09 | -.03 | -.14 | .15 | -.10 | -.08 |
| | $(.37\times10^{-3})$ | (.08) | (.09) | (.09) | (.08) | (.09) | (.10) | (.10) | (.10) | (.10) | (.10) |
| Bonds | $.97\times10^{-4}$ | -.05 | -.02 | -.15 | -.21 | -.24 | .19 | -.06 | .36 | .30 | .22 |
| | $(.17\times10^{-3})$ | (.17) | (.20) | (.21) | (.19) | (.17) | (.18) | (.20) | (.21) | (.20) | (.16) |

TABLE 6. EFFICIENCY TESTS BASED ON LAGGED PRICES
(FULL SAMPLE)

| Market | Constant | Lagged Futures 1 | 2 | 3 | 4 | 5 | Lagged Spot 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SPI | $.31\times10^{-2}$ | -.08 | -.09 | -.12 | .60 | .47 | .24 | .27 | .25 | -.95* | -.49 |
| | $(.39\times10^{-2})$ | (.24) | (.36) | (.40) | (.40) | (.35) | (.29) | (.45) | (.47) | (.47) | (.40) |
| Bills | $.50\times10^{-3}$ | .12 | .01 | .07 | .13 | .03 | -.02 | -.15 | .19 | -.12 | -.07 |
| | $(.35\times10^{-3})$ | (.08) | (.08) | (.08) | (.08) | (.08) | (.10) | (.10) | (.10) | (.10) | (.10) |
| Bonds | $.73\times10^{-4}$ | .09 | .01 | .01 | -.16 | -.22 | .08 | -.07 | .15 | .23 | .16 |
| | $(.16\times10^{-3})$ | (.14) | (.16) | (.17) | (.16) | (.14) | (.13) | (.15) | (.16) | (.15) | (.12) |

Notes: Dependent variable in each case is changed in future price. Estimated new contract dummies are not reported.

TABLE 7: EFFICIENCY TESTS BASED ON EXPECTED PREMIUMS

| Market | Pre-Crash Sample Constant | Expected Premium | DW | Full Sample Constant | Expected Premium | DW |
|---|---|---|---|---|---|---|
| SPI | $.76 \times 10^{-2}$ | .07 | 2.14 | $.26 \times 10^{-2}$ | .11 | 1.72 |
| | ($.21 \times 10^{-2}$) | (.15) | | ($.39 \times 10^{-2}$) | (.22) | |
| Bills | $.58 \times 10^{-3}$ | -.04 | 1.96 | $.46 \times 10^{-3}$ | -.02 | 1.86 |
| | ($.38 \times 10^{-3}$) | (.12) | | ($.36 \times 10^{-3}$) | (.11) | |
| Bonds | $.65 \times 10^{-4}$ | -.08 | 1.91 | $.78 \times 10^{-4}$ | -.03 | 1.78 |
| | ($.18 \times 10^{-3}$) | (.18) | | ($.17 \times 10^{-3}$) | (.13) | |

TABLE 8: ARCH TESTS FOR CONDITIONAL HETEROSKEDASTICITY

| | Lag Length | Pre-Crash Sample | Full Sample |
|---|---|---|---|
| SPI | 1 | 1.13 | 0.30 |
| Bills | 1 | 17.74* | 14.54* |
| Bonds | 3 | 7.82* | 8.09* |

Note: The test statistic is a $\chi^2$ test for joint significance of the $\beta$ coefficients in equation (6). An asterisk denotes significance at the 5% level.

TABLE 9: GRANGER CAUSALITY TESTS - VOLATILITY

| | Pre-crash sample | | | Full sample | | |
|---|---|---|---|---|---|---|
| Volatility | Volume | Lagged Volume | Lagged Futures Volatility | Volume | Lagged Volume | Lagged Futures |
| SPI | $-.20\times10^{-6}$* | $.19\times10^{-6}$* | .03 | $.11\times10^{-6}$ | $.93\times10^{-6}$ | .09 |
| | $(.95\times10^{-7})$ | $(.96\times10^{-7})$ | (.06) | $(.39\times10^{-6})$ | $(.90\times10^{-6})$ | (.06) |
| Bills | $.12\times10^{-8}$ | $-.93\times10^{-9}$ | .13* | $.15\times10^{-8}$ | $-.88\times10^{-9}$ | .12* |
| | $(.14\times10^{-8})$ | $(.14\times10^{-8})$ | (.06) | $(.12\times10^{-8})$ | $(.19\times10^{-8})$ | (.06) |
| Bonds | $.45\times10^{-9}$ | $.21\times10^{-9}$ | .44* | $.12\times10^{-9}$ | $-.76\times10^{-10}$ | .33 |
| | $(.29\times10^{-9})$ | $(.25\times10^{-9})$ | (.10) | $(.44\times10^{-9})$ | $(.40\times10^{-9})$ | (.18) |

Notes: The dependent variable in each case is the squared change in spot price $(s_t-s_{t-1})^2$.

TABLE 10: GRANGER CAUSALITY TESTS IN LEVELS

| | Pre-Crash Sample | | | Full Sample | | |
|---|---|---|---|---|---|---|
| | Lag Length Selected | F1 | F2 | Lag Length Selected | F1 | F2 |
| SPI | 1 | 0.65 | 4.69* | 2 | 1.01 | 2.41 |
| Bills | 2 | 0.24 | 3.26* | 2 | 0.54 | 4.25* |
| Bonds | 2 | 1.73 | 8.98* | 2 | 1.28 | 14.60* |

Notes: $F_1$ tests for causality from spot to futures prices.
$F_2$ tests causality in the reverse direction.

## Appendix: Outline of Contract Specifications

This appendix summarises the main features of contract specification for the three contracts studied in the text. Full details are available in various SFE publications.

### 1. 90-day Bank Accepted Bills

- Deliverable contract (although in practice little physical delivery actually takes place; contracts are usually closed out prior to termination of trading).
- Contract unit: $500,000 face value.
- Delivery months: In practice only March, June, September and December contracts are traded in significant volumes, with trading concentrated in the two nearest of these contract months.
- Termination of trading: Wednesday prior to second Friday of the delivery month.

### 2. 10-year Treasury Bonds

- Non-deliverable (i.e. mandatory cash settlement).
- Contract unit: $100,000 face value.
- Contract months: March, June, September and December with trading concentrated in the nearest contract month.
- Termination of Trading: 15th or next business day of the contract month.

### 3. Share Price Index

- Non-deliverable.

- Contract unit: $100 times all ordinaries index.

- Contract months: March, June, September, December, with trading concentrated in the nearest contract month.

- Termination of trading: last business day of contract month.

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