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Efficiency and Liquidity in the Electricity Market: A Preliminary Analysis

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EFFICIENCY AND LIQUIDITY IN THE ELECTRICITY MARKET: A PRELIMINARY ANALYSIS

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ABSTRACT

Following varying degrees of deregulation of the New South Wales and Victorian electricity markets, consumers in those states have faced market determined prices, and since September 1997 instruments for risk management, in the form of electricity futures contracts, have been available.

This paper addresses two important questions in relation to these new markets. The first is whether the electricity futures prices, determined on the Sydney Futures Exchange, reflect all publicly available information as fully as possible. This issue is investigated by the forecast error approach, which permits a test of the semi-strong efficient markets hypothesis (EMH). Rejection of this hypothesis would imply that agents are responding to price signals which are not of the best possible quality, so that unarbitraged profit opportunities remain, and some misallocation of resources could occur.

The second question addressed is whether there is evidence of increasing returns to liquidity in this market. Liquidity is measured here by the standard

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deviation of market clearing prices, and a simple binomial model is employed to generate the hypothesis of increasing returns. An implication of support for the hypothesis of increasing returns is that larger markets could be expected to grow further, and contracts with smaller volumes could be expected to disappear. This would apply also to multiple contracts in the same commodity.

The results suggest first, that the EMH cannot be rejected, and second, that there is no significant relationship between volume and liquidity in these markets at this stage.

Keywords: electricity futures; market efficiency; liquidity; increasing returns.

JEL Codes: G13, G14

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1. INTRODUCTION

Futures markets perform three major functions: first, they collect and disseminate information; second, they perform a forward pricing function, and third, they facilitate risk management through hedging. It is important that futures prices reflect public information as fully as possible, for otherwise economic agents are not responding to the best possible price signals. If futures markets are not informationally efficient, the forward pricing function will be performed in a sub-optimal way and a misallocation of resources will occur, and also hedging will not be as effective as possible. It is important also that futures markets are as liquid as possible, so that buyers and sellers can trade at desired prices. A reduction in liquidity means an increase in transactions costs for both parties, which is likely to act as a disincentive to transactions.

Economists have studied the informational efficiency of futures markets for several decades. Attention at first was directed to whether information in own past prices was reflected as fully as possible in current prices (weak form efficiency: see Cargill and Rausser, 1975 for a useful summary of results). More recently attention has focused on the question whether all public information is reflected in prices as fully as possible (semi-strong form efficiency). Three different methodologies have been employed to address this issue, that is, to test the semi-strong efficient markets hypothesis. These are first, the model forecasting approach, which compares post-sample forecasts of the spot price by an economic model with the forecasts implicit in a lagged futures price (see Leuthold and Hartmann 1979). Second, the forecast error (futures price minus delivery date spot price) approach, which tests for a systematic relationship between current and lagged forecast errors (see Hansen and Hodrick, 1980). Third, the event studies approach investigates the response of futures prices to a series of relevant event announcements (see Chance, 1985). In this paper the forecast error approach is used to study semi-strong form efficiency, because the short sample period for the new Victorian and New South Wales electricity futures contracts preclude the model forecasting approach, and there appears to be no series of announcements of an event relevant to the electricity market. The forecast error approach was introduced by Hansen and Hodrick (1980) to study the efficiency of key foreign exchange rates against the US dollar, and has been employed by Goss (1983) and Sephton and Cochrane (1990) in studies of non-ferrous metal on the London Metal Exchange. All these authors rejected the semi-strong EMH for some of the commodities investigated.

Telser and Higinbotham (1977) argued that liquidity of futures markets varies inversely the standard deviation of market clearing prices and they found empirically, in their sample of 51 commodities on US exchanges, that this standard deviation varied negatively with turnover. Goss and Avsar (1998) defined liquidity in terms of the ask-bid spread (ask price minus bid price), and found that for two thirds of the Sydney Futures Exchange contracts studied, including the major Bank Accepted Bills and Share Price Index futures, there was a significant negative relationship between volume and ask-bid spread. With deregulation of electricity spot markets in Victoria and New South Wales, the Sydney Futures Exchange (SFE) introduced electricity futures contracts in September 1997. These contracts refer to electrical energy traded in the Victorian and NSW wholesale pools, based on a flat load profile, in units of 500 MWh, and are quoted for maturity every calendar month, up to 12 months ahead. These contracts provide for mandatory cash settlement, unlike the electricity contracts introduced on the New York Mercantile Exchange in March 1996, which provide for physical delivery during on-peak hours (6 am to 10 pm). (The Sydney Futures Exchange introduced a peak load electricity futures contract in March 1999.)

In Australia, monthly average production of electric power in 1995 was 13.5 billion KWh, which compares with Sweden 12.0 billion KWh, UK 28.1 billion KWh, Germany 33.0 billion KWh, Japan 58.3 billion KWh and USA 233.8 billion KWh (*CRB Commodity Yearbook* 1996). The electricity futures contracts traded on the SFE provide an important risk management tool for producers, consumers and distributors of electricity: for example, a generator can lock in current prices for future electric power production by selling futures contracts (short hedger). An industrial consumer, on the other hand, can hedge against the risk of a rise in electricity input prices by buying futures contracts (long hedger), while an electric power distributor, which may be long or short in the actuals market, can hedge spot market price risks by taking a futures market position of opposite sign. Moreover, the presence of base and peak load contracts may provide the opportunity for arbitrage between these two markets, and speculators, essential to any successful futures market, will be able to back their expectations about price levels or inter-month price spreads.

In the remainder of this paper, model specifications and methodology are discussed in Section 2, while data, tests for stationarity and estimation methods are discussed in Section 3. Results are presented and interpreted in Section 4, and Section 5 suggests some conclusions.

2. MODEL SPECIFICATION

Futures prices, as market anticipations of delivery date spot prices, will be subject to forecast error if new information arrives between the date of futures price quotation and the delivery date. Thus forecast errors (the difference between the delivery date spot price and the prior futures price) contain information. If the market is efficient, however, this information will be taken into account in price formation very rapidly, and there will be no systematic relationship between current and prior forecast errors. Moreover, the forecast error approach assumes that relevant publicly available information is contained in prior forecast errors for own and related commodities. Semi-strong form market efficiency, therefore, requires that there is no systematic relationship between the current forecast error for a particular commodity, and prior forecast errors for own and related commodities. In this case, the related commodities are assumed to be the Victorian and NSW electricity contracts. The equation to be estimated is

$$A_{t+k} - F_{t,t+k} = \alpha + \sum_{j=1}^{2} \beta_j \left(A_t^j - F_{t-k,t}^j\right) + e_{t+k} \quad (1)$$

where A_t = spot price of electricity at time t;

$F_{t,t+k}$ = electricity futures price at time t, for maturity at $(t + k)$;

j = 1 for Victorian electricity;

j = 2 for NSW electricity;

α, β_j = coefficients to be estimated;

t = time in months;

e_{t+k} = error term.

The semi-strong EMH is addressed by testing the joint hypothesis $H(\alpha, \beta_j = 0)$. Market efficiency in this sense means that for an agent trading on this set of public information the expected return is zero. While rejection of the EMH implies that unarbitraged gains exist, non-rejection is no proof of market efficiency, because there is the possibility that an alternative test may lead to rejection.

Goss and Avsar (1998) defined liquidity in terms of ask-bid spread. Ask and bid price data, however, are not available for electricity contracts on the SFE. In this paper, therefore, the standard deviation of market clearing prices is employed as a measure of liquidity, following Telser and

Higinbotham (1977, pp.970, 975): liquidity varies inversely with this standard deviation. On the assumption that the distribution of market clearing prices is asymptotically normal, Telser and Higinbotham (1977, pp.970, 976) argue that the standard deviation is a decreasing function of the square root of the number of transactions. This reasoning led Telser (1981, p.17) to conclude that there are increasing returns to liquidity. Much evidence has accumulated, however, to suggest that daily price changes in futures markets are not normally distributed, but are leptokurtic (see Harris, 1987; Hsieh, 1988; Hall *et al*, 1989). For this reason, a simple Binomial model is used here, as in Goss and Avsar (1998), to predict a direct relationship between the number of transactions and liquidity. If success is defined as buyer and seller each able to transact at desired prices, the probability of success is given by the Binomial Distribution as

$$f(x) = \frac{n!}{x!(n-x)!} p^x q^{n-x} \qquad (2)$$

where x = number of successes;

n = number of trials;

p = probability of success in a single trial;

q = probability of non-success.

It is clear from (2) that the probability of zero successes decreases as the number of trials increases; hence the probability of one or more successes increases with n. It is assumed that the probability of success varies inversely with the standard deviation of market clearing prices.

The hypothesised negative relationship between volume and standard deviation is given by

$$V_t = \alpha + \beta SD_{t,t+1} + e_t \tag{3}$$

where $SD_{t,t+1}$ = standard deviation of prices in period t, for a futures contract with maturity in $(t + 1)$;

V_t = volume in period t for a given futures contract for all delivery months;

α = constant;

$\beta < 0$;

e_t = error term;

t = time in months.

This hypothesis, if valid, would explain why large futures exchanges, such as the Chicago Board of Trade, which are relatively more liquid, are experiencing increasing volumes, while medium size exchanges, such as MATIF (Marché a Terme Internationale de France), which are relatively less liquid, are experiencing reduced volumes, and are being forced to close, or to merge with other exchanges in order to survive.

It should be noted that in Stein (1986, pp.74-75) an increase in sample size leads to a reduction in forecast error due to misuse of information (his "Bayesian error") while in this paper an increase in sample size leads to increased liquidity.

3. DATA, STATIONARITY AND ESTIMATION

In this section the data, tests for unit roots and methods of estimation are discussed.

3.1 Data

Spot price data are the same as the cash settlement price, i.e. they are monthly averages of the spot price each half hour, for the Victorian and NSW pools, in Australian dollars per MWh. These data were obtained from the TransGrid web site (www.tg.nsw.gov.au) for the period October 1997 to November 1998, and from NEMMCO for the period December 1998 to April 1999. Futures price data are closing prices, on the last trading day of the month, for futures contracts one month from maturity for Victoria and NSW, in Australian dollars per MWh, obtained from the SFE web site (www.sfe.com.au).

Volume data are total numbers of contracts traded per month, for Victoria and NSW base load electricity futures contracts. (Spot and futures prices and volume data are provided in Appendix 2.) These new futures markets are thinly traded, and for this reason, the standard deviation of market clearing prices was calculated from all intra-day transaction prices, each month, for a futures contract one month from maturity, for both Victoria and NSW (transaction price data were purchased from the SFE).

3.2 Stationarity

To avoid spurious regression results, it is necessary that the residuals of the estimating equations (1), (3) are stationary. This condition will be fulfilled if all variables in these equations are stationary (i.e. integrated I(0)), or alternatively, if some of these variables are non-stationary, this condition will be fulfilled only if the non-stationary variables are integrated of the same order and are cointegrated. To investigate whether the variables in the models (1), (3) are stationary, unit root tests were conducted using both Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (see Banerjee *et al*, 1993, chapter 4 for an authoritative and helpful discussion). Both these procedures test the null hypothesis of a single unit root, against the alternative hypothesis that the series is stationary. For the variables employed in the models in this paper, these tests produced essentially similar results, and where there is ambiguity in the test results for a particular variable the Phillips-Perron tests are preferred, because of their generally greater power (see Banerjee *et al*, 1993, p.113). For reasons of space, only the results of the Phillips-Perron tests are reported here, and these are provided in Table 1. To allow for the low power of these tests (see Evans and Savin, 1981) and the small sample size, a ten per cent significance level has been employed. It can be seen from Table 1 that the Phillips-Perron tests support the view that all six variables are stationary, and the estimation of (1), (3) can proceed in the anticipation that the residuals of these equations will be stationary.

3.3 Estimation

Equation (1) contains, as regressors, a lagged dependent variable, and because of the interdependence between Victorian and NSW electricity markets, an endogenous regressor. These regressors will be correlated with the error term in (1), and OLS estimates of the coefficients in this equation will be inconsistent. Instrumental variable (IV) estimates will be consistent in these circumstances, and are preferred. Since the data are sampled at monthly intervals, and a one month lag is employed for prior forecast errors, the data are non-overlapping. This should minimise the autoregressive effect of news upon the error term.

Equation (3) also contains an endogenous regressor, and IV methods are employed to estimate the coefficients of this equation, for the same reasons as stated above. The estimations referred to in this section were executed using *Eviews 2.0* Lilien *et al* (1995).

4. RESULTS

The semi-strong EMH is addressed by testing the joint hypothesis that all coefficients of equation (1) are zero. With IV estimation of (1), this is a χ^2 test with 3 degrees of freedom. The results of IV estimation[1] of (1) for Victorian and NSW electricity are provided in Table 2, together with calculated and critical χ^2 values to test the joint hypothesis $H(\alpha,\beta_1,\beta_2 = 0)$. It will be seen that none of the individual coefficient estimates is significant, for either Victorian or NSW electricity, and the hypothesis $H(\alpha,\beta_1,\beta_2 = 0)$cannot be rejected at the 5% level, in either case. The Durbin-Watson statistic does not indicate the presence of first order autocorrelation in the residuals of these relationships.

The results of further diagnostic tests on the residuals are provided in Appendix 1. The Ljung-Box Q Statistic tests the null hypothesis that all autocorrelation coefficients, up to lag 12 in this case, are zero, and this test suggests that the residuals are not affected by autocorrelation. The Phillips-Perron test suggests that the residuals are stationary, while the Jarque-Bera test, which addresses the hypothesis that the residuals are normally distributed, indicates that the null of normality can be rejected for NSW at a level of 6.18%, a result which possibly is influenced by the small sample size. Overall, therefore, these diagnostics do not constitute a serious qualification to the estimates of equation (1), and the results are consistent with the view that there is no systematic relationship between current forecast errors for Victoria and NSW, and an information set comprising lagged forecast errors for both states. The EMH, therefore, cannot be rejected.

Consider now the hypothesis of increasing returns to liquidity. This hypotheis requires that the estimates of β, in equation (3), are negative and significant. In Table 3, which presents the results of IV estimation[2] of equation (3), it can be seen that neither of the estimates of β is significant, although the estimate for NSW is negative. These results, therefore, do not support the increasing returns hypothesis. This outcome may be due to the small sample size, which is of less than one and a half years duration; in Goss and Avsar (1998), in which the increasing returns hypothesis was supported for a majority of the contracts studied, sample size ranged from 29 to 41 monthly observations.

The Durbin-Watson statistic, reported in Table 3, does not suggest the presence of first order autocorrelation in the residuals of equation (3), while the Ljung-Box Q statistic, reported in Appendix 1, does not lead to rejection of the hypothesis that all autocorrelation coefficients, up to lag 12, are zero. Furthermore, the PP test in Appendix 1 suggests that the residuals of (3) are stationary, while the Jarque-Bera statistic is consistent with the view that these residuals are normally distributed, for both Victorian and NSW electricity.[3]

5. CONCLUSIONS

This paper investigates the informational efficiency and the liquidity in the new Victorian and New South Wales electricity futures markets. The semi-strong efficient markets hypothesis is tested using the forecast error approach, due to the small number of observations. Forecast errors (futures price minus delivery date spot price) contain information, due to the arrival of news after the futures price is quoted; if the market is efficient, there should be no systematic relationship between the current forecast error for a particular contract and the prior forecast errors for both Victorian and NSW electricity, which are assumed to comprise the set of public information. The results suggest that the EMH cannot be rejected.

Liquidity in this paper is measured by the standard deviation of transaction prices, for the near future, for each calendar month. The hypothesis of increasing returns to liquidity postulates that there is a negative relationship between the standard deviation of prices and monthly volume. This negative relationship is predicted by a binomial model in which the probability of agents executing a transaction, at the desired price, increases with the number of contracts traded. The implication of this hypothesis, which is consistent with the tendency to concentration in world futures markets, is that transactions costs, insofar as they are governed by the liquidity component, could be expected to decrease as the market expands. In this paper, however, the results did not support this hypothesis, and indeed there was no significant relationship between volume and liquidity.

The policy implication of the first result is that this study does not call into question the quality of the price signals faced by agents in these markets. The second result suggests that further research should be undertaken on the liquidity issue, when a larger number of observations is available.

TABLE 1
UNIT ROOT TESTS: PHILLIPS-PERRON

Variable	Calculated Test Statistic	10% Critical Value	Order of Integration
Victoria			
$A_{t+k} - F_{t,t+k}$	– 4.9818	– 2.6672	I(0)
V_t	– 3.4223	– 2.6672	I(0)
$SD_{t,t+1}$	– 5.8806	– 2.6672	I(0)
NSW			
$A_{t+k} - F_{t,t+k}$	– 3.8311	– 2.6672	I(0)
V_t	– 4.3027	– 3.3228	I(0)
$SD_{t,t+1}$	– 3.5962	– 2.6829	I(0)

TABLE 2
COEFFICIENT ESTIMATES FOR EQUATION (1)*

	$\hat{\alpha}$	$\hat{\beta}_1$	$\hat{\beta}_2$	*DW*	*T*
Victorian Electricity	– 0.9295 (– 0.5699)	1.2919 (1.5950)	– 1.3281 (– 1.4236)	2.2318	16
NSW Electricity	– 1.7217 (– 0.6601)	– 0.5199 (– 0.2881)	0.5421 (0.3215)	1.9363	16

* **Notes:** Asymptotic *t* values are in parentheses.
Estimation is by IV.
T is number of observations.
Calculated χ^2 values to test $H(\alpha, \beta_1, \beta_2 = 0)$:
Victorian Electricity: 2.9872
NSW Electricity: 0.7812
Critical $\chi^2_3(0.05) = 7.815$

TABLE 3
COEFFICIENT ESTIMATES FOR EQUATION (3)*

	$\hat{\alpha}$	$\hat{\beta}$	*DW*	*T*
Victorian Electricity	117.6376 (1.0467)	139.9809 (1.3589)	1.6387	17
NSW Electricity	623.8725 (0.7189)	– 223.4611 (– 0.2520)	2.0947	15

* **Notes**: Asymptotic *t* values are in parentheses.
Estimation is by IV.
T is number of observations.
There are two less observations for NSW estimates than for Victorian estimates, because in October 1998 and January 1999 there was zero volume in NSW near future.

APPENDIX 1
DIAGNOSTIC TESTS ON RESIDUALS

Test \ **Equation**	**(1) VIC**	**(1) NSW**	**(3) VIC**	**(3) NSW**
Ljung-Box Q Statistic				
Calculated χ^2	8.4882	6.8208	16.914	7.8986
Critical $\chi^2_{12}(0.05)$	21.026	21.026	21.026	21.026
Phillips-Perron Test				
Calculated PP Statistic	– 4.4985	– 3.9999	– 3.1438	– 6.0314
10% Critical Value	– 2.6829	– 2.6829	– 2.6745	– 3.3393
Jarque-Bera Test				
Calculated Test Statistic	1.0445	5.5680	0.4898	2.3717
Probability Value	0.5932	0.0618	0.7828	0.3055

APPENDIX 2: DATA

OBSERVATION	VIC			NSW		
	S_{t+1}	$F_{t,t+1}$	V_t	S_{t+1}	$F_{t,t+1}$	V_t^*
1	33.29	15.95	441	18.39	16.55	314
2	10.96	20.00	399	11.38	18.00	331
3	9.19	21.00	71	10.99	18.75	253
4	10.34	18.00	281	12.63	15.95	100
5	8.97	14.50	277	10.53	14.15	451
6	10.20	12.90	203	11.31	11.90	231
7	15.99	12.30	322	17.73	12.15	289
8	21.94	19.00	357	22.50	22.25	280
9	22.34	23.10	66	24.32	22.75	189
10	22.70	22.00	166	24.96	22.50	337
11	21.09	23.50	301	22.26	24.85	564
12	23.14	22.40	443	21.52	22.50	1305
13	17.84	23.75	486	18.54	24.30	210
14	35.58	23.30	246	35.94	22.00	612
15	22.91	27.00	77	23.22	26.25	479
16	28.35	30.75	214	19.83	28.75	625
17	16.25	25.40	292	17.53	23.35	
18	20.57	23.00	287	21.25	22.50	

* The reason for two less volume observations for NSW than for Victoria is given in Notes to Table 3.

ENDNOTES

1 The instruments employed in the estimation of equation (1), for both Victoria and NSW, were the dependent variable and both regressors, each lagged one period.

2 The instruments employed in the estimation of equation (3), for both Victoria and NSW, were the dependent variable and the regressor, each lagged one period.

3 A further point deserves comment. Further examination of the residuals of (1) reveals the presence of a significant MA(1) process, for the Victorian version only. If the error term of (1) is represented by $e_{t+k} = u_{t+k} + \lambda u_{t+k-1}$ the estimate $\hat{\lambda} = 0.9432$ (30.065) is obtained (*t* value in parenthesis). Similarly, a significant

negative MA(1) process was found for the NSW version only of Equation (3). If the error term of (3) is represented $e_t = u_t + \lambda u_{t-1}$ the estimate $\hat{\lambda} = -0.9891$ (−1942.723) is obtained (t value in parenthesis). In the absence of overlapping observations, these results were not predictable, and constitute a puzzle.

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