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Modelling price and volatility inter-relationships in the Australian wholesale spot electricity markets

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ABSTRACT

This paper examines the inter-relationships of wholesale spot electricity prices among the four regional electricity markets in the Australian National Electricity Market (NEM): namely, New South Wales, Queensland, South Australia and Victoria using the constant conditional correlation and Tse and Tsui's (Tse, Y.K., Tsui, A.K.C., 2002. A multivariate generalised autoregressive conditional heteroscedasticity model with time-varying correlations. Journal of Business and Economic Statistics 20 (3), 351–362.) and Engle's (Engle, R., 2002. Dynamic conditional correlation: a sample class of multivariate generalized autoregressive conditional heteroskedasticity models. Journal of Business and Economic Statistics 20 (3), 339–350.) dynamic conditional correlation multivariate GARCH models. Tse and Tsui's (Tse, Y.K., Tsui, A.K.C., 2002. A multivariate generalised autoregressive conditional heteroscedasticity model with time-varying correlations. Journal of Business and Economic Statistics 20 (3), 351–362.) dynamic conditional correlation multivariate GARCH model which takes account of the Student *t* specification produces the best results. At the univariate GARCH(1,1) level, the mean equations indicate the presence of positive own mean spillovers in all four markets and little evidence of mean spillovers from the other lagged markets. In the dynamic conditional correlation equation, the highest conditional correlations are evident between the well-connected markets indicating the presence of strong interdependence between these markets with weaker interdependence between the not so well-interconnected markets.

1. Introduction

The Australian National Electricity Market (NEM) was established on 13 December 1998. It currently comprises four state-based [New South Wales (NSW), Victoria (VIC), Queensland (QLD) and South Australia (SA)] and one non-state-based [Snowy Mountains Hydro-electric Scheme (SNO)] regional markets operating as a nationally interconnected grid. Within this grid, the largest generation capacity is found in NSW, followed by QLD, VIC and SA, while electricity demand is highest in NSW, followed by VIC, QLD and SA. The NEM, encompasses privately and publicly owned generators, transmission and distribution network providers and traders (for details of the NEM's regulatory background, institutions and operations see ACCC, 2000; IEA, 2001; NEMMCO, 2008a). However, each state's network was (and still is) characterized by a very small number of participants and sizeable differences in electricity prices were found. One of the objectives in establishing the NEM was to provide a nationally integrated and efficient electricity market.

However, a defining characteristic of the NEM is the limitations of physical transfer capacity. QLD has two interconnectors that together can import and export to and from NSW, NSW can export to and from the SNO and VIC can import from the SNO and SA and export to the SNO and to SA. There is currently no direct connector between NSW and SA and QLD is only directly connected to NSW. As a result, the NEM itself is not yet strongly integrated. During periods of peak demand, the interconnectors become congested and the NEM separates into its regions, promoting price differences across markets and exacerbating reliability problems of regional utilities (ACCC, 2000; IEA, 2001; NEMMCO, 2008a).

While the appropriate regulatory and commercial mechanisms do exist for the creation of an efficient national market, and these are expected to have an impact on the price of electricity in each region, it is argued that the complete integration of the separate regional electricity markets has not yet been realised. In particular, the limitations of the interconnectors between the member states suggest that, for the most part, the regional spot markets are relatively isolated.

This paper is motivated by the fact that the operations of the electricity market is similar to that of financial markets and modelling the dynamics of the conditional means which focus on the behaviour of the spot electricity prices and the conditional variance which assesses the risk management of these highly competitive markets. A fuller understanding of the dynamics of electricity pricing is likely to throw light on the efficiency of pricing and the impact of interconnection within the centralized markets which still are primarily composed of commercialized and corporatized public sector entities. A fuller

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understanding of the pricing relationships between these markets enables the benefits of interconnection to be assessed as a step towards the fuller integration of the regional electricity markets into a national electricity market. This provides policy inputs into both the construction of new interconnectors and the preparation of guidelines for the reform of existing market mechanisms.

There are many studies that use various univariate generalized autoregressive conditional heteroskedasticity (GARCH) models to assess the dynamics within spot electricity markets. This is then extended to multivariate GARCH (MGARCH) models to capture volatility clustering between spot electricity prices. The univariate autoregressive conditional heteroskedasticity (ARCH) models [as introduced by Engle (1982)] and GARCH models [as proposed by Bollerslev (1986)] have already been widely employed in modelling the dynamics of spot electricity markets. Suitable surveys of GARCH modelling in the spot electricity markets may be found in Knittel and Roberts (2001), Solibakke (2002), Hadsell et al. (2004), Higgs and Worthington (2005) and Chan and Gray (2006).

The only studies to date that have extended the univariate GARCH analyses to MGARCH applications as proposed by Bollerslev (1990) are De Vany and Walls (1999a), Bystrom (2003), Worthington et al. (2005) and Haldrup and Nielsen (2006). De Vany and Walls (1999a) use cointegration analysis between pairs of US regional electricity markets to assess market integration while Bystrom (2003) applies the constant correlation bivariate GARCH model to the short-term hedging of the Nordic spot electricity prices with electricity futures. Worthington et al. (2005) employ the multivariate GARCH (MGARCH) BEKK (Baba, Engle, Kraft and Kroner) model to capture the price and volatility spillovers among five spot electricity markets in Australia. The disadvantage of the MGARCH BEKK model is that the estimated coefficients for the variance–covariance matrix cannot be interpreted on an individual basis: "instead, the functions of the parameters which form the intercept terms and the coefficients of the lagged variance, covariance, and error terms that appear are of interest" (Kearney and Patton, 2000: 36). So far Worthington et al. (2005) produce the only study that utilizes the MGARCH model to assess the inter-relationships among five Australian spot electricity markets. Haldrup and Nielsen (2006) use a Markov regime switching model with long memory in each of the regime states to model the interdependence between pairs of electricity markets in the Nordic Pool regions.

The aim of this research is to extend on the paper by Worthington et al. (2005) by employing a family of constant and dynamic conditional correlation MGARCH models to capture the effects of cross-correlation volatility spillovers between the four Australian spot electricity markets. This permits a greater understanding of pricing efficiency and cross-correlation volatility spillovers between these interconnected markets. If there is a lack of significant inter-relationships between regions then doubt may then be cast on the ability of the NEM to overcome the exercise of regional market power as its primary objective, and on its capacity to foster a nationally integrated and efficient electricity market.

To the author's knowledge a detailed study of the applications of constant and dynamic correlation MGARCH models to assess the behaviour of the inter-relationships between more than two spot electricity markets has not been undertaken. It is within the context of previous limited empirical work that the present paper is conducted.

Accordingly, the purpose of this paper is to investigate the price volatility and inter-relationships in four Australian regional electricity markets by employing three conditional correlation MGARCH models namely: the constant conditional correlation, Tse and Tsui's (2002) and Engle's (2002) dynamic conditional correlation MGARCH models. If there is a lack of significant inter-relationships between regional markets then doubt may then be cast on the ability of the NEM to foster a nationally integrated and efficient electricity market. The remainder of the paper is divided into four sections. The second section surveys the transmission and trading of electricity across the regional markets. The third section explains the data employed in the analysis and presents some brief summary statistics. The fourth section discusses the methodology employed. The results are dealt with in the fifth section. The paper ends with some brief concluding remarks in the final section.

2. Transmission and trading of electricity in the NEM

Historically, each state in the NEM developed its own transmission network and linked it to another state's system via interconnector transmission lines. Power is transmitted between regions to meet energy demands that are higher than local generators can provide, or when the price of electricity in an adjoining region is low enough to displace the local supply. The scheduling of generators to meet demand across the interconnected power systems is constrained by the physical transfer capacity of the interconnectors. When the limit of an interconnector is reached, National Electricity Market Management Company Limited (NEMMCO) schedules the most cost-efficient sources of supply from within the region to meet the remaining demand. For example, if prices are very low in VIC and high in SA, up to 680 MW of electricity can be exported to SA across the interconnector. Once this limit is reached, the system uses the lowest priced generators in SA to meet the outstanding consumer demand.

The limitations of transfer capability within the centrally coordinated and regulated NEM are one of its defining features. QLD became part of the NEM in July 2000 with the completion of the interconnector Directlink, which can export and import 180 MW to and from NSW. In February 2001, interconnection between QLD and NSW was considerably strengthened with the introduction of the QLD and NSW Interconnector (QNI) where QLD can export 950 MW to and import 700 MW from NSW. NSW can export 1150 MW to the SNO and import 3000 MW from the SNO. VIC can import 1900 MW from the SNO and 420 MW from SA and export 1100 MW to the SNO and 680 MW to SA. The greatest transfer capacity is between SNO to NSW and SNO to VIC, that is, SNO is a generation region that exports most of its power to other regions. New interconnectors are being commissioned and upgrades to existing interconnectors are continually being reviewed. There is currently no direct connector between NSW and SA. QLD is only connected directly to NSW. In 2004 capacity was increased by 250/250 MW (forward/reverse) between SA and NSW; while in 2006 an upgrade of 200/200 MW (forward/reverse) was commissioned between NSW and QLD; 400/400 MW between NSW and VIC and 150 MW between VIC and SA (NEMMCO, 2008b). The increased transmission capacity and new generation will produce greater price convergence across the regional markets and foster a nationally integrated and stable spot electricity market.

With interconnectivity across regional spot electricity markets in the NEM, Table 1 presents descriptive statistics of daily inter-regional quantity flows from 1 January 2006 to 31 December 2007 (ESAA, 2009). On average NSW and SA import respectively 20,803.54 MW and 3196.69 MW of its power from other regions on a daily basis, while QLD and VIC export respectively 15,347.67 MW and

Table 1
Summary statistics of daily inter-regional quantity flows to Australian spot electricity markets, 1 January 2006–31 December 2007.

	Daily inter-regional quantity flows			
	NSW	QLD	SA	VIC
Mean	−20,803.54	15,347.67	−3196.69	2249.27
Median	−20,427.00	16,118.00	−3033.50	2649.50
Maximum	2542.00	30,282.00	7673.00	31,396.00
Minimum	−52,365.00	−6546.00	−15,200.00	−31,877.00
Std. dev.	9168.73	7618.06	4668.99	10,841.08

Notes: Inter-regional quantity flows are in megawatt with positive quantities as exports and negative quantities as imports; NSW—New South Wales, VIC—Victoria, QLD—Queensland and SA—South Australia.