# The Impact of Market Participants' Behaviour on Stock, Derivatives and Energy Markets


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# Summary

This thesis examines the market behaviour of participants in stock, derivative and energy markets to analyse their reactions around exogenous events and factors that the extant literature considers material. The analysis focuses on three key markets and contributes to the literature in each relevant area by extending knowledge on the impact of corporation reputation risks on stock performance, the influence of international energy prices on investors in various industries and the effect of policy uncertainty on pricing behaviour in electricity wholesale markets. The first of three papers in the thesis fills a gap in the knowledge of corporate social responsibility and corporate financial performance by examining how investors (an essential stakeholder class) react to increases in corporate reputation risks in US-listed companies from undesirable environmental, social and corporate governance activities that are illuminated in media reporting. Results from this study using 331,517 US observations indicate that reputation risks have a significant impact on the stock performance of affected firms and the magnitude of investor reactions is dependent on firm characteristics such as size, liquidity and industry classification. The second paper examines the impact of major international energy prices on industries in China, one of the largest global importers and consumers of energy commodities. Using firm-level data of 3750 stock listings across both the Shanghai and Shenzhen stock exchanges, segregated into 138 sub-industries under the Global Industry Classification Standard, this study provides a comprehensive analysis of aggregated industry behaviour in relation to the price movements of Brent and WTI crude oil futures, Henry Hub natural gas and Newcastle thermal coal. The research provides empirical evidence that crude oil futures have the most influence on Chinese industries and further analysis suggests that China's key oil pricing reform on 27 March 2013 has more closely aligned market behaviour to international oil benchmarks. The third paper analyses the impact of energy policy on electricity generation and pricing behaviour in Australia. This research focuses on the impact of introducing a carbon-pricing mechanism (i.e. a 'carbon tax') on wholesale electricity markets and how energy policy uncertainty affects generation behaviour. Empirical evidence suggests the carbon tax significantly increased wholesale electricity costs during the two-year regime, after controlling for relevant variables such as local region demand, supply, price volatility, monopolistic characteristics, supply and interregional factors. In addition, there are indications that policy uncertainty may have reduced generation capacity and increased wholesale electricity prices.

* Chapter 4 has been published in the *Journal of Futures Markets* and Chapters 3 and 5 have been submitted for review to leading international academic journals.

# Statement

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except when due acknowledgement has been made.

The work in this thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: ____________________

Date: ____________________

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# Chapter 1: Introduction

This chapter provides brief abstracts for the three papers presented in this thesis. The formal introductions for each research topic are provided in Chapters 3, 4 and 5, respectively.

### 1.1 Impact of corporate reputation risks on participants' behaviour in US stock markets

This first study examines the impact of corporate reputation risks (CRR) from adverse media coverage of environmental, social and governance (ESG) issues on stock performance at the firm level. With increasing international focus on companies' behaviour, there is a mounting spotlight on firms' corporate social responsibility (CSR) and the consequent value which investors (an essential stakeholder class) place on a firm's ESG reputation. Empirical results indicate that escalating CRR from detrimental ESG media reporting have a substantially negative corollary effect on the stock prices of smaller and less actively traded firms. Further analysis reveals that the stock performance of corporations in the 'sin' triumvirate (i.e. alcohol, tobacco and gaming) are not significantly affected by negative media coverage. Instead, firms in the candy and soda, steel works, banking and insurance industries are the most susceptible to investors' responses to the undesirable media spotlight. Interestingly, the most significant stock price shocks from heightened CRR are associated with the candy and soda industry, which may indicate the rise of 'sugar' as a new vice.

### 1.2 Impact of international energy future prices on industry behaviour in China

This second study examines how the returns and volatility of future contracts for Brent crude oil (Brent), West Texas Intermediate crude oil (WTI), Henry Hub natural gas (HHNG) and Newcastle thermal coal (NTC) impact on industries in China. Using the firm-level data of 3750 stock listings across both Shanghai and Shenzhen stock exchanges, segregated into 138 sub-industries under the Global Industry Classification Standard (GICS), this research finds evidence that crude oil futures have the most significant influence on Chinese industries. Further analysis suggests that the stock returns of oil-related companies are more closely aligned to Brent and WTI's futures returns following China's key oil pricing reform on 27 March 2013. Overall, there is evidence to suggest that Chinese industries are more exposed to global crude oil futures volatility since this reform.

### 1.3 Impact of energy policy on participants' behaviour in Australia's wholesale electricity markets

This third study examines the impact of energy policy on generation behaviour and wholesale electricity spot prices in Australia. The research focuses first on the impact of introducing a carbon-pricing mechanism (CPM) and provides empirical evidence that the 'carbon tax' increased wholesale electricity costs by approximately 22% to 68% during the two-year regime, after controlling for relevant variables such as local region demand, supply, price volatility, monopolistic characteristics and interregional factors. The most and least affected states were New South Wales and Tasmania, respectively, and there was a noticeable shift from coal to hydro power during the CPM period. Further, results suggest that the closures of coal-fired power plants *ex post* abolishment of the CPM (period of policy uncertainty) led to generation-capacity declines and higher wholesale electricity prices. There are also indications that wind is increasingly cost-efficient, but its rate of growth was limited during the sample period, which may suggest investors' reluctance to invest during times of policy uncertainty.

### 1.4 Summary

The remainder of this dissertation is structured as follows: Chapter 2 introduces the relevant literature review for each topic examined in this dissertation, Chapter 3 examines the impact of CRR on stock market performance, Chapter 3 studies the impact of international energy price movements on Chinese industries, Chapter 5 evaluates the impact of policy uncertainty on electricity markets, and Chapter 6 concludes the thesis.

# Chapter 2: Literature Review

This chapter provides a brief overview of the literature on the market behaviour theme that connects the three topics outlined in this dissertation. The relevant literature, motivation and hypothesis for each research area are presented extensively in Chapters 3, 4 and 5.

## 2.1 Literature on market behaviour theories

Generally, a marketplace can be viewed as an autonomous entity composed of a heterogeneous group of participants of varying rationalities. Research in traditional finance typically revolves around arbitrage principles (Miller and Modigliani, 1958), the modern portfolio theory (Markowitz, 1952), the capital asset pricing theory (Sharpe, 1964; Lintner, 1965; and Black, 1972) and the option-pricing theory (Black, Scholes & Merton, 1973). Based on these approaches, markets and participants are assumed to be efficient and systematic. For example, the efficient market hypothesis (EMH) states that in an efficient market, all the available information is incorporated when estimating the prices of financial assets and is based on the principle that investors behave rationally in the financial market. In decision-making, the expected utility theory (EUT) proposes that investors behave rationally by judging all the alternatives on the basis of their utility and the associated risks, and make a balanced decision when they have to choose a course of action among various alternatives in a world of uncertainty.

However, Kahneman and Tversky (1979) found results that are inconsistent with the EMH and EUT. This led to their development of prospect theory, which is an alternative to the EUT in explaining decision-making under uncertainty and suggests that the investment decision-making process is influenced by various behavioural biases that encourage investors to deviate from rationality and make irrational investment decisions. In particular, the theory suggests that investors' decision-making is more influenced by expectations of future gains and losses than actual final outcomes. The emergence of this theory is a new concept combining behavioural and psychological aspects in economic and financial decision-making that challenges the efficient and rational market perspectives and provides an explanation of why investors behave in a particular manner when investing in financial assets. This section provides a summary of the four common behavioural biases in market participants' decision-making process.

### 2.1.1 Overconfidence

The concept of overconfidence is a well-established and common bias which describes participants that ignore investment risks because of their excessive confidence in their knowledge and skills. Prior literature provides evidence that excessive trading on stock markets is often caused by investors' overconfidence (Odean, 1999) and these participants are likely to achieve lower returns (Barber and Odean, 2000) and have exposure to higher risk (Barber and Odean, 2001). This behavioural bias can be measured in three ways: (i) overestimation, which is defined as overstating one's own ability (Soll, 2007); (ii) over-placement, whereby people think of themselves as better than others (Larrick, Burson and Soll, 2007); and (iii) over-precision, which is excessive certainty regarding the accuracy of one's own beliefs (Odean, 1999; Barber and Odean, 2000, 2001). The general notion that an overconfidence bias influences rational decision-making behaviour in market venues is confirmed by De Bondt and Thaler (1995), Daniel et al., (1998), Barber and Odean (1999, 2000, 2001), Statman et al. (2006), Doukas and Petmezas (2007) and Grinblatt and Keloharju (2009).

### 2.1.2 Disposition effect

The disposition effect is another important behavioural bias whereby participants have a tendency to hold onto a loss-making stock and are more susceptible to selling a winning asset (see Shefrin and Statman, 1985). Findings from Odean (1998) indicate that due to tax motivations (at the end of the financial year), investors are more willing to part with their loss-making stocks, which provides empirical support for this theory. Other studies such as those of Ferris et al. (1988), Weber and Camerer (1998), Gomes (2005), Dhar and Zhu (2006), Frazzini (2006), Barber and Odean

(2008), Barberis and Xiong (2009) and Calvet et al. (2009) provide further evidence to support the general concept of the disposition effect in marketplaces.

### 2.1.3 Herding

Herding refers to market behaviour whereby rational participants start to behave irrationally by imitating the judgements of others when making decisions, and different categories of investors may display herding behaviour for different reasons. For example, individual investors may have a herd tendency because they are following the decisions of a large group or noisy traders, while institutional investors are likely to embrace herding characteristics because they seek to imitate others in the industry to protect their reputational or compensation concerns. Overall, it is more likely for individual investors to adopt herding behaviour compared to institutional market participants (Lee et al., 2004). The existence of this behavioural bias is well-documented in the literature (Lakonishok et al., 1992; Hirshleifer et al., 1994; Trueman, 1994; Grinblatt et al., 1995; Nofsinger and Sias, 1999; Wermers, 1999; Dennis and Strickland, 2002; Hirshleifer and Teoh, 2003; Sias, 2004; Clement and Tse, 2005; Avramov et al., 2006).

### 2.1.4 Home bias

The term ‘equity home bias’, also referred to as ‘home bias’, defines a situation in which market participants (individuals or institutions) have a preference for owning domestic assets instead of foreign securities in their portfolio (French and Poterba, 1991; Tesar and Werner, 1995). Despite several reasons proposed for this market behaviour, including investment barriers, transaction costs, information asymmetry, inflation hedging and non-tradable assets, there is no consensus explanation for this market behaviour and it is especially puzzling since the diversification theory suggest that investors are likely to be better off from the realised returns of an international portfolio compared to a domestic portfolio (e.g. Cooper and Kaplanis, 1994; Tesar and Werner, 1995; Bohn and Tesar, 1996; Coval and Moskowitz, 1999; Lewis, 1999; Pastor, 2000; Strong and

Xu, 2003; Ahearne et al., 2004; Bradshaw et al., 2004; Van Nieuwerburgh and Veldkamp, 2009; Seasholes and Zhu, 2010).

### 2.2 Summary

Overall, extant literature provides several theories to expect different participant reactions (from rational to irrational) to exogenous events which provide substantial motivations for understanding their market behaviour and the consequential impacts on various venues of interest. While there are four common behavioural biases, this thesis focuses on the original efficient market hypothesis (EMH) to examine if exogenous events and factors leads to rational market behaviour of participants in stock, derivative and energy markets across US, China and Australia when estimating the prices of financial assets. The first of three papers in the thesis fills a gap in the knowledge of corporate social responsibility and corporate financial performance by analysing the stock market behaviour of investors (an essential stakeholder class) to changes in corporate reputation risks in US-listed companies from negative media coverage of environmental, social and corporate governance issues. The second paper examines if the stock market behaviour of listed firms in China (one of the largest global importers and consumers of energy commodities) are more closely aligned to international oil benchmarks *ex post* the key oil pricing reform on 27 March 2013. The study provides a comprehensive analysis using the Global Industry Classification Standard 138 sub-industries and also investigates the impact of major international energy futures contract prices (i.e. crude oil, natural gas and thermal coal) on various industries. The third paper analyses the impact of energy policy on electricity generation behaviour and pricing patterns in Australia, with a focus on the impact of introducing a carbon-pricing mechanism (i.e. a 'carbon tax') on wholesale electricity markets and seek to empirically examine if energy policy can affect generation behaviour (i.e. does a carbon tax modify the behaviour of coal-fired power stations).

# Chapter 3: Does Environmental, Social and Governance Reputation Matter? Evidence from Financial Markets

## 3.1 Introduction

Societal demands for increasing corporate social responsibility (CSR) beyond that of regulatory requirements in recent years have drawn significant practitioner and academic attention firmly back to the relationship between 'doing good' and corporate financial performance (CFP). The question of whether directly promoting positive environmental, societal and governance (ESG) activities can also lead to beneficial economic outcomes for the related business entity is an area of significant interest.

Generally, there are two differing views on the link between CSR and CFP. The first, proposed by distinguished economist Milton Friedman, suggests that the imposition of CSR is a misuse of valuable company resources, since the prospective tangible benefits are significantly overshadowed by the implementation costs, and it is therefore an inequitable and fundamentally unfair taxation on shareholders (Friedman, 1970). Conversely, proponents of CSR build on stakeholder theory (Freeman, 1983) and its practical evolution (Jones, 1995) to hypothesise that it can help in the long-term financial success of corporations by establishing and strengthening trust in relationships with a variety of constituents (consumers, employees, local communities, activists, etc.).

These two opposing theories have led academics to empirically investigate many different approaches regarding the extent to which CSR can lead to demonstrably superior firm financial performance or the opposite. Brooks and Oikonomou (2018) provide an excellent and extensive literature review on the nexus between CSR and CFP which provides significant motivation for understanding the implications of firm capital in the form of ESG activities and the monetary value investors place on these activities.

Nevertheless, to date no academic research has investigated how negative ESG media coverage affects a company's reputational capital and the consequential impact on its stock-market performance at the firm level. Internationally, the issue of corporate reputation risks (CRR) is increasingly of concern to companies as they seek to continually manage threats arising from changes in perceptions by key stakeholders (Sarstedt et al., 2013; Deephouse et al., 2016). The extant literature provides substantial evidence that this challenge is growing as traditional media expansion, along with a surge in social media, growing awareness of corporate pursuits, increasing demands for corporate transparency, high expectations from various stakeholders and customer loyalty deterioration, has contributed to the momentum of firm risks from heightened corporate reputation risks. Thus far, studies have provided evidence that corporate reputation can offer sustainable competitive advantage and benefit a firm through better financial, investment and economic performance, higher employee productivity and easier access to financial resources (Beatty and Ritter, 1986; Turban and Cable, 2003; Sarstedt et al., 2013; Gatzert, 2015; Deephouse et al., 2016). Conversely, reputation risks associated with ESG issues increase financial risk and potential stakeholder sanctions (Kolbel et al., 2017), which leads to negative long-run stock returns (Glossner, 2017). Despite the emergence of this body of literature, the extent to which CRR impacts on stock-market performance is largely unexplored.

This study attempts to fill the gap by concentrating first on the impact of heightened CRR, through undesirable ESG activities highlighted in media reports, on the CFP of perpetrating companies. For this purpose, the US stock markets are ideally suited for CFP evaluation as they focus on the reaction of investors (an essential stakeholder group) to undesirable ESG behaviours that can directly affect their valuation of the underlying firm. The link between ESG-related reputation risks and investors' reactions is particularly important since the dissatisfaction and withdrawal of this key stakeholder class can increase the cost of capital or seriously damage a corporation's ability to raise equity and continue as a going concern (Clarkson, 1995). Empirical results from this analysis are likely to be beneficial for practitioners and academics as they provide evidence about the value and relevance placed by a key category of stakeholders on CRR caused by detrimental media coverage of ESG issues. Further, if unfavourable media reporting makes a demonstratable impact on firms' market valuation, this may provide avenues for stakeholders to guide companies away from unwanted ESG behaviours and avert costly attention (Fombrun and Shanley, 1990; Chen and Meindl, 1991; Berman et al., 1999; Henriques and Sadorsky, 1999; Baron, 2005; Siegel and Vitaliano, 2007). From a regulatory prospective, this may arguably be a more effective incentive to motivate firm behaviour when compared to voluntary disclosures, which can be selective in nature (Owen et al., 2001; Hodder-Webb et al., 2009; Schaltegger and Burritt, 2010).

The second part of this paper focuses on identifying factors that may help explain differences at the firm level in stock-market reactions to adverse ESG media reporting. Given the diverse firm characteristics and inherent natures of some industries, it is unlikely that all companies are affected equally by negative media coverage of ESG issues. Prior literature discussing information asymmetry suggest that larger firms, particularly major index constituents, that are actively traded are likely to have greater analyst followings, more robust disclosures and generally better information flow. Therefore, they are less likely to experience significant negative price movements from adverse media coverage of ESG issues since these issues may already be known and factored into stock prices. Conversely, in smaller, less liquid firms, the cost of acquiring information is high and media reports may be a critical source of information asymmetry reduction (McWilliams and Siegel, 2001; Chan, 2003; Frankel and Li, 2004; Siegel and Vitaliano, 2007) for market participants, since they lack direct interaction with the corporation (Deephouse, 2000). Consequently, negative media coverage may cause greater price shocks in these companies. Further, Hong and Kacperczyk (2009) also suggest that industries associated with 'sin' (e.g. alcohol, tobacco and gaming) will likely experience disproportionate levels of stakeholder attention, regulatory scrutiny and litigation risk. Hence, by focusing on cross-sectional heterogeneity, this research can provide firm-specific information to corporate executives, portfolio managers and stakeholders on the importance of ESG reputation management to help minimise risk.

Overall, this research contributes to knowledge of both reputational risk and market behaviour by finding empirical evidence that firm size, S&P500 constituency, trading activities, reputation status and industry classifications explain significant differences in investors' stock-market reactions to heightened CRR from adverse ESG media coverage. Results indicate that only firms in the four smallest deciles experience statistically significant negative stock-price movements from adverse ESG media coverage and the magnitude of investors' reaction is proportional to firm size. It is also observed that S&P500 constituents and heavily traded companies generally do not experience significant market reaction from increased reputation risks via negative media coverage. In addition, companies with good reputation status (i.e. low to moderate ESG risk exposure) and firms in industries associated with (i) candy and soda, (ii) steel works, (iii) banking and (iv) insurance are observed to be more susceptible to negative price shocks from unfavourable ESG media coverage. It is noteworthy that the heavily scrutinised 'sin' triumvirate of the alcohol, tobacco and gaming industries are not significantly impacted by increases in CRR from negative ESG media reporting.

The remainder of this chapter is organised as follows. The next section provides a review of the literature and hypothesis development. The third section presents descriptions of the data and research methodologies used for this study. The fourth section presents the empirical results and conclusions are provided in the final section.

## 3.2 Related literature and hypothesis development

### 3.2.1 Relationship between corporate social performance and company financial performance

The history of connecting a company's corporate social performance (CSP) to CFP can be traced back to Moskowitz (1972), who identified 14 listed companies as businesses with outstanding social responsibility. Subsequently, he observed that over a six-month period stock prices of these companies surpassed the total benchmark returns of both the S&P Industrial index and Dow Jones Industrial Average index, suggesting outperformance by firms with good CSR. While the literature has evolved significantly in terms of methodological rigour, larger and richer datasets and general sophistication, Moskowitz arguably pioneered the analysis of CSR practices in relation to market variables.

Over the next few decades, various studies attempted to link the impact of companies' CSP to their CFP. Starting with the relationship between environmental disclosures and stock prices, both Belkaoui (1976) and Blacconiere and Northcut (1997) documented empirical evidence to support the value and relevance of environmental information to firm stock prices in financial markets. Other research emphasised the financial impact of environmental performance as an alternative to disclosure and observed that firms with positive (negative) environmental corporate performance had increases (decreases) in abnormal stock returns (Klassen and McLaughlin 1996; Konar and Cohen 2001; Thomas 2001). In addition to stock-market returns, Graham, Maher and Northcut (2001), Graham and Maher (2006) and Bauer and Hann (2010) all provided empirical evidence from corporate bond ratings or yields to support a negative association between environmental risk management and CFP. Sharfman and Fernando (2008) further extended the literature by demonstrating that enhanced corporate environmental performance led to a significant reduction in firms' costs of capital and provided firms with increased ability to replace equity with debt financing, which is likely to result in higher tax benefits.

As well as environmental considerations, the literature also recognises the importance of social factors, particularly a firm's relationship with its employees and the overall level of employee satisfaction, and the consequential impact on capital markets' behaviour. Using firm inclusion in Fortune's 'Best Companies to Work For' list, studies such as those of Filbeck and Preece (2003), Fulmer, Gerhart and Scott (2003), Edmans (2011) and Faleye and Trahan (2011) all observed that constituents of the list possess statistically significant positive risk-adjusted stocks returns. Other studies like that of Brammer et al. (2009) documented similar findings with different datasets and Kane et al. (2005) also demonstrated that during periods of economic adversity, companies with better employee relations are better at obtaining labour concessions, which reduces their probability of financial distress. Overall, these findings support the notion that firms with strong social performance in the form of robust employer relations have a source of significant competitive advantage.

While CFP has been predominantly linked to the core concept of firm sustainability in the form of environmental practices and employee relations, the literature has expanded significantly beyond this. Firm relationships with a broader range of social stakeholders, including local communities in the jurisdiction which it operates, the safety standards of the products and services offered, its overall charitable contributions, and its treatment of diversity issues, minorities, indigenous people's rights and respect for human rights in general, are aspects whose financial effects have also been focal points of academic studies (see Clarkson, 1995; Hillman and Keim, 2001; Mattingly and Berman, 2006; Jiao, 2010; Chang et al., 2014).

Overall, the broader literature provides an overall consensus that there is a statistically significant positive but economically modest relationship between CSP and CFP at the firm level, despite some variations in the financial impacts of CSR activities depending on the stakeholder group that they relate to (suppliers, employees, customers, regulators, community, the environment and others). This observation is generally supported by literature reviews (see Margolis and Walsh, 2003; Malik, 2015; Brooks and Oikonomou, 2018) and meta-analyses (Orlitzky et al., 2003; Margolis et al., 2009; Friede et al., 2015; Lu and Taylor, 2016).

### 3.2.2 Hypothesis development

One key foundation of the business cases for CSR resides in stakeholder theory. Clarkson (1995) extends this by providing a distinction between primary and secondary stakeholder groups based on their necessity to a corporation's status. Essentially, primary stakeholders are deemed essential to firm survival such that, if the group becomes dissatisfied and withdraws from the corporate system, in whole or in part, the corporation will suffer serious financial consequences or be unable to continue operating as a going concern. Studies adopting the segregation of stakeholders into primary and other (secondary) categories have provided evidence to suggest that CSR activities targeting primary stakeholders are value-creating, whereas CSR activities focused on secondary stakeholders may not yield any tangible economic benefits or may be detrimental to the market value of firms (Hillman and Keim, 2001; Jiao, 2010; Chang et al., 2014). Despite these findings, there is a paucity of research focusing on the market reaction of investors, a critical stakeholder class, to increases in CRR.

It is noteworthy that for many stakeholders, the media (particularly the business press) is the main source of information asymmetry reduction. By conducting original investigations and disseminating the news more broadly, the media can influence public opinion (Huberman and Regev 2001; Miller 2006; Bushee et al., 2010; Drake et al., 2014; Rogers et al., 2016). Therefore, media coverage can exert a great deal of influence on CSR behaviour (Fombrun and Shanley, 1990; Chen and Meindl, 1991; Berman et al., 1999; Henriques and Sadorsky, 1999; Baron, 2005; Siegel and Vitaliano, 2007).

The agenda-setting theory indicates that media organisations will likely focus more on newsworthy items with significant public interest and emphasise coverage of specific issues which increase their prominence on the community's agenda (McCombs and Shaw 1972; Carroll and McCombs 2003). As the media gives more attention to these topics, the public is more likely to categorise these issues as important (Deephouse 2000) and adjust their perception of the reported company accordingly. This enhanced media coverage leads to magnified investor attention and reaction to highlighted issues (e.g. Hamilton 1995; Peress 2014, 2016) and agenda setting is particularly influential when information is circulated by prominent media outlets with substantial audiences (Kolbel et al., 2017).

Further, the literature provides evidence that media criticism can cause tangible damage to the implicated firm as awareness of an issue increases. For example, Kothari et al. (2009) observed that adverse media coverage of firm performance is associated with increased stock-return volatility and cost of capital, and Farrell and Whidbee (2002) documented a heightened probability of forced executive turnover from detrimental media events. While prior studies have focused on the effects of negative media coverage on firm performance, it is worth highlighting that the media is also a primary channel for information on ESG issues, which can increase financial risk and potential stakeholder sanctions (Kolbel et al., 2017) and lead to negative long-run stock returns (Glossner, 2017). Similar to media coverage that directly criticises firm performance, adverse media coverage of ESG matters affects CRR, which is likely to threaten financial profitability and stability and generate additional risk that is highly relevant for investors. Hence, it is hypothesised that:

*H3.1: Stock price movements and CRR are negatively associated,* ceteris paribus.

It is well-recognised in financial markets that information plays a critical role in the price discovery process. The investor recognition hypothesis advanced by Merton (1987) posits that in informationally incomplete markets, investors are not aware of all securities. Consequently, stocks with lower investor recognition need to offer higher returns to compensate their holders for being imperfectly diversified. By disseminating information to a wide audience, media coverage broadens investor recognition. Thus, stocks with intense media coverage earn a lower return than stocks that are not well known. In equilibrium, cross-sectional variation in the benefits and costs associated with gathering and disclosing information leads to variation in information asymmetry.

The existence of information asymmetry between managers and investors is a fundamental issue which can cause an unwillingness to trade and increases a company's cost of capital (Bhattacharya and Spiegel, 1991). Studies examining this issue have provided substantial evidence that the level of information asymmetry differs between companies, with smaller firms that are less actively traded generally possessing more information disparity and vice versa (e.g. Finnerty, 1976; Grant, 1980; Elliot et al., 1984; Atiase, 1985; Seyhun, 1986; Collins et al., 1987; Freeman, 1987; Bhushan, 1989; Lakonishok and Lee, 2001). Hence, news coverage and the media are more likely to provide new material to investors (see Chan, 2003; and Frankel and Li, 2004) in smaller companies that are infrequently traded and so adverse media reporting may cause greater price shocks as it contains new information. This leads to the following hypotheses:

*H3.2: Stock price movements from CRR and firm size are negatively associated,* ceteris paribus.

*H3.3: Stock price movements from CRR and trading turnover value are positively associated,* ceteris paribus.

Stakeholder theory also provides reasons why highly visible companies such as S&P500 constituents (which tend to be larger firms that are frequently traded) will experience lower stock-price movements compared to less visible firms. First, these corporations tend to have more diverse stakeholder demands (Fiss and Zajac, 2006), which leads to higher investment in their CSR activities to satisfy these demands. Second, more visible firms tend to be more susceptible to crises, so they are more inclined to engage in CSR activities as a method of building positive reputation capital for when a crisis arises (Godfrey, 2005). The concept that highly visible firms are likely to invest significantly more in CSR activities to have some hedge against undesirable media reporting on ESG issues suggests that S&P500 firms are less likely to experience adverse price movements compared to non-constituents:

*H3.4: Stock price movements from CRR for S&P500 constituents are negatively associated,* ceteris paribus.

Information shocks can also play a significant role in stock-price movements. Hence, it is anticipated that firms with good reputation status (e.g. limited or no previous negative media coverage) are more likely to experience a greater price reaction from adverse ESG media reporting since intense media coverage may reveal unexpected information on the affected company or focus market participants' attention on CSR activities that would otherwise go undetected or be considered negligible (Miller 2006; Bednar et al., 2013; Rogers et al., 2016):

*H3.5: Stock price movements from CRR and firm reputation status are positively associated,* ceteris paribus.

Finally, Hong and Kacperczyk (2009) observed that companies involved in the businesses of alcohol, tobacco and gaming (i.e. 'sin' stocks) receive less coverage from analysts than do stocks of otherwise comparable characteristics, and face greater litigation risk and regulatory scrutiny heightened by social norms. Therefore, it is posited that different industries are confronted with different levels of stakeholder attention, regulatory scrutiny and litigation risk, which will lead to varying investor reactions:

*H3.6: Stock price movements from CRR are related to industry classification,* ceteris paribus.

## 3.3. Data and research design

### 3.3.1 Data and sample

This study covers US publicly traded companies from January 2007 to December 2018. Stock-price data was obtained from the Center for Research in Security Prices (CRSP), the four factors from the Fama, French and Carhart model were extracted from Wharton Research Data Services (WRDS), S&P500 constituents were extracted from Compustat and the reputation risk data was obtained from the RepRisk database.[1]

Table 3.1 provides details of sample selection. There are 804,432 monthly firm observations in RepRisk for the sample period, 472,915 were removed as they do not contain the necessary market data in CRSP, none were eliminated due to missing Fama, French and Carthoche factors files.

**Table 3.1: Sample Selection Methodology**

Table 3.1 provides a summary of the filtering process to obtain the final sample utilized for this research.

| Filtering Process | Observations |
|---|---|
| U.S. firms observations covered in RepRisk from fiscal year January 2007 to December 2018 | 804,432 |
| Less observations with missing data in CRSP files | (472,915) |
| Less observations with missing data in Fama, French and Carhart factors files | (0) |
| Final Sample | 331,517 |

### 3.3.2 CRR and reputation status variables

To measure the impact of negative ESG media coverage on CRR, this study utilised the ESG reputation risk index (RRI) from RepRisk AG,[2] a data provider that integrates human intelligence with technology to detect ESG incidents. From January 2007, its extensive research process to build RRI and track the ESG performance of over 130,000 listed and non-listed companies started with the daily collection of information from over 90,000 media, stakeholder and other public sources for news items that criticise companies for ESG issues (in 20 different languages). On

[1] The study's sample period commenced from January 2007 as this coincided with the first availability of the RepRisk database.

[2] See Hasan and Habib (2020) for a description of the RepRisk database's advantages over CSR data from MSCI (formerly KLD).

identification of an incident, further screening is performed by RepRisk analysts to verify that the issue is ESG-related, remove duplicates and characterise the nature of the event. Then each incident is evaluated and given proprietary scores for severity (the harshness of the perceived impact of the incident) and reach (the influence or the readership of the source).

Based on these factors, RepRisk computes the monthly current RRI which denotes the current level of a firm's media and stakeholder exposure to ESG-related issues. The current RRI indexes typically range from zero (the lowest exposure) to 100 (the highest exposure). More importantly, there is a RepRisk Rating (RRR), consisting of a letter rating from AAA to D, that facilitates benchmarking and integrating of ESG and business conduct risks, as well as other metrics such as the UN global Compact Violator Flag. The RRR methodology combines two factors: (i) company-specific ESG risk exposure (represented by the RRI); and (ii) country-sector ESG risk exposure (which is calculated by the headquarters ESG risk exposure value and the international ESG risk exposure value, both equally weighted). Table 3.2 presents RepRisk descriptions that were utilised to create the *RRR Scores* and *Reputation Status Band* for the purpose of this study.

**Table 3.2: Grouping Methodologies**

Table 3.2 provides the RepRisk Rating (RRR) and the ESG risk exposure related to each band. For the purpose of this study, the highest RRR 'AAA' is associated with an RRR score of 1, the RRR 'AA' is associated with an RRR score of 2, the RRR 'A' is associated with an RRR score of 3, etc. and the lowest RRR score of 10 is given to the RRR 'D'. Reputation status band 1 represents firms with low ESG risk exposure (i.e. RRR of 'AAA', 'AA' or 'A'), reputation status band 2 represents firms with moderate ESG risk exposure (i.e. RRR of 'BBB', 'BB' or 'B', reputation status band 3 represents firms with high ESG risk exposure (i.e. RRR of 'CCC', 'CC' or 'C') and reputation status band 4 represents firms with very high ESG risk exposure (i.e. RRR of 'D').

| RepRisk Rating (RRR) | RRR Score | ESG-related Risk Representation | Reputation Status Band |
|---|---|---|---|
| AAA | 1 | | |
| AA | 2 | Low ESG risk exposure | 1 |
| A | 3 | | |
| BBB | 4 | | |
| BB | 5 | Moderate ESG risk exposure | 2 |
| B | 6 | | |
| CCC | 7 | | |
| CC | 8 | High ESG risk exposure | 3 |
| C | 9 | | |
| D | 10 | Very high ESG risk exposure | 4 |

The use of third-party data is important in evaluating whether firm intentions translate into real actions (RepRisk, 2016) and several recent studies have started to use RepRisk data as a proxy for CRR from adverse media coverage (e.g. Kolbel et al., 2017; Schembera and Scherer, 2017; Cui et al., 2018; Burke et al., 2019; Asante-Appiah, 2020; Dai et al., 2020).[3]

### 3.3.3 Firm characteristics and industry variables

To analyse whether various firm and industry characteristics can help explain differences in investors' reactions to changes in CRR from adverse media coverage of ESG issues, this study adopts the following measures:[4]

$$\text{Market Capitalization} = \text{Total Outstanding Shares} * \text{Stock Price} \tag{3.1}$$

where the total outstanding shares are the number of shares issued by the company and the stock price is the daily closing price of the company.

$$\text{Trading Turnover Value} = \text{Total Traded Volume} * \text{Stock Price} \tag{3.2}$$

where the total traded volume is the sum of the daily trading volume for the company and the stock price is the daily closing price of the company.

For S&P500 constituents, the index components were extracted from Compustat for the entire duration of the study sample (i.e. January 2007 to December 2018). Firms in this study are given a dummy variable of 1 during the period when they were a component of the S&P500 index and

[3] Numerous high-profile global firms and institutions, including some of the Big Four accounting firms, use RepRisk data to assess ESG reputation risk. Global companies that subscribe to RepRisk ESG data include Bank of America, Barclays Bank, Citi Bank, Deloitte, KPMG, PricewaterhouseCoopers, Société Générale, UBS and World Bank Group (www.reprisk.com/our-clients).

[4] Relevant corporate action adjustment factors are applied to both shares and stock prices.

0 otherwise. S&P500 constituents were updated constantly throughout the sample period to account for additions and deletions of companies.

To analyse the impact on CRR from adverse ESG media coverage, this research adopts the Fama and French 48 (FF48) industry classifications (Fama and French, 1997). In addition, since the ‘sin’ triumvirate of alcohol, tobacco and gaming receive particular stakeholder attention, regulatory scrutiny and litigation risk, this research implements the methodology outlined by Hong and Kacperczyk (2009) to create an additional ‘gaming’ industry which includes companies in the following North American Industry Classification System (NAICS) codes: 7132, 71312, 713210, 71329, 713290, 72112 and 721120. This is separate and distinct from the FF48 industry groups.

### 3.3.4 Methodology

The primary interest of this research is to determine whether changes in RRR scores (which denote changes in CRR arising from adverse media coverage) provide incremental information, beyond the generally accepted return-generating factors such as the Fama, French and Carhart four factors, in describing the stock returns of US listed companies. To achieve this, the research characterises excess US stock returns as a function of the Fama, French and Carhart four-factor model and the monthly RRR changes:

$$(R_{Full,t} - R_{f,t}) = \beta_0 + \beta_1 RRRC_t + \beta_2 (R_{m,t} - R_{f,t}) + \beta_3 SMB_t + \beta_4 HML_t + \beta_5 WML_t + Firm\,FE + Year\,FE + \varepsilon_t \tag{3.3}$$

The study extends the analysis further by grouping the sample based on firm size, S&P500 constituency, reputation status and FF48 (and gaming) industry classifications:

$$(R_{Size,t} - R_{f,t}) = \beta_0 + \beta_1 RRRC_t + \beta_2 (R_{m,t} - R_{f,t}) + \beta_3 SMB_t + \beta_4 HML_t + \beta_5 WML_t + Firm\,FE + Year\,FE + \varepsilon_t \tag{3.4}$$

$$(R_{Turnover,t} - R_{f,t}) = \beta_0 + \beta_1 RRRC_t + \beta_2(R_{m,t} - R_{f,t}) + \beta_3 SMB_t + \beta_4 HML_t + \beta_5 WML_t + Firm\,FE + Year\,FE + \varepsilon_t \quad (3.5)$$

$$(R_{S\&P500,t} - R_{f,t}) = \beta_0 + \beta_1 RRRC_t + \beta_2(R_{m,t} - R_{f,t}) + \beta_3 SMB_t + \beta_4 HML_t + \beta_5 WML_t + Firm\,FE + Year\,FE + \varepsilon_t \quad (3.6)$$

$$(R_{RStaus,t} - R_{f,t}) = \beta_0 + \beta_1 RRRC_t + \beta_2(R_{m,t} - R_{f,t}) + \beta_3 SMB_t + \beta_4 HML_t + \beta_5 WML_t + Firm\,FE + Year\,FE + \varepsilon_t \quad (3.7)$$

$$(R_{Industry,t} - R_{f,t}) = \beta_0 + \beta_1 RRRC_t + \beta_2(R_{m,t} - R_{f,t}) + \beta_3 SMB_t + \beta_4 HML_t + \beta_5 WML_t + Firm\,FE + Year\,FE + \varepsilon_t \quad (3.8)$$

where $(R_{Full} - R_f)$ is the monthly excess group stock returns for the full sample of US listed companies, $(R_{size} - R_f)$ is the monthly excess stock returns grouped by firm size (into deciles based on market capitalisation), $(R_{Turnover} - R_f)$ is the monthly excess stock returns grouped by trading turnover value (into deciles), $(R_{S\&P500} - R_f)$ is the monthly excess stock returns grouped by S&P500 constituency (with a dummy variable of 1 denoting S&P500 constituents and 0 otherwise), $(R_{Rstatus} - R_f)$ is the monthly excess stock returns grouped by reputation status, $(R_{Industry} - R_f)$ is the monthly excess stock returns grouped by FF48 (and 'gaming') industry classifications, *RRRC* is the numerical change in RRR score and $(R_m - R_f)$ is the market premium, representing the excess returns of the market over the risk-free interest rate. *SMB* is the monthly equally weighted average of the stock returns on the small stock portfolios (portfolios with small market cap stocks) minus the stock returns on the large stock portfolios (portfolios with large market cap stocks) and represents the *size* premium. *HML* is the equally weighted average of the stock returns on the high book-to-market ratio stock portfolios minus the stock returns on the low book-to-market ratio stock portfolios and represents the *value* premium. *WML* is the equally weighted average of the stock returns on winner portfolios (portfolios of stocks with the highest prior stock returns) minus the stock returns on loser portfolios (portfolios of stocks with the lowest prior stock returns) and represents the momentum factor. In all regressions, dummy variables are included to control for firm and year fixed effects. Stock returns are adjusted for corporate actions and all variables are winsorised at 1% and 99% levels.

## 3.4 Results

### 3.4.1 Investors' reaction to heightened CRR from media coverage

One of the key objectives of this paper is to examine whether increases in CRR from adverse media coverage of ESG issues impact on the stock performance of listed companies (Glossner, 2017; Kolbel et al., 2017). Table 3.3 presents regression results detailing how changes to RRR scores (which correspond to RRR grade changes) affect the stock performance of the entire sample of US listed companies from January 2007 to December 2018. The variable of interest is the RRRC (which represents the numerical change in RRR scores) and a positive coefficient indicates that each unit decline in RRR score (signifying an increase in reputation risk from ESG-related issues) is associated with a negative stock-return performance of −0.39% after controlling for the Fama, French and Carhart four factors. This is consistent with the hypothesis that company stock performance is negatively affected by increasing reputation risk arising from adverse ESG-related media reporting.

**Table 3.3: Impact of increased CRR from adverse media coverage on stock performance of US listed companies (full sample)**

Table 3.3 provides regression results analysing the impact of increased CRR from adverse media coverage on stock performance of US listed companies (full sample) from January 2007 to September 2019.

| US listed companies | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|
| Full sample | 331,517 | 0.0039** | 1.0638** | 0.4984** | 0.0825** | -0.2065** | Yes | Yes | 0.24 |
| | | [0] | [0] | [0] | [0] | [0] | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

### 3.4.2 Impact of various firm characteristics on increased CRR

This study extends the analysis of CRR in relation to various firm characteristics and industry classifications to identify whether they explain differences in the stock performance of affected firms (e.g. Finnerty, 1976; Grant, 1980; Elliot et al., 1984; Atiase, 1985; Seyhun, 1986; Collins et al., 1987; Freeman, 1987; Bhushan, 1989; Lakonishok and Lee, 2001). Table 3.4 provides regression results for the impact of RRRC on companies of varying market capitalisation by deciles. Results indicate that only the stock performance of firms in the smallest deciles (i.e. 7, 8, 9 and 10) was significantly affected by heightened CRR from adverse media reporting. Further, the stock returns of the smallest firms appeared to experience the most severe negative investors' response to adverse media reporting, i.e. for each unit increase in RRR score, investors penalised the stock prices of affected firms by −0.8% in Decile 7, −1.03% in Decile 8, −1.17% in Decile 9 and −1.62% in Decile 10.

Similar to firm size, this research segregates companies into deciles based on their average monthly trading turnover value to analyse whether market activity affects investors' reaction to changes in CRR. Findings are reported in Table 3.5 and, consistent with the firm size results, it is observed that only the stock performance of the least actively traded companies (i.e. 6, 7, 8, 9 and 10) was significantly impacted by increased CRR from adverse media reporting on ESG issues. The top half of companies by trading turnover value did not appear to be significantly affected. Regression results indicate that every unit increase in RRR score for companies in the lower half of the trading activity spectrum impacted their stock performance by −0.76%, −0.74%, −1.48%, −1.21% and −0.99% in Deciles 6, 7, 8, 9 and 10, respectively. It is noteworthy that companies in the lower half of the trading activity spectrum are usually also the smallest by market capitalisation.

Table 3.6 presents the regression analysis for the impact of CRR change from negative media reporting on S&P500 constituent stocks and non-constituents. Results suggest that only non-S&P500 constituents experienced significant negative stock-price reactions from heightened unfavourable media coverage. Generally, the stock performance of affected companies declined by −0.48% per unit increase in RRR score. Consistent with findings in Table 3.4 and 3.5, S&P500 constituents are usually highly visible firms that are larger by market capitalisation and are also among the most actively traded.

Table 3.7 presents the regression results for the impact of increased CRR from adverse media reporting by reputation status. Results suggest that companies with higher reputation status (i.e. lower ESG risk exposure) experienced statistically significant stock-price reactions from spikes in undesirable media coverage. It is observed that only firms in reputation status band 1 (low ESG risk exposure) and 2 (moderate ESG risk exposure) experienced deteriorations in stock performance, of −0.5% and −0.3% for each unit increase in RRR score, respectively.

**Table 3.4: Impact of increased CRR from adverse media coverage on stock performance of US listed companies (by market capitalisation)**

Table 3.4 provides regression results analysing the impact of increased CRR from adverse media coverage on stock performance of US listed companies from January 2007 to December 2018. Firms are segregated into deciles based on their market capitalisation.

| Decile | Avg. Market Capitalisation ('000s) | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $160,002,002 | 39,588 | 0.000 | 0.9895** | -0.028 | -0.017 | -0.0934** | Yes | Yes | 0.32 |
| | | | [0.926] | [0] | [0.123] | [0.324] | [0] | | | |
| 2 | $11,214,638 | 38,561 | 0.002 | 1.0462** | 0.2156** | 0.0572** | -0.1298** | Yes | Yes | 0.32 |
| | | | [0.106] | [0] | [0] | [0.004] | [0] | | | |
| 3 | $5,510,385 | 34,450 | 0.004 | 1.083** | 0.3261** | 0.022 | -0.1406** | Yes | Yes | 0.32 |
| | | | [0.072] | [0] | [0] | [0.318] | [0] | | | |
| 4 | $3,102,854 | 32,158 | 0.002 | 1.0847** | 0.5402** | 0.038 | -0.1922** | Yes | Yes | 0.29 |
| | | | [0.468] | [0] | [0] | [0.166] | [0] | | | |
| 5 | $2,000,947 | 31,936 | 0.002 | 1.1388** | 0.5968** | 0.1505** | -0.2219** | Yes | Yes | 0.29 |
| | | | [0.408] | [0] | [0] | [0] | [0] | | | |
| 6 | $1,256,704 | 35,797 | -0.002 | 1.0581** | 0.6775** | 0.1802** | -0.1899** | Yes | Yes | 0.27 |
| | | | [0.436] | [0] | [0] | [0] | [0] | | | |
| 7 | $740,624 | 36,732 | 0.008** | 1.0855** | 0.678** | 0.1894** | -0.2431** | Yes | Yes | 0.25 |
| | | | [0.006] | [0] | [0] | [0] | [0] | | | |
| 8 | $422,223 | 29,378 | 0.0103* | 1.0932** | 0.7975** | 0.1983** | -0.2879** | Yes | Yes | 0.21 |
| | | | [0.025] | [0] | [0] | [0] | [0] | | | |
| 9 | $199,549 | 27,549 | 0.0117** | 1.0249** | 0.843** | 0.063 | -0.2926** | Yes | Yes | 0.21 |
| | | | [0.009] | [0] | [0] | [0.16] | [0] | | | |
| 10 | $53,783 | 25,368 | 0.0162* | 1.0322** | 0.6315** | -0.089 | -0.3798** | Yes | Yes | 0.16 |
| | | | [0.014] | [0] | [0] | [0.174] | [0] | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

**Table 3.5: Impact of increased CRR from adverse media coverage on stock performance of US listed companies (by trading turnover value)**

Table 3.5 provides regression results analysing the impact of increased CRR from adverse media coverage on stock performance of US listed companies from January 2007 to December 2018. Firms are segregated into deciles based on their trading turnover value.

| Decile | Avg Turnover (Monthly) | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8,017,496,965 | 37,132 | 0.002 | 1.0734** | 0.027 | 0.007 | -0.133** | Yes | Yes | 0.30 |
| | | | [0.313] | [0] | [0.228] | [0.758] | [0] | | | |
| 2 | 2,093,121,474 | 37,392 | 0.001 | 1.068** | 0.3061** | 0.029 | -0.1657** | Yes | Yes | 0.30 |
| | | | [0.473] | [0] | [0] | [0.187] | [0] | | | |
| 3 | 1,125,405,136 | 33,440 | 0.003 | 1.1436** | 0.4076** | -0.006 | -0.2397** | Yes | Yes | 0.28 |
| | | | [0.182] | [0] | [0] | [0.838] | [0] | | | |
| 4 | 677,846,871 | 39,412 | -0.001 | 1.1179** | 0.393** | 0.0615* | -0.2203** | Yes | Yes | 0.30 |
| | | | [0.724] | [0] | [0] | [0.011] | [0] | | | |
| 5 | 420,370,739 | 38,144 | -0.002 | 1.0029** | 0.5054** | 0.1259** | -0.1562** | Yes | Yes | 0.26 |
| | | | [0.491] | [0] | [0] | [0] | [0] | | | |
| 6 | 256,107,210 | 30,737 | 0.0076* | 1.1214** | 0.5975** | 0.1117** | -0.2162** | Yes | Yes | 0.25 |
| | | | [0.013] | [0] | [0] | [0.001] | [0] | | | |
| 7 | 146,105,537 | 33,046 | 0.0074* | 1.1093** | 0.7197** | 0.1394** | -0.243** | Yes | Yes | 0.22 |
| | | | [0.047] | [0] | [0] | [0] | [0] | | | |
| 8 | 79,701,536 | 28,430 | 0.0148** | 1.1236** | 0.9158** | 0.1624** | -0.2239** | Yes | Yes | 0.23 |
| | | | [0.001] | [0] | [0] | [0] | [0] | | | |
| 9 | 34,173,596 | 27,138 | 0.0121* | 1.083** | 0.7568** | 0.1849** | -0.2686** | Yes | Yes | 0.20 |
| | | | [0.012] | [0] | [0] | [0] | [0] | | | |
| 10 | 7,688,151 | 26,646 | 0.0099* | 0.7452** | 0.6116** | 0.060 | -0.2404** | Yes | Yes | 0.16 |
| | | | [0.044] | [0] | [0] | [0.22] | [0] | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

**Table 3.6: Impact of increased CRR from adverse media coverage on stock performance of US listed companies (by S&P500 constituency)**

Table 3.6 provides regression results analysing the impact of increased CRR from adverse media coverage on stock performance of US listed companies from January 2007 to December 2018. The dummy variable 1 denotes S&P500 constituent stocks and 0 represents non-constituents.

| S&P500 Constituency | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|
| Non-constituents | 268,873 | 0.0048** | 1.0713** | 0.5929** | 0.082** | -0.2285** | Yes | Yes | 0.23 |
| | | [0] | [0] | [0] | [0] | [0] | | | |
| Constituents | 62,644 | 0.001 | 1.0277** | 0.1063** | 0.0814** | -0.1144** | Yes | Yes | 0.34 |
| | | [0.421] | [0] | [0] | [0] | [0] | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

**Table 3.7: Impact of increased CRR from adverse media coverage on stock performance of US listed companies (by reputation status band)**

Table 3.7 provides regression results analysing the impact of increased CRR from adverse media coverage on stock performance of US listed companies from January 2007 to December 2018, segregated into quartiles by reputation status. Reputation status band 1 represents firms with low ESG risk exposure (i.e. RRR of 'AAA', 'AA' or 'A'), reputation status band 2 represents firms with moderate ESG risk exposure (i.e. RRR of 'BBB', 'BB' or 'B', reputation status band 3 represents firms with high ESG risk exposure (i.e. RRR of 'CCC', 'CC' or 'C') and reputation status band 4 represents firms with very high ESG risk exposure (i.e. RRR of 'D').

| Reputation Status Band | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 266,311 | 0.005** | 1.053** | 0.613** | 0.115** | -0.194** | Yes | Yes | 0.24 |
| | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | |
| 2 | 53,159 | 0.003* | 1.078** | 0.193** | -0.07** | -0.244** | Yes | Yes | 0.27 |
| | | 0.016 | 0.000 | 0.000 | 0.002 | 0.000 | | | |
| 3 | 11,606 | 0.002 | 1.169** | -0.364** | -0.040 | -0.343** | Yes | Yes | 0.32 |
| | | 0.490 | 0.000 | 0.000 | 0.359 | 0.000 | | | |
| 4 | 441 | -0.005 | 1.321** | -1.156** | -0.413 | -0.337 | Yes | Yes | 0.28 |
| | | 0.812 | 0.000 | 0.000 | 0.095 | 0.067 | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

### 3.4.3 Industry effects on CRR from negative media coverage

As observed by Hong and Kacperczyk (2009), different industries are confronted with varying levels of stakeholder attention, regulatory scrutiny and litigation risk. Table 3.8 presents the regression results focused on cross-industry heterogeneity. Table 3.8a provides analysis of firm stock returns grouped by FF48 industry classification and Table 3.8b provides additional analysis of the gaming industry. Interestingly, the stock performance of companies in the 'sin' triumvirate did not experience negative investors' reactions to adverse ESG-related media coverage. These findings provide some evidence to suggest that ESG-related CRR for companies associated with 'sin' industries may already be factored into their stock prices.

## Table 3.8a: Impact of increased CRR from adverse media coverage on stock performance of US listed companies (by FF48 industry classification)

Table 3.8 (Panel A) provides regression results analysing the impact of increased CRR from adverse media coverage on stock performance of US listed companies from January 2007 to December 2018. Firms are segregated into industries based on FF48 classification.

| FF48 Industry Classification | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 1,018 | 0.000 | 1.064** | 0.128 | -0.146 | -0.134 | Yes | Yes | 0.21 |
| | | [0.98] | [0] | [0.464] | [0.37] | [0.252] | | | |
| Food Products | 6,523 | 0.010 | 0.7191** | 0.2418** | -0.022 | -0.1388** | Yes | Yes | 0.17 |
| | | [0.068] | [0] | [0] | [0.727] | [0.002] | | | |
| Candy & Soda | 2,264 | 0.0189** | 0.6737** | 0.172 | -0.052 | -0.1248* | Yes | Yes | 0.21 |
| | | [0.009] | [0] | [0.058] | [0.529] | [0.034] | | | |
| Beer & Liquor | 2,037 | -0.001 | 0.8032** | 0.070 | 0.057 | 0.016 | Yes | Yes | 0.27 |
| | | [0.893] | [0] | [0.451] | [0.519] | [0.8] | | | |
| Tobacco Products | 1,100 | -0.007 | 0.6702** | 0.036 | 0.070 | -0.141 | Yes | Yes | 0.15 |
| | | [0.587] | [0] | [0.85] | [0.691] | [0.269] | | | |
| Recreation | 1,548 | -0.002 | 1.0579** | 0.6038** | 0.158 | -0.221 | Yes | Yes | 0.23 |
| | | [0.908] | [0] | [0.002] | [0.377] | [0.078] | | | |
| Entertainment | 3,142 | 0.000 | 1.1559** | 0.8127** | 0.160 | -0.4099** | Yes | Yes | 0.26 |
| | | [0.987] | [0] | [0] | [0.147] | [0] | | | |
| Printing and Publishing | 2,138 | -0.001 | 1.0701** | 0.5581** | 0.6283** | 0.033 | Yes | Yes | 0.33 |
| | | [0.956] | [0] | [0] | [0] | [0.637] | | | |
| Consumer Goods | 4,075 | 0.010 | 1.019** | 0.3928** | 0.4686** | -0.1502* | Yes | Yes | 0.29 |
| | | [0.117] | [0] | [0] | [0] | [0.011] | | | |
| Apparel | 3,084 | -0.005 | 0.9957** | 0.8504** | 0.4759** | -0.2131** | Yes | Yes | 0.30 |
| | | [0.543] | [0] | [0] | [0] | [0.003] | | | |
| Healthcare | 3,908 | -0.004 | 0.9175** | 0.8799** | -0.009 | -0.102 | Yes | Yes | 0.25 |
| | | [0.591] | [0] | [0] | [0.918] | [0.094] | | | |
| Medical Equipment | 6,464 | 0.007 | 0.8734** | 0.6838** | -0.1431* | -0.1214** | Yes | Yes | 0.26 |
| | | [0.223] | [0] | [0] | [0.013] | [0.003] | | | |
| Pharmaceutical Products | 12,839 | 0.016 | 1.0254** | 0.7074** | -0.4544** | -0.3281** | Yes | Yes | 0.15 |
| | | [0.084] | [0] | [0] | [0] | [0] | | | |
| Chemicals | 6,489 | 0.003 | 1.3222** | 0.6224** | 0.114 | -0.2732** | Yes | Yes | 0.36 |
| | | [0.575] | [0] | [0] | [0.081] | [0] | | | |
| Rubber and Plastic Products | 1,406 | -0.001 | 1.1007** | 0.7235** | 0.4403** | -0.2993** | Yes | Yes | 0.40 |
| | | [0.945] | [0] | [0] | [0] | [0] | | | |
| Textiles | 721 | -0.022 | 1.1569** | 0.6122** | 0.5816** | -0.202 | Yes | Yes | 0.33 |
| | | [0.302] | [0] | [0.003] | [0.003] | [0.153] | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Construction Materials | 3,578 | 0.004 | 1.2697** | 0.8696** | 0.4532** | -0.1842** | Yes | Yes | 0.38 |
| | | [0.626] | [0] | [0] | [0] | [0.001] | | | |
| Construction | 3,638 | 0.003 | 1.2035** | 1.1375** | 0.5253** | -0.2544** | Yes | Yes | 0.37 |
| | | [0.741] | [0] | [0] | [0] | [0] | | | |
| Steel Works Etc | 4,541 | 0.0136* | 1.544** | 0.3783** | -0.152 | -0.3764** | Yes | Yes | 0.37 |
| | | [0.038] | [0] | [0] | [0.059] | [0] | | | |
| Fabricated Products | 753 | -0.006 | 1.325** | 0.9077** | 0.286 | -0.2505* | Yes | Yes | 0.39 |
| | | [0.634] | [0] | [0] | [0.1] | [0.047] | | | |
| Machinery | 6,903 | 0.006 | 1.312** | 0.6043** | 0.091 | -0.1424** | Yes | Yes | 0.38 |
| | | [0.24] | [0] | [0] | [0.086] | [0] | | | |
| Electrical Equipment | 2,536 | -0.002 | 1.0339** | 0.7394** | 0.128 | -0.040 | Yes | Yes | 0.24 |
| | | [0.825] | [0] | [0] | [0.265] | [0.623] | | | |
| Automobiles and Trucks | 4,907 | 0.006 | 1.4781** | 0.8371** | 0.5476** | -0.3711** | Yes | Yes | 0.43 |
| | | [0.398] | [0] | [0] | [0] | [0] | | | |
| Aircraft | 1,612 | -0.009 | 1.004** | 0.2705** | -0.006 | -0.224** | Yes | Yes | 0.31 |
| | | [0.254] | [0] | [0.006] | [0.951] | [0.001] | | | |
| Shipbuilding, Railroad Equipment | 432 | 0.020 | 1.3229** | 0.9568** | 0.6545** | 0.129 | Yes | Yes | 0.33 |
| | | [0.447] | [0] | [0] | [0.009] | [0.468] | | | |
| Defense | 1,018 | 0.011 | 0.6729** | 0.5185** | -0.4534** | -0.3319** | Yes | Yes | 0.16 |
| | | [0.396] | [0] | [0.004] | [0.006] | [0.005] | | | |
| Precious Metals | 1,674 | -0.002 | 0.4424** | -0.278 | -1.0821** | -0.803** | Yes | Yes | 0.14 |
| | | [0.867] | [0] | [0.124] | [0] | [0] | | | |
| Non-Metallic and Industrial Metal Mining | 3,826 | 0.012 | 1.3614** | 0.211 | -0.5798** | -0.6546** | Yes | Yes | 0.24 |
| | | [0.284] | [0] | [0.108] | [0] | [0] | | | |
| Coal | 1,805 | 0.014 | 1.2999** | 0.7088** | -0.245 | -0.3634* | Yes | Yes | 0.19 |
| | | [0.473] | [0] | [0.002] | [0.239] | [0.013] | | | |
| Petroleum and Natural Gas | 17,934 | 0.003 | 1.3108** | 0.6469** | 0.035 | -0.3547** | Yes | Yes | 0.24 |
| | | [0.5] | [0] | [0] | [0.505] | [0] | | | |
| Utilities | 14,851 | 0.002 | 0.6671** | -0.0875** | -0.1542** | 0.022 | Yes | Yes | 0.18 |
| | | [0.444] | [0] | [0.007] | [0] | [0.311] | | | |
| Communication | 11,678 | 0.005 | 1.0457** | 0.030 | -0.099 | -0.2291** | Yes | Yes | 0.23 |
| | | [0.253] | [0] | [0.579] | [0.055] | [0] | | | |
| Personal Services | 4,219 | -0.019 | 1.0552** | 0.8157** | -0.011 | -0.125 | Yes | Yes | 0.22 |
| | | [0.088] | [0] | [0] | [0.919] | [0.104] | | | |
| Business Services | 29,854 | 0.007 | 1.1573** | 0.5857** | -0.1981** | -0.0916** | Yes | Yes | 0.20 |
| | | [0.072] | [0] | [0] | [0] | [0.001] | | | |
| Computers | 6,140 | 0.002 | 1.2187** | 0.7725** | -0.3697** | -0.229** | Yes | Yes | 0.29 |
| | | [0.79] | [0] | [0] | [0] | [0] | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Electronic Equipment | 12,491 | 0.001 | 1.3482** | 0.5982** | -0.2072** | -0.1933** | Yes | Yes | 0.30 |
| | | [0.766] | [0] | [0] | [0] | [0] | | | |
| Measuring and Control Equipment | 3,245 | 0.014 | 1.0625** | 0.6257** | -0.2122** | 0.095 | Yes | Yes | 0.27 |
| | | [0.085] | [0] | [0] | [0.008] | [0.098] | | | |
| Business Supplies | 3,194 | 0.002 | 1.2068** | 0.62** | 0.7536** | -0.3049** | Yes | Yes | 0.32 |
| | | [0.882] | [0] | [0] | [0] | [0] | | | |
| Shipping Containers | 1,153 | -0.002 | 1.1341** | 0.4057** | -0.138 | -0.3736** | Yes | Yes | 0.42 |
| | | [0.878] | [0] | [0] | [0.161] | [0] | | | |
| Transportation | 9,674 | -0.007 | 0.9545** | 0.512** | 0.3007** | -0.1723** | Yes | Yes | 0.23 |
| | | [0.177] | [0] | [0] | [0] | [0] | | | |
| Wholesale | 9,718 | 0.007 | 1.0781** | 0.6496** | 0.2514** | -0.1679** | Yes | Yes | 0.27 |
| | | [0.219] | [0] | [0] | [0] | [0] | | | |
| Retail | 17,625 | 0.002 | 1.0016** | 0.7863** | 0.3609** | -0.1511** | Yes | Yes | 0.25 |
| | | [0.535] | [0] | [0] | [0] | [0] | | | |
| Restaurants, Hotels, Motels | 6,824 | 0.002 | 1.0453** | 0.6528** | 0.1597* | -0.3007** | Yes | Yes | 0.28 |
| | | [0.788] | [0] | [0] | [0.012] | [0] | | | |
| Banking | 19,935 | 0.0096** | 0.9641** | 0.3091** | 0.8163** | -0.2493** | Yes | Yes | 0.28 |
| | | [0.003] | [0] | [0] | [0] | [0] | | | |
| Insurance | 10,471 | 0.0094* | 1.114** | 0.239** | 0.5091** | -0.2653** | Yes | Yes | 0.29 |
| | | [0.044] | [0] | [0] | [0] | [0] | | | |
| Real Estate | 2,546 | -0.003 | 1.3632** | 0.475** | 0.328** | -0.3189** | Yes | Yes | 0.32 |
| | | [0.819] | [0] | [0] | [0.006] | [0] | | | |
| Trading | 38,081 | -0.001 | 0.9156** | 0.2188** | 0.098** | -0.2092** | Yes | Yes | 0.30 |
| | | [0.478] | [0] | [0] | [0] | [0] | | | |
| Almost Nothing | 2,049 | 0.001 | 1.0144** | 0.288** | -0.2036* | -0.1639* | Yes | Yes | 0.24 |
| | | [0.935] | [0] | [0.008] | [0.046] | [0.024] | | | |
| Non-classifiable Establishments | 13,856 | 0.009 | 1.0226** | 0.8775** | -0.1918** | -0.2296** | Yes | Yes | 0.18 |
| | | [0.168] | [0] | [0] | [0.009] | [0] | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

**Table 3.9b: Impact of increased CRR from adverse media coverage on stock performance of US listed companies in the 'gaming' industry**

Table 3.8 (Panel B) provides regression results for US firms in the 'gaming' industry from January 2007 to December 2018. Consistent with Hong and Kacperczyk (2009), this study adopts the NAICS classification and identifies gaming stocks as those displaying the following NAICS codes: 7132, 71312, 713210, 71329, 713290, 72112, and 721120. This is separate and distinct from the Fama and French (1997) 48 industry groups.

| Industry | Observations | RRRC | (RM-RF) | SMB | HML | WML | Firm Effect | Year Effect | Adj. R-squared |
|---|---|---|---|---|---|---|---|---|---|
| Gaming | 354 | 0.037 | 1.5809** | 1.5541** | 0.604 | -1.0166** | Yes | Yes | 0.30 |
| | | [0.24] | [0] | [0.002] | [0.202] | [0.003] | | | |

*Denotes significance at the 5% level and ** denotes significance at the 1% level.

On the contrary, results indicate that firms in the (i) candy and soda, (ii) steel works, (iii) banking and (iv) insurance sectors were significantly affected by heightened reputation risks from undesirable media coverage. The candy and soda industry appeared to be most affected with a significant deterioration in adjusted stock performance of −1.9% for each unit increase in RRR score. Similarly, companies in the steel works, banking and insurance industries experienced adverse share price movements of −1.4%, −1.0% and −0.9%, respectively, for every uptick in RRR score. This may suggest media coverage provides new information on these industries which significantly affects investors' valuation of these industries. The magnitude of stock-price shocks from increased CRR (via negative ESG media reporting) may signify the rise of 'sugar' as a new vice and investors are pricing this accordingly into their valuation of companies.

## 3.5 Conclusion

Globally, there is increasing pressure on companies to engage in positive CSR activities and maintain good corporate reputations. Despite extensive research on the links between CSR and CFP (see Brooks and Oikonomou, 2018), none has examined how CRR from ESG issues lead to financial consequences from an essential stakeholder class, investors. Using a sample of US publicly listed companies over the period January 2007 to September 2019, this paper fills a gap in the literature by providing empirical evidence that reputation risk has a significant and negative impact on the stock performance of affected firms.

This study extends the analysis to identify firm- and industry-specific differences that can help explain cross-sectional differences in the market behaviour of investors towards companies with increasing reputation risks. Results indicate that firm size, trading activities, S&P500 constituency, reputation status and industry classification play important roles in the market behaviour of investors. It is observed that larger firms that are actively traded, particularly major index constituents (like S&P500 companies), did not experience a statistically significant impact on their stock performance from increased CRR. It is probable that these firms are more visible with less information asymmetry, hence increased reputation risks from adverse ESG-related media coverage do not have a material impact on their stock performance, as these factors are already known and priced in. Conversely, firms that are most significantly affected by heightened CRR are associated with the smallest size and liquidity deciles, indicating that they are likely to be less visible and recognised. This suggests adverse media coverage of ESG may provide new information to investors in these companies that was not known or considered previously. Further, companies with good reputation status (i.e. low to moderate ESG risk exposure) are also more likely to be impacted by spikes in CRR, possibly indicating information shocks. Overall, these findings provide support for the information asymmetry theory and fertile ground for future research.

Finally, this research also provides empirical evidence to indicate that the stock performance of firms in the 'sin' triumvirate (i.e. alcohol, tobacco and gaming) is not significantly affected by negative ESG media reporting. Given the high-level scrutiny these industries are usually confronted with, it is probable that additional focus on their undesirable ESG behaviour does not warrant investors' revaluation of their underlying business. Rather, it is companies associated with (i) candy and soda, (ii) steel works, (iii) banking and (iv) insurance that are observed to be more vulnerable to negative price shocks from unfavourable ESG media coverage. It is noteworthy that the highest negative stock performance impact of −1.9% from increases in CRR across various analysis in the entire paper is attributed to the candy and soda industry, suggesting the advent of 'sugar' as a new vice.

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# Chapter 5: The Impact of Energy Policy on Electricity Generation and Prices: Evidence from Australia

## 5.1 Introduction

A policy of ensuring the security, reliability and affordability of electricity markets is increasingly important internationally. With an abundance of natural resources, Australia is one of the world's largest exporters of energy materials. Despite this advantage, policy uncertainty over the past decade has contributed to a lack of concrete investment in energy-generation assets and increasingly high electricity prices (see Keating 2010, Nelson et al. 2010, 2012, CCA/AEMC, 2017).[9]

A focus on climate change in Australian energy policies originated from a key 2007 election commitment to introduce an Emissions Trading Scheme (ETS) by 2010 and a goal to expand the mandatory renewable-energy target so that 20% of electricity supply would be from renewable sources by 2020. Since then, climate change policy has significantly influenced the energy sector in Australia.

In April 2009, the Australian Government postponed the start of its carbon trading scheme due to growing pressure from industries that the costs of introducing the carbon trading scheme would be unsustainable for many businesses in the context of the global financial crisis. The Clean Energy Bill was eventually proposed in February 2011, in July 2011 the Clean Energy Plan was released, and the Clean Energy Bill 2011 (with amendments to the original ETS) was passed by the House of Representatives and the Senate in October and November 2011, respectively. The Carbon Pricing Mechanism (CPM), a central component of the Clean Energy Bill, was officially

[9] www.aemc.gov.au/sites/default/files/content/Towards-the-next-generation-Delivering-affordable-secure-and-lower-emissions-power.pdf

implemented on 1 July 2012 in a bid to reduce greenhouse gas emissions to 5% below 2000 levels by 2020, and to 80% below 2000 levels by 2050.

The objective of the CPM (which was effectively viewed as a 'carbon tax') was to incentivise Australia's largest emitters to enhance energy efficiency and invest in sustainable energy. Under the CPM, businesses emitting over 25,000 tonnes of carbon dioxide equivalent (tCO2e) emissions per year were required to purchase emissions units from the government (Clean Energy Regulator 2013). During the 3-year introductory phase, the price of uncapped permits was fixed (starting at $23 per tonne of CO2e and increasing to $25.40/tCO2e) with a planned transition to an Emission Trading Scheme (ETS) in July 2015. However, the election of a new government in September 2013 prompted the Clean Energy Legislation (Carbon Tax Repeal) Act, which was passed by the Senate on 17 July 2014 to abolish the CPM (backdated from 1 July 2014) and the Emission Reduction Fund was set up.

As of 2013, Australia was the 12th highest emitter of greenhouse gases per capita in the world and 16th in total $CO_2$ emissions (kt per year). Since Australia's climate pledge under the Paris Agreement in 2015, the Commonwealth Government and relevant market bodies have been reviewing climate policies, market rules and regulations. It is expected that the implementation of the Paris Agreement is likely to affect energy security. As of 2016, Federal energy policies continue to support the coal mining and natural gas industries through subsidies for fossil fuel use and production, as the exports of those industries contribute significantly to the earnings in foreign exchange and government revenue.[10] An emissions reduction target for Australia as a country has been established (26% to 28% by 2030) and the government was appraising policies in 2017 to ensure they remained effective in meeting this target and the Paris Agreement commitments. The National Energy Guarantee (NEG), which seeks to provide certainty to the energy market, was

[10] In June 2015, the Commonwealth Government downgraded the renewable energy target from 41,000 GWh per year to 33,000 GWh.

proposed in late 2017 but had not passed as of July 2018. This indicates the persistence of energy policy uncertainty during this period.[11]

In the context of this policy environment, it is beneficial to understand how background energy policies affect wholesale electricity prices, which has significant implications for all consumers and is therefore of interest to regulators and legislators. Hence, this study seeks to provide empirical evidence using historical data to extend understanding of the tangible implications of energy policy on issues like the impact of the CPM on market behaviour and the impact of the retirement of ageing coal-fired power stations on generation capacity and wholesale electricity prices during periods of uncertainty.

This research first incorporates relevant determinants of costs for wholesale electricity spot prices from existing literature, utilises these factors to examine the impact of the CPM (from 1 July 2012 to 1 July 2014) and analyses whether there were structural shifts in generation behaviour from coal to other fuel sources as a consequence of carbon mitigation policies. Further, using the closures of ageing coal-fired power plants *ex post* the CPM (i.e. during a period of energy policy uncertainty) as event studies, this research analyses the impacts on generation capacity, documents the effects on wholesale electricity spot prices and observes the critical shifts in import–export (reliance) relationships between connected states. With a significantly longer time series compared to other empirical studies in Australia (O’Gorman and Jotzo, 2014; Maryniak et al., 2018), this chapter provides additional analysis of the relationship between modern renewable energy sources (i.e. wind and solar) and wholesale electricity spot prices over time.

### 5.2 Literature review and hypothesis development

The review of existing literature on the fundamental factors that influence electricity prices can be segregated into three broad categories, game-theory, simulation and time-series models (see

[11] The sample period for this study is from 1 July 2010 to 30 June 2018.

Aggarwal et al., 2009). Game-theory models often focus on the strategies of the market players, simulation models create detailed representations of the electricity system and time-series models use historical data on the dependent variable. While there is a significant body of work in the areas of electricity demand forecasting and price prediction (see e.g. Bunn, 2000; Nogales et al., 2002; Conejo et al., 2005), there is limited research that focuses on the various effects of cost drivers of wholesale electricity spot prices, but this is beneficial to evaluate in the current policy environment of Australia.

Prior studies that attempted to address these questions generally utilised simulated as opposed to historical data (Bierbrauer et al., 2005; Knittel and Roberts, 2005). Empirical studies are particularly useful as the complexities in wholesale electricity markets are difficult to capture in market simulations. While subject to their own set of assumptions and limitations, direct analyses of market data can provide valuable insights and are a vital supplement to simulation work. The concept of using historical statistics to achieve the objective of understanding the determinants of electricity costs is similar and consistent with the work of Alberola et al. (2008), Boogert and Dupont (2008) and O'Mahoney and Denny (2013).

This study draws on prior research to provide guidance on relevant factors that may affect electricity prices. Sijm et al. (2008), Karakatsani and Bunn (2008) and O'Mahoney and Denny (2012) identified fundamental variables such as demand and supply which are conventionally included in electricity pricing models. Other studies such as those of Janczura et al. (2013) and Clements et al. (2015) observed that the wholesale spot market for electricity is volatile and prone to price spikes, and Worthington et al. (2005), Forrest and MacGill (2013) and Apergis and Lau (2015) highlighted that the Australian National Electricity Market (NEM, see below) is more price unstable compared to other markets.

In an Australian context, this study recognises the important of interregional flows (i.e. trade between regions), which are affected by demand from other connected states (Forrest and MacGill, 2013) and are also constrained by the interconnection capacity, which is critical to the balancing of supply and demand for the NEM (Worthington et al, 2005; Maryniak et al. 2018). Zhou (2009) and Apergis and Lau (2015) also suggested that there is a relatively high degree of market power exercised by generators across regional markets. Hence, this research includes proxies for local region demand, supply, price volatility, interregional demand and monopolistic characteristics as explanatory variables.

The focus of this chapter is the impact of energy policy on wholesale electricity spot prices, which has become a critical issue for energy security, reliability and affordability in Australia. One key aspect of research in this area is the analysis of the relationship between carbon emission policies and electricity prices. The introduction of CPM is of particular interest as it is analogous to additional taxes which may distort production and consumption decisions. For instance, the 'carbon tax' may increase the price consumers pay for wholesale electricity without increasing producers' revenues, which effectively creates a 'tax wedge' that leads to market inefficiency and lowers real economic output (Fullerton, 1982; Browning, 1994). It is noteworthy that the majority of carbon emission policies studies were conducted on the European Union Emissions Trading Scheme.[12] In Australia, Nelson et al. (2012) provided an extensive review of the impact of carbon prices on electricity markets (see also O'Gorman and Jotzo, 2014; Apergis and Lau, 2015; Maryniak et al, 2018). From a policy prospective, the intention behind imposing the carbon tax was to encourage producers to move away from coal-fired generation and into gas and renewable sources of energy by increasing the cost of fossil fuel combustion. Although there is evidence to suggest that carbon prices have impacts on both electricity spot and futures prices, most studies

[12] See also Sijm et al. (2006), Bonacina and Gulli (2007), Hirschhausen and Zachmann (2008), Bunn and Fezzi (2009), Daskalakis and Markellos (2009), Fell (2010), Blyth and Bunn (2011), Chevallier (2011), Gronwald et al. (2011), Sijm et al. (2012), Benth et al. (2013), Jouvet and Solier (2013), Nazifi (2013), Huisman and Kilic (2015) and Kanamura (2016).

have not controlled for relevant cost determinants and there is limited research analysing structural shifts in generation behaviour, which are the underlying intent of carbon pricing schemes.

To support legislators in evaluating the efficacy of climate change policymaking, this research examines the impact of carbon pricing scheme on wholesale electricity prices and hypothesises that:

*H5.1: The adoption of the CPM will lead to higher wholesale electricity prices across all NEM regions,* ceteris paribus.

Further, since the underlying objective of the CPM was to encourage a shift from coal towards less carbon-intensive fuel sources, the study also considers whether there were structural shifts in the utilisation of various fuel sources for electricity generation (e.g. coal, natural gas, hydro, wind, solar). It is proposed that as coal generation became more expensive under the CPM in Australia, other energy sources were likely to become increasingly price attractive, which created a change in the size of the contribution from renewable sources. Therefore:

*H5.2: The adoption of the CPM will lead to lower electricity generation from coal,* ceteris paribus.

From a research prospective, the energy policy uncertainty in Australia *ex post* CPM also provides opportunities to examine how the withdrawal of coal-fired power plants affected electricity generation capacity and wholesale electricity prices during this period. This issue is increasingly of interest as the retirement of large-scale coal-fired generation is likely to have a major impact on the generating capacity of a region and the remaining coal generators in Australia are ageing, with many nearing the end of their 50-year lifecycles. While it is ideal and advisable to require that large-scale capacity withdrawal occurs only with sufficient notice, the lack of clear and consistent energy policies that are well understood and accepted by all stakeholders is likely to confuse the market and impede investment in generation capacity, since the effect of uncertainty associated with future carbon emission regulations magnifies the anxiety of risk-averse investors concerning profits (Fan et al., 2010; Nelson et al., 2010, 2012).[13] From a policy prospective, in the absence of adequate replacement capacity, the closure of coal-fired power plants is of concern, as this has the potential to reduce base-load generation supply, which is likely to increase wholesale electricity spot prices. Hence:

*H5.3: Coal-fired power plant closure leads to lower generation capacity and higher wholesale electricity prices,* ceteris paribus.

The remainder of the chapter is structured as follows. Section 2 provides institutional details on the wholesale electricity markets in Australia, Section 3 describes the data and methodology, Section 4 presents the empirical results and Section 5 provides a summary of the findings and concludes.

## 5.2 Institutional Details

### 5.2.1 National Electricity Market

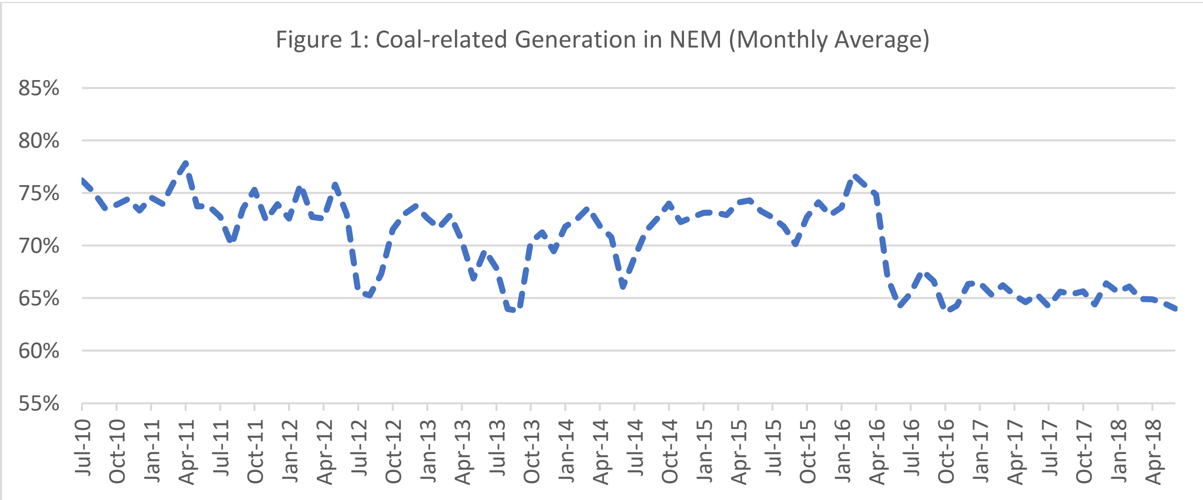
In Australia, the electricity generation sector is segregated into three markets: the National Electricity Market (NEM), which operates in the eastern states; the Wholesale Electricity Market, which serves Western Australia; and an integrated electricity utility, which operates in the Northern Territory. The NEM network, which represents over 90% of Australian electricity demand,[14] is the focus of this study. It began operation on 13 December 1998 and consists of five regions which coincide with the adjacent states of New South Wales (NSW including the Australian Capital Territory), Victoria (VIC), Queensland (QLD), South Australia (SA) and

[13] Uncertainty about the emissions pathway in the power sector certainly impacted on the outlook – all new investment came from renewable energy. In 2017, a review of climate change policies was carried out and the Energy Security Board recommended the creation of a national guarantee scheme with a reliability standard and an emissions reduction standard. At the same time, states have developed their own policies, mostly aimed at increasing energy efficiency and renewable energy deployment.
[14] See Forrest and MacGill (2013).

Tasmania[15] (TAS). The sales of electricity go through a wholesale pool managed by the independent Australian Electricity Market Operator (AEMO) and the transmission network carries power from generators to primarily local electricity distributors across the five connected states. Most consumers do not participate directly in the NEM and purchase their electricity through retailers. It is noteworthy that coal generators constitute most of the available capacity. However, across the entire NEM the role of coal in power generation[16] has declined from approximately 80% in July 2009 to 65% in March 2018 (see Figure 5.1).

**<u>Figure 5.1: Coal-related generation in NEM (monthly average)</u>**

Figure 1 provides coal related generation as a proportion of total electricity generation (in %) over the sample period from 1 July 2010 to 30 June 2018.




[15] Joined in May 2005.
[16] Includes coal seam methane as a fuel source in QLD.

### 5.2.2 Coal-fired power stations

Table 5.1 presents information on the 23 coal-fired power stations in operation within the NEM and indicates that they are ageing. It is highly probable that Australia's ageing coal plants will continue to be retired without significant investment in life extension, due to age and safety considerations. Many are expected to reach the end of their useful life of around 50 years by 2035 and three stations have already been scheduled for withdrawal.[17] Based on AEMO estimates (2016), 25% of Australia's coal-fired capacity is expected to be retired within the next 10 years. With increasing emphasis on carbon emission policies, the market appears to have little commercial interest in building new coal-fired power plants.[18] This suggests a pressing need to understand the impact of unreplenished coal generation on electricity prices.

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[17] As of 31 July 2018.

[18] The last coal-fired power station built in Australia was Bluewaters in 2009.

## Table 5.1:Announced year of decommissioning of coal-fired power plants in the NEM (Australia)

Table 5.1 provides details on the announced year of decommissioning for coal-fired power plants in NEM (Australia).

| State | Power Station | Primary Fuel Type | Year of Commissioning | Announced Year of Decommissioning | Age (Years) | Registered Capacity (MW) |
|---|---|---|---|---|---|---|
| NSW | Bayswater | Black Coal | 1982–1984 | 2035 | 34–36 | 2640 |
| NSW | Eraring | Black Coal | 1982–1984 | – | 34–36 | 2880 |
| NSW | Liddell | Black Coal | 1971–1973 | 2022 | 45–47 | 2000 |
| NSW | Mt Piper | Black Coal | 1993 | – | 25 | 1400 |
| NSW | Vales Point B | Black Coal | 1978 | – | 40 | 1320 |
| QLD | Callide B | Black Coal | 1989 | – | 29 | 700 |
| QLD | Callide C | Black Coal | 2001 | – | 17 | 810 |
| QLD | Gladstone | Black Coal | 1976–1982 | – | 36–42 | 1680 |
| QLD | Gladstone (QAL) | Black Coal | 1973 | – | 45 | 25 |
| QLD | Kogan Creek | Black Coal | 2007 | – | 11 | 750 |
| QLD | Millmerran | Black Coal | 2002 | – | 16 | 851 |
| QLD | Stanwell | Black Coal | 1993–1996 | – | 22–25 | 1460 |
| QLD | Tarong | Black Coal | 1984–1986 | – | 32–34 | 1400 |
| QLD | Tarong North | Black Coal | 2002 | – | 16 | 443 |
| QLD | Yabulu (Coal) | Black Coal | 1974 | – | 44 | 37.5 |
| VIC | Loy Yang A | Brown Coal | 1984–1987 | 2048 | 32–35 | 2210 |
| VIC | Loy Yang B | Brown Coal | 1993–1996 | – | 22–25 | 1026 |
| VIC | Yallourn W | Brown Coal | 1975, 1982 | – | 36–43 | 1480 |

The retirement of older coal plants is consistent with the move towards a low-carbon economy under the Paris Agreement since 2015. The withdrawals appear to have accelerated since the announcement of the CPM, as approximately 10 coal-fired power plants have been retired from service in the NEM network. Table 5.2 presents details of each power station and the average daily offered capacity 12 months pre- and post each closure for the states where the generators are based. The statistics suggest a lack of replacement capacity especially *ex post* CPM.

With the repeal of the CPM, there is significant policy uncertainty, which appears to have affected investment in generation capacity, and many have attributed the high electricity prices in Australia to this factor (CCA/AEMC, 2017). The withdrawal of four coal-fired power stations *ex-post* carbon tax abolition (i.e. Anglesea, Northern, Playford and Hazelwood) provides an opportunity to empirically examine how these closures affected supply generation and wholesale electricity spot prices. It is noteworthy that the latest withdrawal, of the Hazelwood power station, from the NEM has had the most significant impact on offered capacity (among all 10 coal power plant closures) for the affected state (i.e. VIC).

**Table 5.2: Withdrawal of coal-fired power plants in the NEM (Australia)**

Table 5.2 provides details on withdrawal of coal-fired power plants in NEM (Australia).

| State | Power Station | Primary Fuel Type | Year of Commissioning | Date of Closure | Registered Capacity (MW) | Avg Daily Offered Capacity MW (Pre-12m) | Avg Daily Offered Capacity MW (Post-12m) | Change (%) |
|---|---|---|---|---|---|---|---|---|
| NSW | Munmorah** | Black Coal | 1969 | Jul-12 | 600.0 | 12,133.37 | 12,474.52 | 2.81% |
| NSW | Redbank | Black Coal | 2001 | Aug-14 | 143.8 | 12,469.77 | 11,947.66 | -4.19% |
| NSW | Wallerawang C | Black Coal | 1976–1980 | Nov-14 | 1,000.0 | 12,286.60 | 12,030.31 | -2.09% |
| VIC | Morwell | Brown Coal | 1958–1962 | Aug-14 | 189.0 | 9,320.84 | 9,673.37 | 3.78% |
| VIC | Anglesea | Brown Coal | 1969 | Aug-15 | 160.0 | 9,709.15 | 9,304.09 | -4.17% |
| VIC | Hazelwood | Brown Coal | 1964–1971 | Mar-17 | 1,760.0 | 9,359.17 | 8,135.49 | -13.07% |
| QLD | Swanbank B | Black Coal | 1970–1973 | May-12 | 500.0 | 10,448.09 | 9,743.75 | -6.74% |
| QLD | Collinsville | Black Coal | 1968–1998 | Dec-12 | 180.0 | 10,268.91 | 9,669.61 | -5.84% |
| SA | Northern | Brown Coal | 1958 | May-16 | 546.0 | 2,375.03 | 2,228.66 | -6.16% |
| SA | Playford | Brown Coal | 1960 | May-16 | 240.0 | | | |

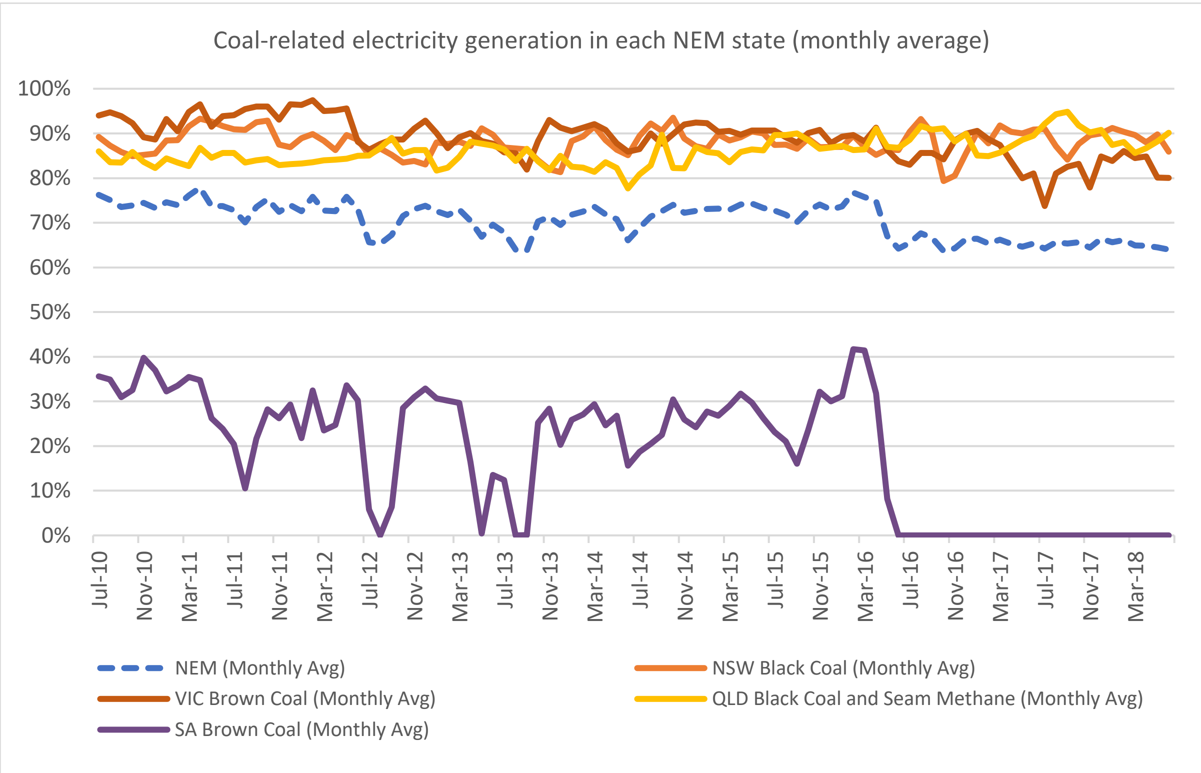
* Carbon pricing scheme (*Clean Energy Act 2011*) came into effect on 1 July 2012 and ended on 1 July 2014.

** Munmorah was placed on standby from August 2010 until June 2012. In July 2012, Delta Electricity announced its closure due to slowing demand, competition from more efficient generators and renewable sources, and the carbon price (Delta 2012).

In addition, the withdrawal of the Northern and Playford power stations in SA from the grid on May 2016 removed coal power generation entirely from the state. This is also the predominant reason for the decline in coal generation across the NEM shown in Figure 5.1. Generally, the role of coal generation in the larger economic states (i.e. NSW, QLD and VIC) are observed to be relatively unchanged[19] (refer to Figure 5.2). The complete removal of coal generators in SA on May 2016 (ex-post repeal of the carbon pricing scheme) provides a unique opportunity to examine how a move away from fossil fuel can impact on electricity prices.[20] It is of note that there was a system-wide blackout in SA on 28 September 2016 which left the entire state without electricity. This strengthens the need to empirically understand the impact of withdrawing coal power stations from the NEM and the requisites for better planning regarding future removals.

**Figure 5.2: Coal-related electricity generation in each NEM state (monthly average)**

Figure 2 provides coal related generation as a proportion of total electricity generation (in %) in each NEM state over the sample period from 1 July 2010 to 30 June 2018.




[19] TAS relies mostly on hydro and gas for electricity generation.
[20] Although SA does not generate electricity using coal, it may still be reliant on power generated by coal that is provided by interconnected states when domestic state generation is insufficient.

### 5.3 Data and methodology

The source data in this research is extracted from the AEMO website (www.aemo.com.au) and includes regional-level intra-day and end-of-day energy trading data (e.g. demand, price, generation, availability, ancillary services and interconnector flow) on the Australian NEM.

The wholesale market of the NEM is a real-time energy market operated by the AEMO where a centrally coordinated dispatch process is used to match demand and supply instantaneously in real time. Registered generators (larger than 30 MW) offer to supply the market with specific amounts of electricity at nominated prices for each 5-minute interval through the day. Supply bids are stacked from the lowest price to the highest price and the dispatch price for each 5-minute interval is set to be equal to the last bid needed to meet demand in a given period. Since the market is settled on a 30-minute period, the wholesale spot price is calculated every 30 minutes as the average of the dispatch prices for the six 5-minute intervals that make up the period. The spot price is used as the basis for the settlement of financial transactions for all energy traded in the NEM.[21]

This research examines the impact of policy uncertainty on wholesale electricity spot prices from 1 July 2010 to 30 June 2018. This time frame covers: (i) the 2-year period before the start of the CPM (July 2010 to June 2012); (ii) the sample period when the carbon tax was effective but due to the political climate (upcoming elections with abolition of the CPM as a key promise of the opposition) there was uncertainty among market participants about how long the tax would be in place (eventually July 2012 – September 2013); (iii) the period when the tax was still effective but it had become clear that the tax would be abolished in the near future (after September 2013, before July 2014); and (iv) the periods around the closures of four coal-fired power station *ex-post* the CPM (Anglesea, Northern, Playford and Hazelwood). A time-series analysis of the relationships

[21] As of July 2017, there was a market price cap of \$14,200/MWh and a minimum spot price set at −\$1,000/MWh (for situations where it was not possible or too costly for participants to switch off their supply during the off-peak period, they could offer negative bids to ensure that they were scheduled to supply). The wholesale costs accounted for around 20% of the retail accounts and additional charges were added to the price paid by domestic and business consumers for electricity which included network costs, service fees, and market and other retail charges (AEMO: Carbon price–market review).

between various energy sources (wind, solar, battery storage) and wholesale electricity spot prices will also be presented.

### 5.3.1 Univariate analysis of wholesale electricity spot prices

The first part of this research adopts a univariate approach and analyses how wholesale electricity spot price varied around the CPM regime (i.e. 1 July 2010 to 30 June 2014) and the sample period pre- and post- the closure of each coal generator *ex post* the carbon tax (Anglesea, Northern, Plyford and Hazelwood). To control for seasonality factors (Knittel and Roberts, 2005) and provide insights across a longer horizon on replacement generation capacity, all analyses are completed on a yearly basis. Further, to coincide with the carbon pricing regime, this study reports and analyses each Australian financial year (i.e. 1 July to 30 June) rather than calendar year (i.e. 1 January to 31 December) for the sample period.

For robustness, this study adopts three measures of electricity prices measured in AUD/MWh: (i) daily average price (Price); (ii) daily volume-weighted average price (VWAP); and (iii) daily average peak price (Peak). Price is the average of the settlement prices over 48 half-hourly trading intervals on each calendar day in each state. VWAP is the volume-weighted average settlement price in Australian dollars over 48 half-hourly trading intervals on each calendar day in each state. Peak is the average peak price from 7:00 am to 10:00 pm EST over 30 half-hourly trading intervals on each calendar day in each state.

### 5.3.2 Multivariate analysis of electricity prices around CPM

To determine whether there were any systematic differences in wholesale electricity prices within the NEM during the CPM's two-year regime, it is important to control for relevant factors identified in the literature such as local region (state) demand and generation sufficiency, monopolistic concentration, price volatility and interconnected state(s) generation sufficiency (see Worthington et al., 2005; Karakatsani and Bunn, 2008; Sijm et al., 2008; Zhou, 2009; O'Mahoney and Denny, 2012; Apergis and Lau, 2015; Forrest and MacGill, 2013; Janczura et al., 2013; Clements et al., 2015; Maryniak et al. 2018). Further, consistent with Bessec and Fouquau (2008), Lee and Chiu (2011), and Mulder and Scholtens (2013), this study adopts the use of natural logs and winsorises the regression variables at 1% and 99% levels to remove bias from outliers. The following equation is estimated using an OLS regression:

$$\textit{Log Electricity Prices}_{sd} = \alpha + \beta_1 \textit{LogDemand}_{sd} + \beta_2 \textit{HHI}_{sd} + \beta_3 \textit{LogOffered Capacity}_{sd} + \beta_4 \textit{Price Volatility}_{sd} + \beta_5 \textit{LogInterconnected State}_{sd} + \textit{Event}_{sd} + \varepsilon_{it} \quad (5.1)$$

where $s$ represents the *regional state* in the sample for all tested variables, $\textit{LogElectricity Prices}_{sd}$ is the natural log of the volume-weighted average price on calendar day $d$, $\textit{LogDemand}_{sd}$ is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day $d$ in each regional state $s$, $\textit{HHI}_{sd}$ is the Herfindahl–Hirschman Index (HHI)[22] that measures market concentration on each calendar day $d$ in each regional state $s$, $\textit{LogOffered Capacity}_{sd}$ is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day $d$ in each regional state $s$, $\textit{Price Volatility}_{sd}$ is measured using the standard deviation of intra-day prices on each calendar day $d$ in each regional state $s$, $\textit{LogInterconnected State}_{sd}$ is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day $d$ in each *other* regional state that is interconnected with regional state $s$ and $\textit{Event}_{sd}$ is a dummy variable that takes the value of 1 during the two-year CPM regime and 0 otherwise.

[22] The HHI measures market concentration and is calculated by squaring the market share of each firm competing in each state and then summing the resulting numbers. It ranges from close to zero to 10,000 and a higher HHI indicates more monopolistic concentration and less competition.

### 5.3.3 Multivariate analysis of electricity prices around withdrawal of coal-fired power stations

Consistent with multivariate analysis of the CPM, to analyse the impact of coal-fired power station withdrawal from the NEM, it is important to control for local region (state) demand and generation sufficiency, monopolistic concentration, price volatility and interconnected state(s) generation sufficiency. Similarly, this study adopts the use of natural logs and winsorises the regression variables at 1% and 99% levels to remove bias from outliers. The following equation is estimated using an OLS regression:

$$Log\ Electricity\ Prices_{sd} = \alpha + \beta_1 LogDemand_{sd} + \beta_2 HHI_{sd} + \beta_3 LogOffered\ Capacity_{sd} + \beta_4 Price\ Volatility_{sd} + \beta_5 LogInterconnected\ State_{sd} + Event_{sd} + \varepsilon_{it} \quad (5.2)$$

where *s* represents the *regional state* in the sample for all tested variables, $LogElectricity\ Prices_{sd}$ is the natural log of the volume-weighted average price on calendar day *d*, $LogDemand_{sd}$ is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, $HHI_{sd}$ is the HHI that measures market concentration on each calendar day *d* in each regional state *s*, $LogOffered\ Capacity_{sd}$ is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, $Price\ Volatility_{sd}$ is measured using the standard deviation of intra-day prices on each calendar day *d* in each regional state *s*, $LogInterconnected\ State_{sd}$ is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in in each *other* regional state that is interconnected with regional state *s* and $Event_{sd}$ is a dummy variable that takes the value of 1 *ex-post* the withdrawal of a coal-fired power plant and 0 otherwise.

### 5.3.4 Renewable sources

This study also analyses the relationships between modern renewable sources (i.e. wind and solar) and wholesale electricity spot prices across time. To determine how the relationships between wind/solar and wholesale electricity spot prices changed over the sample period, the study controls for similar factors like local region (state) demand and generation sufficiency, monopolistic concentration, price volatility and interconnected state(s) generation sufficiency, utilises natural logs and winsorises the regression variables at the 1% and 99% levels. The following equation is estimated using an OLS regression:

$$Log\ Electricity\ Prices_{sd} = \alpha + \beta_1 LogDemand_{sd} + \beta_2 HHI_{sd} + \beta_3 LogOffered\ Capacity_{sd} + \beta_4 Price\ Volatility_{sd} + \beta_5 LogInterconnected\ State_{sd} + LogFuels_{sd} + \varepsilon_{it} \tag{5.3}$$

where $s$ represents the *regional state* in the sample for all tested variables, $LogElectricity\ Prices_{sd}$ is the natural log of the volume-weighted average price on calendar day $d$, $LogDemand_{sd}$ is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day $d$ in each regional state $s$, $HHI_{sd}$ is the HHI that measures market concentration on each calendar day $d$ in each regional state $s$, $LogOffered\ Capacity_{sd}$ is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day $d$ in each regional state $s$, $Price\ Volatility_{sd}$ is measured using the standard deviation of intra-day prices on each calendar day $d$ in each regional state $s$, $LogInterconnected\ State_{sd}$ is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day $d$ in each *other* regional state that is interconnected with regional state $s$ and $LogFuels_{sd}$ are the natural log of each fuel source in megawatts that contributes to electricity generation on each calendar day $d$ in each regional state $s$.

## 5.4 Results

### 5.4.1 Wholesale electricity prices

Table 5.3 reports the three different measures of average daily wholesale electricity prices (annually based on the financial year of the Australian Government) from 1 July 2009 to 30 June 2018. Results suggest that wholesale electricity prices have generally increased over the sample period.

**Table 5.3a: Price (daily average)**

Table 5.3a provides details on the average daily wholesale electricity prices in each NEM state.

| | NSW | VIC | QLD | SA | TAS | NEM |
|---|---|---|---|---|---|---|
| 2010 | $36.74 | $27.09 | $30.97 | $32.58 | $29.44 | $31.36 |
| 2011 | $29.67 | $27.28 | $29.07 | $30.28 | $32.58 | $29.78 |
| 2012 | $55.10 | $57.44 | $67.02 | $69.75 | $48.30 | $59.52 |
| 2013 | $52.26 | $51.49 | $58.42 | $61.71 | $41.98 | $53.17 |
| 2014 | $35.17 | $30.35 | $52.52 | $39.29 | $37.16 | $38.90 |
| 2015 | $51.60 | $46.14 | $59.99 | $61.67 | $102.70 | $64.42 |
| 2016 | $81.22 | $66.58 | $93.12 | $108.66 | $75.40 | $85.00 |
| 2017 | $82.27 | $92.33 | $72.87 | $98.10 | $86.98 | $86.51 |

*Results are reported annually based on Australia's financial year (i.e. 1 July to 30 June of each relevant year)

**Table 5.4b: Volume-weighted average price (VWAP)**

Table 5.3b provides details on the daily volume-weighted average wholesale electricity prices in each NEM state.

| | NSW | VIC | QLD | SA | TAS | NEM |
|---|---|---|---|---|---|---|
| 2010 | $39.23 | $28.19 | $32.66 | $35.55 | $30.23 | $33.17 |
| 2011 | $30.27 | $27.97 | $29.82 | $31.50 | $32.78 | $30.47 |
| 2012 | $55.66 | $59.12 | $68.74 | $72.19 | $48.52 | $60.85 |
| 2013 | $52.80 | $52.64 | $59.74 | $64.24 | $42.09 | $54.31 |
| 2014 | $35.96 | $31.13 | $56.94 | $41.08 | $37.52 | $40.53 |
| 2015 | $53.58 | $48.60 | $62.41 | $65.23 | $103.48 | $66.66 |
| 2016 | $84.83 | $68.93 | $97.64 | $115.41 | $76.52 | $88.66 |
| 2017 | $83.81 | $95.95 | $74.44 | $102.66 | $87.56 | $88.88 |

*Results are reported annually based on Australia's financial year (i.e. 1 July to 30 June of each relevant year)

**Table 5.5c: Peak price (daily average)**

Table 5.3c provides details on the peak daily wholesale electricity prices in each NEM state.

| | NSW | VIC | QLD | SA | TAS | NEM |
|---|---|---|---|---|---|---|
| 2010 | $44.04 | $30.88 | $37.37 | $39.84 | $32.76 | $36.98 |
| 2011 | $31.90 | $30.52 | $32.39 | $34.28 | $33.00 | $32.42 |
| 2012 | $57.08 | $62.12 | $74.30 | $76.98 | $48.96 | $63.89 |
| 2013 | $54.19 | $54.91 | $63.67 | $68.59 | $43.23 | $56.92 |
| 2014 | $38.29 | $33.87 | $67.09 | $44.74 | $38.13 | $44.43 |
| 2015 | $58.52 | $54.76 | $70.67 | $74.10 | $106.96 | $73.00 |
| 2016 | $92.39 | $75.46 | $111.28 | $124.88 | $80.51 | $96.91 |
| 2017 | $88.36 | $102.32 | $78.42 | $110.07 | $90.38 | $93.91 |

*Results are reported annually based on Australia's financial year (i.e. 1 July to 30 June of each relevant year)

### 5.4.2 Carbon pricing scheme

Table 5.4 presents univariate wholesale electricity prices 12 and 24 months pre- and during the CPM period. Results suggest that there were statistically significant increases in wholesale electricity spot prices across all three measures during the carbon tax regime.

**Table 5.6a: Electricity prices pre- and during the CPM in Australia**

Table 5.4a provides details on the average wholesale electricity prices pre- and during the CPM in each NEM state.

| State | Pre-CPM (12 Months) | Post-CPM (12 Months) | Differences ($) | Differences (%) | P-Value | Pre-CPM (24 Months) | Post-CPM (24 Months) | Differences ($) | Differences (%) | P-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| NSW | $29.67 | $55.10 | $25.43 | 85.70% | 0.00 | $33.20 | $53.68 | $20.48 | 61.67% | 0.00 |
| VIC | $27.28 | $57.44 | $30.16 | 110.54% | 0.00 | $27.19 | $54.46 | $27.28 | 100.33% | 0.00 |
| QLD | $29.07 | $67.02 | $37.95 | 130.53% | 0.00 | $30.02 | $62.72 | $32.70 | 108.95% | 0.00 |
| SA | $30.28 | $69.75 | $39.47 | 130.37% | 0.00 | $31.42 | $65.73 | $34.31 | 109.17% | 0.00 |
| TAS | $32.58 | $48.30 | $15.71 | 48.22% | 0.00 | $31.02 | $45.14 | $14.12 | 45.52% | 0.00 |
| NEM | $29.78 | $59.52 | $29.74 | 99.89% | 0.00 | $30.57 | $56.35 | $25.78 | 84.32% | 0.00 |

**Table 5.7b: Electricity VWAP pre- and during the CPM in Australia.**

Table 5.4b provides details on the volume-weighted average prices pre- and during the CPM in each NEM state.

| State | Pre-CPM (12 Months) | Post-CPM (12 Months) | Differences ($) | Differences (%) | P-Value | Pre-CPM (24 Months) | Post-CPM (24 Months) | Differences ($) | Differences (%) | P-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| NSW | $30.27 | $55.66 | $25.39 | 83.89% | 0.00 | $34.74 | $54.23 | $19.49 | 56.11% | 0.00 |
| VIC | $29.82 | $68.74 | $38.92 | 130.50% | 0.00 | $31.24 | $64.24 | $33.00 | 105.65% | 0.00 |
| QLD | $31.50 | $72.19 | $40.70 | 129.22% | 0.00 | $33.52 | $68.22 | $34.70 | 103.52% | 0.00 |
| SA | $32.78 | $48.52 | $15.73 | 47.98% | 0.00 | $31.51 | $45.30 | $13.80 | 43.78% | 0.00 |
| TAS | $27.97 | $59.12 | $31.16 | 111.42% | 0.00 | $28.08 | $55.88 | $27.81 | 99.05% | 0.00 |
| NEM | $30.47 | $60.85 | $30.38 | 99.71% | 0.00 | $31.82 | $57.58 | $25.76 | 80.96% | 0.00 |

**Table 5.8c: Electricity peak prices pre- and during the CPM in Australia.**

Table 5.4a provides details on the average peak wholesale electricity prices pre- and during the CPM in each NEM state.

| State | Pre-CPM (12 Months) | Post-CPM (12 Months) | Differences ($) | Differences (%) | P-Value | Pre-CPM (24 Months) | Post-CPM (24 Months) | Differences ($) | Differences (%) | P-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| NSW | $31.90 | $57.08 | $25.18 | 78.93% | 0.00 | $37.96 | $55.63 | $17.67 | 46.56% | 0.00 |
| VIC | $32.39 | $74.30 | $41.91 | 129.42% | 0.00 | $34.87 | $68.98 | $34.11 | 97.80% | 0.00 |
| QLD | $34.28 | $76.98 | $42.70 | 124.56% | 0.00 | $37.06 | $72.79 | $35.73 | 96.42% | 0.00 |
| SA | $33.00 | $48.96 | $15.96 | 48.36% | 0.00 | $32.88 | $46.09 | $13.21 | 40.19% | 0.00 |
| TAS | $30.52 | $62.12 | $31.60 | 103.54% | 0.00 | $30.70 | $58.51 | $27.81 | 90.60% | 0.00 |
| NEM | $32.42 | $63.89 | $31.47 | 97.08% | 0.00 | $34.69 | $60.40 | $25.71 | 74.10% | 0.00 |

Table 5.5 provides a multivariate analysis of wholesale electricity prices around the CPM. Results suggest that the carbon pricing scheme had a significant impact on wholesale electricity spot prices across all states within the NEM in Australia. The results are robust after controlling for regional demand, monopolistic qualities, price volatility, generation capacity offered and inter-connected state(s) surplus.

## Table 5.9a: Multivariate analysis of the CPM effect on NSW wholesale electricity spot prices (VWAP)

Table 5.5a provides multivariate analysis of the CPM on NSW wholesale electricity spot prices (VWAP), where *s* represents the regional state in the sample for all tested variables, LogElectricity Prices*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemands*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and Event*sd* is a dummy variable that takes the value of 1 during the two-year CPM regime and 0 otherwise.

| | Pre- and during CPM (12 months) | | Pre- and during CPM (24 months) | | During and post CPM (12 months) | |
|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 4.53125 | 0 | 2.9125 | 0 | 1.76825 | 0 |
| Demand (Daily Average) | 0.77546 | 0 | 0.58721 | 0 | 0.81334 | 0 |
| Herfindahl–Hirschman Index (HHI) | 0.00001 | 0.63 | -0.00001 | 0.29 | -0.00005 | 0 |
| Price Volatility (Stdev) | 0.0106 | 0 | 0.01498 | 0 | 0.01099 | 0 |
| Offered Capacity (Daily Average) | -0.72706 | 0 | -0.45505 | 0 | -0.50436 | 0 |
| VIC Surplus | -0.06201 | 0 | -0.01791 | 0.03 | -0.02493 | 0.05 |
| QLD Surplus | -0.11167 | 0 | -0.06373 | 0 | -0.01089 | 0.52 |
| Carbon Dummy | 0.65337 | 0 | 0.67985 | 0 | -0.43947 | 0 |
| Observations | 731 | | 1461 | | 730 | |
| Adjusted R Square | 0.95 | | 0.94 | | 0.88 | |

## Table 5.10b: Multivariate analysis of the CPM effect on VIC wholesale electricity spot prices (VWAP)

Table 5.5b provides multivariate analysis of the CPM on VIC wholesale electricity spot prices (VWAP), where *s* represents the regional state in the sample for all tested variables, LogElectricity Prices*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemands*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and Event*sd* is a dummy variable that takes the value of 1 during the two-year CPM regime and 0 otherwise.

| | Pre-and-during CPM (12 months) | | Pre-and-during CPM (24 months) | | During-and-post CPM (12 months) | |
|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 1.41251 | 0 | 0.95098 | 0 | 1.5513 | 0 |
| Demand (Daily Average) | 1.4246 | 0 | 1.2568 | 0 | 1.18186 | 0 |
| Herfindahl–Hirschman Index (HHI) | 0.00005 | 0 | 0.00007 | 0 | -0.00001 | 0.67 |
| Price Volatility (Stdev) | 0.00114 | 0 | 0.00132 | 0 | 0.00119 | 0 |
| Offered Capacity (Daily Average) | -1.32123 | 0 | -1.00597 | 0 | -0.89693 | 0 |
| NSW Surplus | -0.07176 | 0 | -0.06615 | 0 | -0.11746 | 0 |
| SA Surplus | -0.01308 | 0 | -0.01388 | 0 | -0.02798 | 0 |
| TAS Surplus | 0.02556 | 0.3 | -0.0585 | 0 | -0.07462 | 0 |
| Carbon Dummy | 0.30733 | 0 | 0.33001 | 0 | -0.20209 | 0 |
| Observations | 731 | | 1461 | | 730 | |
| Adjusted R Square | 0.92 | | 0.89 | | 0.85 | |

## Table 5.11c: Multivariate analysis of the CPM effect on QLD wholesale electricity spot prices (VWAP)

Table 5.5c provides multivariate analysis of the CPM on QLD wholesale electricity spot prices (VWAP), where *s* represents the regional state in the sample for all tested variables, LogElectricity Price*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected State*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and Event*sd* is a dummy variable that takes the value of 1 during the two-year CPM regime and 0 otherwise.

| | Pre-and-during CPM (12 months) | | Pre-and-during CPM (24 months) | | During-and-post CPM (12 months) | |
|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | -0.3518 | 0.62 | -2.23391 | 0 | -4.66663 | 0 |
| Demand (Daily Average) | 1.57939 | 0 | 1.94284 | 0 | 3.01157 | 0 |
| Herfindahl–Hirschman Index (HHI) | -0.00002 | 0.46 | 0.00011 | 0 | 0.00011 | 0 |
| Price Volatility (Stdev) | 0.00111 | 0 | 0.00085 | 0 | 0.00062 | 0 |
| Offered Capacity (Daily Average) | -0.94974 | 0 | -0.91205 | 0 | -1.18578 | 0 |
| NSW Surplus | -0.08702 | 0 | -0.07127 | 0 | -0.1239 | 0 |
| Carbon Dummy | 0.28421 | 0 | 0.2969 | 0 | -0.27892 | 0 |
| Observations | 731 | | 1461 | | 730 | |
| Adjusted R Square | 0.83 | | 0.81 | | 0.81 | |

## Table 5.12d: Multivariate analysis of the CPM effect on SA wholesale electricity spot prices (VWAP)

Table 5.5d provides multivariate analysis of the CPM on SA wholesale electricity spot prices (VWAP), where *s* represents the regional state in the sample for all tested variables, LogElectricity Price*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected State*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and Event*sd* is a dummy variable that takes the value of 1 during the two-year CPM regime and 0 otherwise.

| | Pre-and-during CPM (12 months) | | Pre-and-during CPM (24 months) | | During-and-post CPM (12 months) | |
|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 1.96931 | 0 | 1.23551 | 0 | -0.11947 | 0.71 |
| Demand (Daily Average) | 1.47969 | 0 | 1.66586 | 0 | 1.62725 | 0 |
| Herfindahl–Hirschman Index (HHI) | 0.00003 | 0.06 | 0 | 0.64 | 0.00004 | 0 |
| Price Volatility (Stdev) | 0.00066 | 0 | 0.00046 | 0 | 0.00084 | 0 |
| Offered Capacity (Daily Average) | -1.36881 | 0 | -1.36069 | 0 | -0.94807 | 0 |
| VIC Surplus | -0.17058 | 0 | -0.12877 | 0 | -0.03805 | 0.02 |
| Carbon Dummy | 0.28432 | 0 | 0.32599 | 0 | -0.20129 | 0 |
| Observations | 731 | | 1461 | | 730 | |
| Adjusted R Square | 0.71 | | 0.71 | | 0.81 | |

**Table 5.13e: Multivariate analysis of the CPM effect on TAS wholesale electricity spot prices (VWAP)**

Table 5.5e provides multivariate analysis of the CPM on TAS wholesale electricity spot prices (VWAP), where *s* represents the regional state in the sample for all tested variables, LogElectricity Price*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and Event*sd* is a dummy variable that takes the value of 1 during the two-year CPM regime and 0 otherwise.

| | Pre-and-during CPM (12 months) | | Pre-and-during CPM (24 months) | | During-and-post CPM (12 months) | |
|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 1.44623 | 0.02 | 2.01763 | 0 | 5.75021 | 0 |
| Demand (Daily Average) | 0.47731 | 0 | 0.70508 | 0 | 0.47435 | 0 |
| Herfindahl–Hirschman Index (HHI) | -0.00003 | 0 | -0.00003 | 0 | 0 | 0.61 |
| Price Volatility (Stdev) | 0.00117 | 0 | 0.00119 | 0 | 0.00105 | 0 |
| Offered Capacity (Daily Average) | -0.20905 | 0.17 | -0.70019 | 0 | -1.79027 | 0 |
| VIC Surplus | -0.14775 | 0 | -0.05508 | 0 | 0.12608 | 0 |
| Carbon Dummy | 0.18289 | 0 | 0.22072 | 0 | -0.14801 | 0 |
| Observations | 731 | | 1461 | | 730 | |
| Adjusted R Square | 0.58 | | 0.57 | | 0.43 | |

Based on the coefficients of the carbon dummy variables, wholesale electricity spot prices increased by approximately 68.0% in NSW, 33.0% in VIC, 29.7% in QLD, 32.6% in SA and 22.1% in TAS during the 2-year carbon pricing regime. NSW and TAS appear to have been the most and least affected by the carbon tax, respectively. It is worth highlighting that the majority of the electricity supply in TAS is generated by hydro power stations (refer to Table 5.8 below), which also experienced a substantial increase in net export of electricity to VIC during the carbon tax regime (see Table 5.9). The regression analyses also suggest that regional demand was a major driver of electricity prices, followed by offered capacity (supply) within each state.

### 5.4.3 Withdrawal of coal-fired power stations from the NEM grid

Table 5.6 presents wholesale electricity prices pre- and post closures of coal-fired power stations *ex-post* the CPM.[23] The univariate results suggest that the withdrawal of each coal generator had a

[23] The entire month for each closure is removed, the pre-closure period is the 12 preceding months and the post-closure period is the following 12 months.

significant impact on wholesale electricity spot prices. Although the closure of Hazelwood created the largest decline in offered capacity (see Table 5.7), the complete withdrawal of coal-related power stations in SA appears to have had the most significant impact based on univariate wholesale electricity prices.

**Table 5.14a: Impact of coal-fired power plant withdrawal on average electricity prices**

Table 5.6a provides details on the impact of coal-fired power plant withdrawal on average wholesale electricity prices in Australia.

| State | VIC | SA | | VIC |
|---|---|---|---|---|
| Power Station | Anglesea | Northern | Playford | Hazelwood |
| Date of Closure | Aug-15 | May-16 | | Mar-17 |
| Pre-Closure Price (12 Months) | $30.02 | $53.61 | | $52.63 |
| Post-Closure Price (12 Months) | $49.36 | $109.83 | | $97.92 |
| Differences ($) | $19.34 | $56.22 | | $45.29 |
| Differences (%) | 64.43% | 104.86% | | 86.06% |
| P-Value | 0.00 | 0.00 | | 0.00 |

*The entire month for each closure is removed and the pre-closure is the 12 preceding months and post-closure is the following 12 months.

**Table 5.15b: Impact of coal-fired power plant withdrawal on electricity VWAP**

Table 5.6b provides details on the impact of coal-fired power plant withdrawal on volume weighted average wholesale electricity prices in Australia.

| State | VIC | SA | | VIC |
|---|---|---|---|---|
| Power Station | Anglesea | Northern | Playford | Hazelwood |
| Date of Closure | Aug-15 | May-16 | | Mar-17 |
| Pre-Closure VWAP (12 Months) | $30.85 | $56.44 | | $55.31 |
| Post-Closure VWAP (12 Months) | $52.10 | $117.13 | | $101.37 |
| Differences ($) | $21.25 | $60.68 | | $46.06 |
| Differences (%) | 68.88% | 107.51% | | 83.29% |
| P-Value | 0.00 | 0.00 | | 0.00 |

*The entire month for each closure is removed and the pre-closure is the 12 preceding months and post-closure is the following 12 months.

**Table 5.16c: Impact of coal-fired power plant withdrawal on electricity peak prices**

Table 5.6c provides details on the impact of coal-fired power plant withdrawal on average peak wholesale electricity prices in Australia.

| State | VIC | SA | | VIC |
|---|---|---|---|---|
| Power Station | Anglesea | Northern | Playford | Hazelwood |
| Date of Closure | Aug-15 | May-16 | | Mar-17 |
| Pre-Closure Peak (12 Months) | $33.74 | $63.58 | | $62.89 |
| Post-Closure Peak (12 Months) | $59.10 | $128.41 | | $107.18 |
| Differences ($) | $25.36 | $64.82 | | $44.29 |
| Differences (%) | 75.17% | 101.95% | | 70.42% |
| P-Value | 0.00 | 0.00 | | 0.00 |

*The entire month for each closure is removed and the pre-closure is the 12 preceding months and post-closure is the following 12 months.

**Table 5.17: Withdrawal of coal-fired power plants in the NEM (Australia) *ex-post* the CPM**

Table 5.7 provides details on the withdrawal of coal-fired power plants in NEM (Australia) ex-post CPM.

| State | Power Station | Primary Fuel Type | Year of Commissioning | Date of Closure | Registered Capacity (MW) | Avg Offered Capacity MW (Pre-12m) | Avg Offered Capacity MW (Post-12m) | Change (%) |
|---|---|---|---|---|---|---|---|---|
| VIC | Anglesea | Brown Coal | 1969 | Aug-15 | 160 | 9,709.15 | 9,304.09 | -4.17% |
| SA | Northern | Brown Coal | 1958 | May-16 | 546 | 2,375.03 | 2,228.66 | -6.16% |
| SA | Playford | Brown Coal | 1960 | May-16 | 240 | | | |
| VIC | Hazelwood | Brown Coal | 1964–1971 | Mar-17 | 1,760.00 | 9,359.17 | 8,135.49 | -13.07% |

* CPM (via Clean Energy Act 2011) came into effect on 1 July 2012 and ended on 1 July 2014.

Table 5.8 presents multivariate results on the withdrawals of Angelsea (VIC), Northern and Playford (SA) and Hazelwood (VIC) from the NEM grid in Australia. Results indicate that offered capacity was the largest driver of wholesale electricity spot prices, which suggests constraints regarding supply. This is consistent with the observed drops in offered capacity (supply) shown in Table 5.2. After controlling for regional demand, monopolistic qualities, price volatility, generation capacity offered and inter-connected state(s) surplus, it is observed that the withdrawal of the Hazelwood power station, which created the most significant drop in offered capacity of approximately 13.07%, was also associated with the highest increase of 41.7% in wholesale electricity spot prices. These results suggest differences from the univariate analysis and indicate the importance of controlling for relevant factors in the multivariate analysis. This also provides supporting evidence that the withdrawal of generation capacity without adequate replacement is a key driver of higher electricity prices. The issue of policy certainty to promote investors' confidence is growing more critical with the rapid ageing of the remaining coal-fired power generators.

**Table 5.18: Multivariate analysis of coal-fired power station withdrawal from the NEM *ex-post* CPM on wholesale electricity spot prices (VWAP)**

Table 5.8 provides multivariate analysis of coal-fired power station withdrawal from the NEM *ex-post* the CPM on wholesale electricity spot prices (VWAP), where *s* represents the regional state in the sample for all tested variables, LogElectricity Price*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and Event*sd* is a dummy variable that takes the value of 1 *ex-post* the withdrawal of a coal-fired power plant and 0 otherwise.

| | Pre- and post Anglesea (VIC) withdrawal (12 months) | | Pre- and post Northern and Playford (SA) withdrawals (12 months) | | Pre- and post Hazelwood (VIC) withdrawal (12 months) | |
|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 12.15945 | 0.00 | 1.25627 | 0.08 | 14.34810 | 0.00 |
| Demand (Daily Average) | 1.48295 | 0.00 | 2.14523 | 0.00 | 1.36966 | 0.00 |
| Herfindahl–Hirschman Index (HHI) | 0.00002 | 0.64 | 0.00003 | 0.04 | 0.00012 | 0.01 |
| Price Volatility (Stdev) | 0.01240 | 0.00 | 0.00050 | 0.00 | 0.00488 | 0.00 |
| Offered Capacity (Daily Average) | -2.18639 | 0.00 | -1.42085 | 0.00 | -2.24397 | 0.00 |
| NSW Surplus | -0.11348 | 0.00 | - | - | -0.13094 | 0.00 |
| SA Surplus | -0.03652 | 0.00 | - | - | -0.04004 | 0.00 |
| TAS Surplus | -0.06481 | 0.03 | - | - | -0.11896 | 0.02 |
| VIC Surplus | - | - | -0.46319 | 0.00 | - | - |
| Withdrawal Dummy | 0.13443 | 0.00 | 0.22814 | 0.00 | 0.41709 | 0.00 |
| Observations | 731 | | 731 | | 730 | |
| Adjusted R Square | 0.83 | | 0.63 | | 0.69 | |

### 5.4.4 Shifts in generation behaviour – fuel sources analysis

Table 5.9 presents results for the percentage contribution of all registered fuels sources in each of the five states within the NEM from 1 July 2010 to 30 June 2018. In NSW, black coal's contribution to state electricity generation was relatively consistent at around 88% with slight declines during the CPM period (i.e. 1 July 2012 to 1 July 2014) and a corresponding increase in the use of natural gas and hydro. It is noteworthy that renewable sources such as wind and solar were increasingly contributing to NSW electricity generation after the end of the carbon tax on 1 July 2014. However, the rate of increase appears to be marginal and this is of concern given Australia's commitment to the Paris climate agreement.

**Table 5.19a: Fuel source contributions to electricity generation in NSW**

Table 5.9a provides details on fuel source contributions to electricity generation in NSW.

| | Black Coal % | Hydro % | Kerosene Non-Aviation % | Natural Gas (Pipeline) % | Other Solid Fossil Fuels % | Wind % | Solar % |
|---|---|---|---|---|---|---|---|
| 2010 | 88.67 | 3.48 | 0.00 | 6.12 | 1.68 | 0.05 | 0.00 |
| 2011 | 89.43 | 3.20 | 0.00 | 5.37 | 1.57 | 0.43 | 0.00 |
| 2012 | 86.59 | 4.67 | 0.00 | 6.61 | 1.66 | 0.48 | 0.00 |
| 2013 | 86.34 | 4.07 | 0.00 | 7.16 | 1.84 | 0.59 | 0.00 |
| 2014 | 89.67 | 2.54 | 0.00 | 5.98 | 0.16 | 1.60 | 0.05 |
| 2015 | 87.14 | 4.45 | 0.00 | 5.65 | 0.00 | 2.19 | 0.57 |
| 2016 | 88.34 | 4.80 | 0.00 | 3.78 | 0.00 | 2.26 | 0.81 |
| 2017 | 88.69 | 3.99 | 0.00 | 3.37 | 0.00 | 3.04 | 0.91 |

In VIC, there were noticeable decreases in brown coal's contribution to state generation during the CPM period and from 1 July 2015 onwards. Upon the closure of Hazelwood in March 2017, there were observations of increased utilisation of natural gas and wind. Similarly, in QLD there were observations of natural gas replacing black coal during the carbon tax period and a reversal upon abolition of the carbon legislation.

**Table 5.20b: Fuel source contributions to electricity generation in VIC**

Table 5.9b provides details on fuel source contributions to electricity generation in VIC.

| | Brown Coal % | Hydro % | Natural Gas % | Wind % | Solar % |
|---|---|---|---|---|---|
| 2010 | 92.77 | 5.98 | 1.25 | 0.00 | 0.00 |
| 2011 | 94.91 | 3.46 | 1.39 | 0.24 | 0.00 |
| 2012 | 88.94 | 5.71 | 3.92 | 1.43 | 0.00 |
| 2013 | 88.67 | 4.54 | 4.11 | 2.68 | 0.00 |
| 2014 | 90.22 | 4.17 | 2.66 | 2.95 | 0.00 |
| 2015 | 88.74 | 5.58 | 2.09 | 3.59 | 0.00 |
| 2016 | 85.66 | 6.63 | 3.65 | 4.06 | 0.00 |
| 2017 | 81.85 | 5.62 | 6.59 | 5.92 | 0.07 |

**Table 5.21c: Fuel source contributions to electricity generation in QLD**

Table 5.9c provides details on fuel source contributions to electricity generation in QLD.

| | Black Coal % | Coal Seam Methane % | Diesel Oil % | Hydro % | Kerosene Non-Aviation % | Natural Gas % | Solar % |
|---|---|---|---|---|---|---|---|
| 2010 | 79.15 | 5.21 | 0.00 | 1.67 | 0.06 | 13.92 | 0.00 |
| 2011 | 80.45 | 3.52 | 0.00 | 1.32 | 0.01 | 14.70 | 0.00 |
| 2012 | 81.93 | 3.98 | 0.00 | 1.03 | 0.10 | 12.96 | 0.00 |
| 2013 | 78.89 | 4.21 | 0.00 | 1.15 | 0.02 | 15.72 | 0.00 |
| 2014 | 76.53 | 8.31 | 0.00 | 1.12 | 0.05 | 14.00 | 0.00 |
| 2015 | 83.79 | 4.21 | 0.00 | 0.85 | 0.09 | 11.05 | 0.00 |
| 2016 | 86.63 | 1.83 | 0.00 | 1.11 | 0.11 | 10.31 | 0.00 |
| 2017 | 88.89 | 1.13 | 0.00 | 1.03 | 0.02 | 8.82 | 0.18 |

In SA, there were parallel observations of decreases in the use of brown coal during the CPM which was substituted for by natural gas and wind. It is noteworthy that unlike NSW, VIC and QLD, the overall contribution of coal-fired power plants in SA was traditionally low and natural gas was the predominant supplier. Renewable energy like wind has overtaken brown coal since the implementation of carbon tax and is persistently higher. Since the closure of the Northern and Playford coal-fired stations, SA is heavily dependent on natural gas generators and wind for electricity. In TAS, hydro power is the principal supplier of electricity and is observed to have experienced a substantial increase in contribution during the carbon tax period. However, since the abolition of the carbon tax, there has been a reversion to the use of natural gas combined with the relatively stable contribution of wind.

**Table 5.22d: Fuel source contributions to electricity generation in SA**

Table 5.9d provides details on fuel source contributions to electricity generation in SA.

| | Brown Coal % | Diesel Oil % | Natural Gas % | Wind % | Solar % | Battery Storage % |
|---|---|---|---|---|---|---|
| 2010 | 33.07 | 0.02 | 51.02 | 15.88 | 0.00 | 0.00 |
| 2011 | 25.17 | 0.01 | 53.72 | 21.09 | 0.00 | 0.00 |
| 2012 | 18.71 | 0.01 | 59.41 | 21.87 | 0.00 | 0.00 |
| 2013 | 19.61 | 0.01 | 52.64 | 27.73 | 0.00 | 0.00 |
| 2014 | 26.12 | 0.01 | 43.71 | 30.16 | 0.00 | 0.00 |
| 2015 | 24.97 | 0.03 | 43.72 | 31.28 | 0.00 | 0.00 |
| 2016 | 0.00 | 0.25 | 61.33 | 38.42 | 0.00 | 0.00 |
| 2017 | 0.00 | 0.10 | 62.36 | 37.40 | 0.22 | 0.15 |

**Table 5.23e: Fuel source contributions to electricity generation in TAS**

Table 5.9e provides details on fuel source contributions to electricity generation in NSW.

| | Hydro % | Natural Gas % | Wind % |
|---|---|---|---|
| 2010 | 84.80 | 15.20 | 0.00 |
| 2011 | 85.26 | 14.74 | 0.00 |
| 2012 | 99.53 | 0.38 | 0.09 |
| 2013 | 94.75 | 1.14 | 4.11 |
| 2014 | 92.60 | 0.18 | 7.21 |
| 2015 | 84.27 | 9.18 | 6.55 |
| 2016 | 82.54 | 10.77 | 6.69 |
| 2017 | 84.01 | 9.93 | 6.06 |

### 5.4.5 Interregional electricity flows

Table 5.10a reports the interregional flows of electricity between connected states in the NEM. Results suggest that during the CPM period, there was a significant increase in the supply of hydroelectricity by TAS (to VIC). NSW also imported less electricity from the coal-dominant state of QLD.

**Table 5.24a: Interregional flows by connectors (MwH)**

Table 5.10a provides details on interregional flows by connectors (MwH).

| | QLD to NSW | VIC to TAS | VIC To NSW | VIC To SA |
|---|---|---|---|---|
| 2010 | 17,657.74 | -580.09 | 10,301.52 | 1,550.92 |
| 2011 | 14,577.84 | 796.51 | 8,531.01 | 3,104.80 |
| 2012 | 8,906.57 | -5,592.61 | 8,224.31 | 3,849.58 |
| 2013 | 5,263.23 | -8,521.78 | 10,739.02 | 4,582.86 |
| 2014 | 15,816.58 | 4,034.63 | 14,287.20 | 4,354.11 |
| 2015 | 7,381.65 | 1,701.46 | 11,118.18 | 5,360.08 |
| 2016 | 9,753.65 | 1,077.08 | 10,833.92 | 7,484.25 |
| 2017 | 15,078.19 | -536.61 | 1,790.31 | -825.71 |

The closure of coal-fired power stations *ex-post* the carbon tax regime appears to have had a significant impact on the interregional flow behaviour among the connected states. The complete withdrawal of coal-fired power plants in SA (i.e. Northern and Playford) was accompanied by a spike in interregional flow in 2016, which suggests increased dependence on VIC (a coal-dominant state). With the withdrawal of the Hazelwood power station in 2017, there was a significant shift in interregional flow patterns for VIC (the most interconnected state), which saw net reversals (i.e. from exports to imports) in SA and TAS. The exports from VIC to NSW also declined substantially, which increased NSW's dependence on QLD for electricity requirements.

**Table 5.25b: Interregional flows by state (%)**

Table 5.10a provides details on interregional flows by state (%).

| | NSW Net Change (%) | QLD Net Change (%) | SA Net Change (%) | TAS Net Change (%) | VIC Net Change (%) |
|---|---|---|---|---|---|
| 2010 | -13.07 | 12.80 | -3.64 | 2.11 | 9.03 |
| 2011 | -11.23 | 10.64 | -8.46 | -3.44 | 9.90 |
| 2012 | -8.87 | 6.52 | -10.39 | 21.08 | 5.64 |
| 2013 | -8.51 | 3.94 | -12.91 | 32.44 | 6.21 |
| 2014 | -15.56 | 11.60 | -12.37 | -16.61 | 19.62 |
| 2015 | -9.43 | 5.15 | -15.00 | -6.65 | 15.72 |
| 2016 | -10.42 | 6.70 | -22.24 | -4.68 | 17.79 |
| 2017 | -8.34 | 10.47 | 4.67 | 1.60 | 1.02 |

The impact of coal-fired power plants in the NEM within Australia is supported by the net interregional flow per state shown in Table 10b. Results suggest that SA was increasingly reliant on imports after the complete withdrawal of coal-fired generators (i.e. Northern and Playford). Similarly, VIC moved from being the major exporter of electricity within the NEM to being marginally self-sufficient *ex-post* closure of the Hazelwood power station.

### 5.4.6 Time-series analysis of wholesale electricity prices across NEM[24]

Table 5.11 provides regression analysis for the NEM states on a yearly basis from 1 July 2009 to 30 June 2018. The multivariate analysis of NSW in Table 5.11a supports the univariate results that for NSW, after the closure of the Hazelwood power station, there was a significant shift in reliance from VIC to QLD for electricity requirements. Generally, in NSW there was a negative and significant correlation between dispatched wind generation and wholesale electricity spot prices from 1 July 2012 onwards. This suggests that as the contribution of wind energy increased, wholesale electricity spot prices were likely to fall. Further, in 2016 and 2017 the coefficients were higher, which may indicate greater cost efficiency and suggests that the increased use of wind as an energy source can be beneficial for affordability.

Table 5.11b presents regression analysis for VIC and should be interpreted in conjunction with Table 5.10a, which illustrates the net interregional flows. Results indicate that for periods where TAS was supplying electricity to VIC (i.e. 2010, 2012, 2013 and 2017), there were negative and significant relationships between TAS's surplus and VIC's electricity prices. Generally, negative and significant relationships were observed between VIC's electricity prices and surplus capacity in NSW and SA. This suggests that where there were instances of surplus capacity in NSW and SA, electricity prices were likely to be lower in VIC as exports were not required. Similar to NSW, there was a negative and significant correlation between dispatched wind generation and electricity

[24] Some generators have long-term contracts for fuel sources with mining companies.

prices in VIC since inception. Further, the coefficient of wind as an energy source was gradually higher over time, suggesting that wind may be increasingly cost efficient for electricity prices.

Table 5.11c reports multivariate analysis for QLD, which appears to have been a net exporter of electricity (to NSW). Similar to VIC, when there was surplus capacity in NSW, electricity prices were likely to be lower in QLD as exports were not required.

Table 5.11d presents regression analysis for SA. Results suggest that after the removal of coal-fired power stations, electricity generation measured by offered capacity had a significant influence on electricity prices, suggesting that local supply may be constrained. This is supported by Table 5.10a, which shows a significant increase in exports from VIC. Wind generation was also observed to have had a significant and negative impact on electricity prices in 2017.

Table 5.11e presents multivariate results for TAS. The state was dominated by hydro energy (Table 5.9e), which had a negative and significant impact on wholesale electricity spot prices. This suggests that as the contribution of hydro generation increased, electricity prices were likely to fall. It is noteworthy that as net exports from TAS to VIC increased (i.e. 2010, 2013, 2013 and 2017), the coefficient for hydro energy was lower compared to other non-export years.

## Table 5.26a: Correlation between fuel sources and wholesale electricity spot prices (VWAP) in NSW

Table 5.11a provides multivariate analysis of correlations between fuel sources and wholesale electricity spot prices (VWAP) in NSW, where *s* represents the regional state in the sample for all tested variables, LogElectricity Price*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and LogFuels*sd* is the natural logs of each fuel sources in megawatts that contribute to electricity generation on each calendar day *d* in each regional state *s*.

| | NSW 2010 | | NSW 2011 | | NSW 2012 | | NSW 2013 | | NSW 2014 | | NSW 2015 | | NSW 2016 | | NSW 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | -3.94 | 0.00 | 2.83 | 0.00 | 0.97 | 0.00 | 1.00 | 0.00 | 2.57 | 0.00 | 6.08 | 0.00 | 4.57 | 0.00 | 1.03 | 0.01 |
| Demand | 2.20 | 0.00 | 1.29 | 0.00 | 0.11 | 0.16 | 0.00 | 0.98 | 0.67 | 0.00 | 1.92 | 0.00 | -0.51 | 0.16 | 1.74 | 0.00 |
| HHI | 0.00 | 0.92 | 0.00 | 0.81 | 0.00 | 0.62 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 |
| Price Volatility | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.008 | 0.00 |
| Offered Capacity | -1.37 | 0.00 | -1.33 | 0.00 | -0.40 | 0.00 | -0.22 | 0.00 | -1.40 | 0.00 | -2.77 | 0.00 | -1.51 | 0.00 | -0.52 | 0.00 |
| VIC Surplus Capacity | 0.17 | 0.00 | -0.16 | 0.00 | 0.02 | 0.00 | -0.02 | 0.00 | -0.11 | 0.00 | -0.20 | 0.00 | 0.05 | 0.25 | -0.02 | 0.00 |
| QLD Surplus Capacity | -0.08 | 0.20 | -0.14 | 0.00 | 0.03 | 0.01 | 0.00 | 0.96 | -0.05 | 0.06 | -0.13 | 0.04 | 0.10 | 0.11 | -0.13 | 0.00 |
| Black Coal | 0.34 | 0.09 | -0.01 | 0.94 | 0.33 | 0.00 | 0.33 | 0.00 | 0.47 | 0.00 | 0.13 | 0.62 | 0.94 | 0.00 | -0.54 | 0.00 |
| Hydro | -0.05 | 0.01 | 0.01 | 0.45 | 0.02 | 0.00 | 0.01 | 0.00 | 0.04 | 0.00 | 0.00 | 0.93 | -0.06 | 0.01 | -0.03 | 0.01 |
| Natural Gas (Pipeline) | - | - | 0.02 | 0.04 | 0.01 | 0.07 | -0.01 | 0.02 | 0.00 | 0.98 | 0.00 | 0.90 | -0.02 | 0.21 | -0.01 | 0.26 |
| Other Solid Fossil Fuels | 0.10 | 0.00 | 0.03 | 0.03 | 0.02 | 0.01 | -0.01 | 0.58 | 0.04 | 0.00 | 0.02 | 0.55 | 0.29 | 0.00 | 0.00 | 0.08 |
| Kerosene (Non-Aviation) | -0.01 | 0.30 | 0.00 | 0.10 | 0.00 | 0.06 | 0.00 | 0.42 | 0.02 | 0.00 | - | - | - | - | - | - |
| Wind | 0.01 | 0.25 | 0.00 | 0.68 | -0.01 | 0.02 | -0.01 | 0.04 | -0.02 | 0.01 | 0.00 | 0.83 | -0.08 | 0.00 | -0.07 | 0.00 |
| Solar | - | - | - | - | - | - | - | - | 0.00 | 1.00 | -0.03 | 0.27 | 0.08 | 0.04 | -0.05 | 0.02 |
| Observations | 365 | | 366 | | 365 | | 365 | | 365 | | 366 | | 365 | | 365 | |
| Adjusted R Square | 0.86 | | 0.81 | | 0.90 | | 0.87 | | 0.80 | | 0.73 | | 0.76 | | 0.75 | |

## Table 5.27b: Correlation between fuel sources and wholesale electricity spot prices (VWAP) in VIC

Table 5.11b provides multivariate analysis of correlations between fuel sources and wholesale electricity spot prices (VWAP) in VIC, where *s* represents the regional state in the sample for all tested variables, LogElectricity Prices*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and LogFuels*sd* is the natural logs of each fuel sources in megawatts that contribute to electricity generation on each calendar day *d* in each regional state *s*.

| | VIC 2010 | | VIC 2011 | | VIC 2012 | | VIC 2013 | | VIC 2014 | | VIC 2015 | | VIC 2016 | | VIC 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 4.20 | 0.00 | 3.13 | 0.00 | 1.60 | 0.00 | 1.07 | 0.00 | 3.60 | 0.00 | 6.03 | 0.00 | 2.21 | 0.03 | -0.10 | 0.86 |
| Demand | 1.96 | 0.00 | 1.76 | 0.00 | 1.66 | 0.00 | 1.18 | 0.00 | 1.58 | 0.00 | 1.20 | 0.00 | 1.73 | 0.00 | 1.59 | 0.00 |
| HHI | 0.00 | 0.58 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.19 | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 | 0.02 | 0.00 | 0.80 |
| Price Volatility | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Offered Capacity | -1.16 | 0.01 | -0.60 | 0.00 | 0.24 | 0.07 | 0.05 | 0.56 | -0.90 | 0.00 | -0.86 | 0.02 | -2.69 | 0.00 | -0.05 | 0.82 |
| NSW Surplus Capacity | -0.05 | 0.00 | -0.05 | 0.00 | -0.03 | 0.08 | 0.01 | 0.41 | -0.17 | 0.00 | -0.07 | 0.00 | 0.04 | 0.02 | -0.03 | 0.00 |
| SA Surplus Capacity | 0.01 | 0.65 | -0.02 | 0.01 | -0.02 | 0.00 | -0.02 | 0.00 | -0.02 | 0.08 | -0.02 | 0.28 | 0.00 | 0.83 | -0.02 | 0.02 |
| TAS Surplus Capacity | -0.25 | 0.00 | 0.06 | 0.07 | -0.09 | 0.04 | -0.06 | 0.00 | -0.02 | 0.47 | 0.02 | 0.76 | 0.11 | 0.13 | -0.04 | 0.02 |
| Brown coal | -0.87 | 0.04 | -1.20 | 0.00 | -1.28 | 0.00 | -0.71 | 0.00 | -0.77 | 0.00 | -1.23 | 0.00 | 0.63 | 0.01 | -0.59 | 0.00 |
| Hydro | -0.10 | 0.00 | 0.03 | 0.00 | -0.03 | 0.02 | 0.00 | 0.76 | 0.01 | 0.41 | 0.10 | 0.00 | -0.15 | 0.00 | -0.04 | 0.00 |
| Natural Gas (Pipeline) | 0.03 | 0.00 | 0.01 | 0.01 | -0.01 | 0.45 | -0.02 | 0.00 | 0.03 | 0.00 | 0.13 | 0.00 | 0.18 | 0.00 | 0.01 | 0.00 |
| Wind | - | - | -0.01 | 0.01 | -0.02 | 0.00 | -0.03 | 0.00 | -0.04 | 0.00 | -0.03 | 0.15 | -0.03 | 0.09 | -0.09 | 0.00 |
| Solar | - | - | - | - | - | - | - | - | - | - | - | - | - | - | -0.02 | 0.00 |
| Observations | 365 | | 366 | | 365 | | 365 | | 365 | | 366 | | 365 | | 365 | |
| Adjusted R Square | 0.70 | | 0.79 | | 0.87 | | 0.91 | | 0.81 | | 0.70 | | 0.82 | | 0.83 | |

## Table 5.28c: Correlation between fuel sources and wholesale electricity spot prices (VWAP) in QLD

Table 5.11c provides multivariate analysis of correlations between fuel sources and wholesale electricity spot prices (VWAP) in QLD, where *s* represents the regional state in the sample for all tested variables, LogElectricity Prices*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and LogFuels*sd* is the natural logs of each fuel sources in megawatts that contribute to electricity generation on each calendar day *d* in each regional state *s*.

| | QLD 2010 | | QLD 2011 | | QLD 2012 | | QLD 2013 | | QLD 2014 | | QLD 2015 | | QLD 2016 | | QLD 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | -2.08 | 0.22 | 2.25 | 0.00 | -1.33 | 0.45 | 2.15 | 0.00 | 3.73 | 0.05 | -8.24 | 0.00 | -2.58 | 0.11 | -2.86 | 0.00 |
| Demand | 2.81 | 0.00 | 1.57 | 0.00 | 3.43 | 0.00 | 1.47 | 0.00 | 4.67 | 0.00 | 1.38 | 0.00 | -0.42 | 0.14 | 1.11 | 0.00 |
| HHI | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 | 0.76 | 0.00 | 0.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Price Volatility | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Offered Capacity | -0.75 | 0.15 | -1.32 | 0.00 | 0.30 | 0.41 | -0.12 | 0.25 | -3.35 | 0.00 | -1.52 | 0.00 | 0.97 | 0.00 | -1.78 | 0.00 |
| NSW Surplus Capacity | -0.11 | 0.00 | -0.07 | 0.00 | -0.19 | 0.00 | -0.09 | 0.00 | -0.24 | 0.00 | -0.05 | 0.00 | -0.02 | 0.13 | -0.02 | 0.01 |
| Black coal | -0.44 | 0.41 | 0.06 | 0.65 | -1.94 | 0.00 | -0.78 | 0.00 | -0.73 | 0.06 | 1.54 | 0.00 | -0.15 | 0.69 | 1.40 | 0.00 |
| Coal seam methane | -0.24 | 0.00 | -0.01 | 0.02 | 0.00 | 0.93 | -0.01 | 0.34 | -0.36 | 0.00 | 0.01 | 0.35 | 0.05 | 0.00 | 0.01 | 0.00 |
| Diesel oil | 0.04 | 0.28 | -0.03 | 0.11 | -0.01 | 0.76 | 0.01 | 0.58 | 0.10 | 0.00 | 0.00 | 0.94 | -0.02 | 0.31 | 0.04 | 0.02 |
| Hydro | 0.08 | 0.15 | -0.02 | 0.21 | -0.01 | 0.76 | -0.04 | 0.00 | -0.02 | 0.37 | 0.08 | 0.00 | 0.07 | 0.00 | 0.01 | 0.19 |
| Kerosene (Non-aviation) | 0.04 | 0.00 | 0.02 | 0.00 | 0.00 | 0.73 | 0.00 | 0.26 | 0.03 | 0.00 | 0.04 | 0.00 | 0.04 | 0.00 | 0.00 | 0.40 |
| Natural Gas (Pipeline) | -0.28 | 0.02 | -0.28 | 0.00 | -0.15 | 0.05 | -0.25 | 0.00 | -0.07 | 0.46 | 0.48 | 0.00 | 0.53 | 0.00 | 0.05 | 0.07 |
| Solar | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | 0.46 |
| Observations | 365 | | 366 | | 365 | | 365 | | 365 | | 366 | | 365 | | 365 | |
| Adjusted R Square | 0.65 | | 0.74 | | 0.65 | | 0.94 | | 0.82 | | 0.87 | | 0.84 | | 0.74 | |

## Table 5.29d: Correlation between fuel sources and wholesale electricity spot prices (VWAP) in SA

Table 5.11d provides multivariate analysis of correlations between fuel sources and wholesale electricity spot prices (VWAP) in SA, where *s* represents the regional state in the sample for all tested variables, LogElectricity Price*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemand*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and LogFuels*sd* is the natural logs of each fuel sources in megawatts that contribute to electricity generation on each calendar day *d* in each regional state *s*.

| | SA 2010 | | SA 2011 | | SA 2012 | | SA 2013 | | SA 2014 | | SA 2015 | | SA 2016 | | SA 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | -1.28 | 0.22 | 3.83 | 0.00 | 1.85 | 0.00 | 0.06 | 0.81 | 2.08 | 0.00 | -0.04 | 0.95 | 4.32 | 0.00 | -0.08 | 0.80 |
| Demand | 2.22 | 0.00 | 1.16 | 0.00 | 0.83 | 0.00 | 0.79 | 0.00 | 1.28 | 0.00 | 1.25 | 0.00 | 0.35 | 0.20 | 1.15 | 0.00 |
| HHI | 0.00 | 0.18 | 0.00 | 0.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Price Volatility | 0.00 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Offered Capacity | -0.03 | 0.94 | -1.57 | 0.00 | -0.85 | 0.00 | -0.55 | 0.00 | -1.45 | 0.00 | -1.37 | 0.00 | -2.15 | 0.00 | -0.76 | 0.00 |
| VIC Surplus Capacity | -0.23 | 0.00 | -0.36 | 0.00 | -0.06 | 0.00 | -0.07 | 0.00 | -0.36 | 0.00 | -0.09 | 0.16 | -0.18 | 0.02 | -0.01 | 0.44 |
| Brown coal | -0.43 | 0.00 | 0.00 | 0.90 | -0.01 | 0.00 | -0.01 | 0.08 | 0.04 | 0.04 | -0.03 | 0.00 | - | - | - | - |
| Diesel oil | 0.04 | 0.02 | 0.08 | 0.00 | 0.00 | 0.97 | 0.01 | 0.06 | 0.00 | 0.82 | 0.04 | 0.01 | 0.02 | 0.07 | 0.01 | 0.16 |
| Natural Gas (Pipeline) | -0.40 | 0.03 | 0.20 | 0.24 | 0.25 | 0.00 | 0.22 | 0.00 | 0.28 | 0.00 | 0.54 | 0.00 | 1.08 | 0.00 | 0.33 | 0.00 |
| Wind | -0.07 | 0.20 | -0.07 | 0.43 | -0.13 | 0.00 | 0.07 | 0.03 | 0.06 | 0.24 | 0.14 | 0.01 | 0.01 | 0.93 | -0.08 | 0.01 |
| Solar | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.01 | 0.28 |
| Battery Storage | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.00 | 0.75 |
| Observations | 365 | | 366 | | 365 | | 365 | | 365 | | 366 | | 365 | | 365 | |
| Adjusted R Square | 0.48 | | 0.29 | | 0.92 | | 0.90 | | 0.79 | | 0.79 | | 0.69 | | 0.85 | |

## Table 5.30e: Correlation between fuel sources and wholesale electricity spot prices (VWAP) in TAS

Table 5.11e provides multivariate analysis of correlations between fuel sources and wholesale electricity spot prices (VWAP) in TAS, where *s* represents the regional state in the sample for all tested variables, LogElectricity Prices*sd* is the natural log of the volume-weighted average price on calendar day *d*, LogDemands*sd* is the natural log of the average demand for electricity in megawatt hours over 48 half-hourly trading intervals on each calendar day *d* in each regional state *s*, HHI*sd* is the Herfindahl–Hirschman Index that measures market concentration on each calendar day *d* in each regional state *s*, LogOffered Capacitysd is the natural log of the average electricity generation available for dispatch in megawatt hours over 48 half-hourly trading intervals on each calendar day d in each regional state *s*, Price Volatility*sd* is measured using the standard deviation of intra-day prices on each calendar day d in each regional state *s*, LogInterconnected States*sd* is the natural log of the surplus generation capacity over the maximum demand in megawatt hours on each calendar day *d* in each other regional state that is interconnected with regional state s and LogFuels*sd* is the natural logs of each fuel sources in megawatts that contribute to electricity generation on each calendar day *d* in each regional state *s*.

| | TAS 2010 | | TAS 2011 | | TAS 2012 | | TAS 2013 | | TAS 2014 | | TAS 2015 | | TAS 2016 | | TAS 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* | *Coefficients* | *P-value* |
| Intercept | 2.08 | 0.05 | 1.09 | 0.48 | -0.87 | 0.11 | 2.81 | 0.03 | 2.50 | 0.01 | 4.49 | 0.05 | 6.18 | 0.00 | 2.18 | 0.00 |
| Demand | 1.58 | 0.00 | 1.20 | 0.00 | 1.53 | 0.00 | 0.88 | 0.01 | 1.75 | 0.00 | 0.35 | 0.47 | 1.93 | 0.00 | 1.22 | 0.00 |
| HHI | 0.00 | 0.12 | 0.00 | 0.49 | 0.00 | 0.84 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 | 0.21 | 0.00 | 0.00 |
| Price Volatility | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Offered Capacity | -0.60 | 0.05 | 0.30 | 0.39 | 0.05 | 0.75 | -0.72 | 0.05 | -1.00 | 0.00 | 0.21 | 0.75 | -1.61 | 0.00 | -0.79 | 0.00 |
| VIC Surplus Capacity | -0.41 | 0.00 | -0.48 | 0.00 | -0.07 | 0.00 | 0.13 | 0.00 | -0.20 | 0.01 | 0.02 | 0.84 | -0.56 | 0.00 | -0.03 | 0.01 |
| Hydro | -0.37 | 0.02 | -0.58 | 0.00 | -0.47 | 0.00 | -0.47 | 0.02 | -0.60 | 0.00 | -0.95 | 0.00 | -0.75 | 0.00 | -0.36 | 0.00 |
| Natural Gas (Pipeline) | -0.06 | 0.10 | -0.02 | 0.00 | 0.01 | 0.00 | 0.01 | 0.14 | 0.03 | 0.00 | 0.08 | 0.00 | 0.08 | 0.00 | 0.03 | 0.00 |
| Wind | - | - | - | - | -0.02 | 0.00 | -0.01 | 0.57 | 0.01 | 0.54 | -0.11 | 0.00 | -0.04 | 0.13 | 0.01 | 0.32 |
| Observations | 365 | | 366 | | 365 | | 365 | | 365 | | 366 | | 365 | | 365 | |
| Adjusted R Square | 0.53 | | 0.18 | | 0.69 | | 0.26 | | 0.41 | | 0.57 | | 0.65 | | 0.43 | |

## 5.5 Conclusion and policy implications

The impact of carbon emission policies studies on market behavioural is of significant interest since the objective of these schemes are to encourage energy producers to reallocate away from fossil fuels into renewable sources. Extant literature on this issue has primarily focused on the European Union Emissions Trading Scheme (e.g. Sijm et al., 2006; Bonacina and Gulli, 2007; Hirschhausen and Zachmann, 2008; Bunn and Fezzi, 2009; Daskalakis and Markellos, 2009; Fell, 2010; Blyth and Bunn, 2011; Chevallier, 2011; Gronwald et al., 2011; Sijm et al., 2012; Benth et al., 2013; Jouvet and Solier, 2013; Nazifi, 2013; Huisman and Kilic, 2015; Kanamura, 2016). However, due to potential market microstructure and policies differences, prior research highlights the importance of understanding the impact of carbon prices on electricity markets in Australia (Nelson et al., 2012; O'Gorman and Jotzo, 2014; Apergis and Lau, 2015; Maryniak et al, 2018).

Empirical results from this chapter provide several new insights. First, there was a significant market behavioural shift from coal utilisation to other fuel sources during the carbon pricing regime and a reversal after the abolition of the carbon pricing mechanism. Consequently, the carbon pricing mechanism increased the cost of wholesale electricity spot prices by 22% to 68% across the NEM states in Australia during the effective period, after controlling for factors such as demand, monopolistic characteristics, price volatility, generation capacity and surplus from connected states. NSW appears to have been affected the most and TAS the least by carbon pricing mechanism . This is unsurprising as NSW is heavily reliant on coal, whereas TAS depends more on hydro energy. Moreover, TAS experienced a significant increase in net exports of electricity to VIC (a heavily coal-reliant state) during the carbon pricing regime, which may have mitigated the effect on VIC.

This study also provides evidence that the closures of Angelsea (VIC), Northern, Playford (SA) and Hazelwood (VIC) created a significant reduction in generation capacity and initiated higher wholesale electricity spot prices. The lack of replacement capacity which contributed to the generation capacity decline provides some support for the findings in the CCA/AEMC (2017) report that energy policy uncertainty *ex-post* carbon pricing mechanism may have impeded investment. Further, there were observations of change in interregional flows and reliance after these coal-fired power plant closures, indicating a wide-reaching impact. On a positive note, there were indications that wind appeared to be increasingly cost effective in NSW, VIC and SA between 1 July 2017 and 30 June 2018. Despite this, growth in renewables' contributions (as a proportion of total electricity needs) was relatively modest. It is possible that this may be related to risk aversion by investors due to policy uncertainty, which provides fertile grounds for future research.

Overall, the empirical evidence provided in this study indicates that policy has significant impacts on generation behaviour and wholesale electricity prices, which supports the need for a decisive energy strategy in Australia.

# Chapter 6: Conclusion

This thesis contributes to the understanding of participants' behaviour in three markets by analysing their reactions to: (i) CRR in US stock markets; (ii) international energy futures price movements in Chinese industries; and (iii) energy policy in wholesale electricity markets in Australia. The research reveals that firm, industry and policy characteristics play important roles in explaining different market reactions by participants.

Chapter 3 contributes to the CSR and CFP literature by examining how investors (an essential stakeholder class) react to increases in CRR in US listed companies from adverse media coverage on ESG issues. Using a large US sample consisting of 331,517 observations from January 2007 to September 2019, this study documents evidence that reputation risks have a significant impact on the stock performance of affected firms. The study contributes further to the market behaviour and reputation risk literature by providing evidence that firm size, trading activities, S&P500 constituency, reputation status and industry classification play important roles in the market behaviour of investors.

Generally, it is observed that investors do not react significantly to negative media coverage of ESG-related issues for S&P500 constituents, larger companies and firms that are frequently traded. Due to their high visibility, it is likely that these firms have less information asymmetry and these ESG media reports do not provide new information and are already factored in. On the contrary, firms that experienced the most significant price reaction from investors belong to the smallest size and liquidity deciles. These firms are likely to be less visible and media coverage of negative ESG issues may provide new information to participants in these companies. It is further observed that companies with good reputations status (i.e. low to moderate ESG risk exposure) are also more likely to be impacted by heightened CRR, which may reveal information shocks. These findings provide support for the information asymmetry theory to explain investors' reaction to reputational risks from adverse media coverage of ESG matters.

In addition, this research provides empirical evidence to indicate that the stock performance of firms in the alcohol, tobacco and gaming industries (i.e. the 'sin' triumvirate) are not significantly affected by additional negative ESG media reporting. Given the incessant scrutiny of these industries and the nature of their underlying business, it is likely that investors are accustomed to an adverse ESG media spotlight for these firms. Interestingly, it is companies associated with (i) candy and soda, (ii) steel works, (iii) banking and (iv) insurance that were observed to be more susceptible to negative investors' reactions from unfavourable ESG media coverage. This may suggest an adjustment by investors to a new stakeholders' perception which changes their valuation of the affected corporations. The particularly significant negative price shock of −1.9% from CRR in the candy and soda industry may indicate the rise of sugar as a new vice and the necessity for investors to reappraisal their valuation. Overall, Chapter 3 provides empirical evidence that CRR from adverse media coverage on ESG issues impact investors' behaviour and their reactions are dependent on firm and industry characteristics.

Chapter 4 contributes to the energy and industry nexus by using one of the most comprehensive datasets to analyse the impact of four major international energy prices on industries in China, one of the largest global importers and consumers of energy commodities. Using firm-level data of 3750 stock listings across both the Shanghai and Shenzhen stock exchanges, segregated into 138 sub-industries under the Global Industry Classification Standard, this study provides a comprehensive analysis of aggregated industry behaviour in relation to price movements of Brent and WTI crude oil futures, Henry Hub natural gas and Newcastle thermal coal. The study applied a three-factor Fama and French model over the period from 1 March 2006 to 31 December 2018 and provided evidence that crude oil futures (i.e. Brent and WTI futures) had the most influence on Chinese industries compared to thermal coal (Newcastle) and natural gas (Henry Hub).

Further, this research extends the analysis by segregating the sample period into pre- and post- the Chinese oil pricing reform of 27 March 2013, which is regarded as a major step in market-oriented pricing for refined oil, since this new automatic pricing mechanism shortened the current price adjustment cycle from 22 working days to 10 working days and removed the 4% threshold in world oil price fluctuation. One key observation is that prior to this event, Chinese companies seem to have been relatively insulated from international oil futures volatility (i.e. Brent and WTI) but were more exposed after the key oil pricing reform. As an example, in the pre-event sample, only 3 GICS sub-industries (2 positives and 1 negative) were affected by both Brent and WTI futures price volatility. In the post-event sample, Brent oil futures impacted on 44 GICS sub-industries (0 positive, 44 negatives) and WTI's futures volatility affected 11 GICS sub-industries (0 positive, 11 negatives). It is noteworthy that all affected GICS sub-industries had negative relationships with stronger magnitudes after the key oil reform, which suggests an adverse effect on stock returns for Chinese industries during heightened crude oil futures volatility.

Findings from this study also provide evidence to suggest that Chinese industries related to oil production are more closely aligned with international crude oil benchmarks following the key oil reform event. Prior to the key reform, none of these industries in China appear to have had statistically significant relationships with crude oil futures. Generally, the global benchmark Brent prices appear to have had more influence on Chinese listed stocks compared to the North American focused WTI future prices, particularly after the key China oil pricing reform on 27 March 2013. Overall, Chapter 4 provides empirical evidence that international crude oil benchmarks (i.e. Brent and WTI futures) have a significant influence on aggregated industry stock performance in Chinese markets.

Chapter 5 contributes to the energy policy, electricity generation and pricing literature by focusing on participants' reactions to the implementation of a 'carbon tax' and policy uncertainty. Empirical results from this chapter provide several findings. First, the carbon pricing mechanism increased the cost of wholesale electricity spot prices by approximately 68.0% in NSW, 33.0% in VIC, 29.7% in QLD, 32.6% in SA and 22.1% in TAS during the 2-year carbon pricing regime, after controlling for factors such as demand, monopolistic characteristics, price volatility, generation capacity and surplus from connected states. The state of NSW, which is heavily reliant on coal, was most impacted by the carbon pricing mechanism and TAS, with an abundance of hydro energy, was the least affected. Moreover, TAS also exported a significant amount of electricity to VIC (a heavily coal-reliant state) during the carbon pricing regime, which may have mitigated the effect on VIC. Consistent with the objective of a carbon tax to motivate behavioural shifts towards less carbon-intensive electricity generation, there were observations of utilisation shift from coal to other fuel sources during the carbon pricing regime and a reversal after the abolition of the carbon pricing mechanism.

This study also provides evidence that closures of coal-fired power stations created a significant reduction in generation capacity and initiated higher wholesale electricity spot prices *ex-post* the carbon pricing mechanism, which indicates a period of policy uncertainty. The absence of replacement capacity which contributed to the decline in generation capacity provides some support for findings in the CCA/AEMC (2017) report that energy policy uncertainty *ex-post* carbon pricing mechanism may have delayed investment. It is noteworthy that these closures were observed to have significant impacts on the interregional flow behaviour among connected states. The complete withdrawal of coal-fired power plants in SA (i.e. Northen and Playford) was accompanied by a spike in interregional flow in 2016, which suggests increased dependence on VIC (a coal-dominant state). With the withdrawal of the Hazelwood power station in 2017, there was a significant shift in interregional flow patterns for VIC (the most interconnected state) which saw net reversals (i.e. from exports to imports) in SA and TAS. The exports from VIC to NSW also declined substantially, which increased NSW's dependence on QLD for electricity requirements.

On a positive note, there are indications that wind appeared to be increasingly cost effective in NSW, VIC and SA between 1 July 2017 and 30 June 2018. Despite this, growth in renewables' contributions (as a proportion of total electricity needs) was relatively modest. It is possible that this may be related to risk aversion by investors due to policy uncertainty, which provides fertile ground for future research. Overall, Chapter 5 provides empirical evidence to indicate that energy policy has significant impacts on generation behaviour and wholesale electricity prices.

In conclusion, empirical evidence from this thesis contributes to the literature on market behaviour across three key markets (i.e. stock, derivative and energy markets) in US, China, and Australia by demonstrating that (i) investors (an essential stakeholder class) of US listed companies have adverse stock market behaviour to heightened corporate reputation risks from negative media coverage on environmental, social and corporate governance issues, (ii) international crude oil futures (compared to natural gas and thermal coal) have the most influence on Chinese industries and stock market behaviour of China listed firms are more aligned to international oil benchmarks *ex post* the key oil pricing reform on 27 March 2013, and (iii) the adoption of a carbon pricing mechanism (which was effectively viewed as a 'carbon tax') by Australia has shifted the market behaviour of coal-powered generators and significantly increased wholesale electricity costs during the two-year regime, after controlling for relevant variables such as local region demand, supply, price volatility, monopolistic characteristics, supply and interregional factors. Overall, these findings generally lends support to behavioural rationality by market participants in the examined exogenous events, emphasize the importance of understanding participants' behaviour in various markets and highlight the significance of firm and industry characteristics in explaining the differences in their reactions.

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