Electricity Markets and the Pass-Through Cost of Carbon

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Outline

- **Motivation**
- **The Australian National Electricity Market**
- **Impact of Carbon Trading / Carbon Tax**
- **Empirical Analysis**
- **Conclusions and Future Work**

Motivation

Controversy about impacts of Clean Energy Legislation Package

- Two stage carbon policy mechanism – commencing with a fixed price carbon period from 1 July 2012 and transitioning to an emissions trading scheme (ETS) on 1 July 2015
- One carbon permit will allow the discharge of 1 tonne of CO2 in a compliance year.
- Carbon tax comes into effect on July 1, 2012 with an initial price of $23
- Price of carbon permits will increase to $24.15 in 2013–14 and $25.40 in 2014-15 (reflecting a 2.5% increase in real terms).

Motivation

Research Questions

- What is the impact of the Australian carbon tax on electricity prices?
- What can we expect from theoretical considerations?
- How did actual market prices react to the introduction of the tax?
- What regulatory risks are involved in the process of introducing a price on carbon?

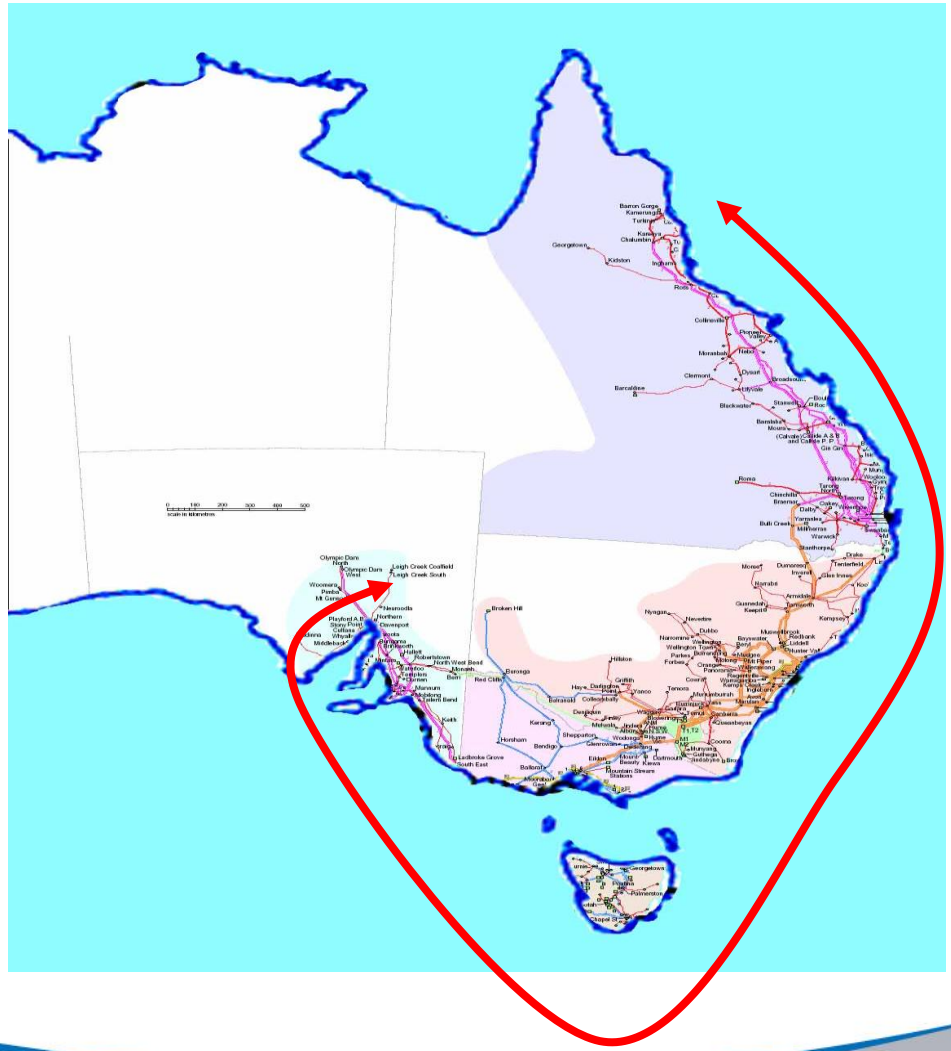
Motivation

Contributions

- One of the first studies to investigate the **actual** impact of forthcoming carbon tax on futures prices in Australian electricity markets
- We consider not only emission intensities and historical electricity prices but also **risk premiums** inherent in Australian electricity futures quotes
- We find that the additional premium for the price of carbon is significant, however, it is lower than what could be expected from considerations of emission intensities

The Australian National Electricity Market (NEM)

- NEM includes six price regions:
  - Queensland (QLD),
  - New South Wales (NSW)
  - Victoria (VIC)
  - South Australia (SA),
  - Tasmania (TAS)
  - Aus Cap Territory (ACT)

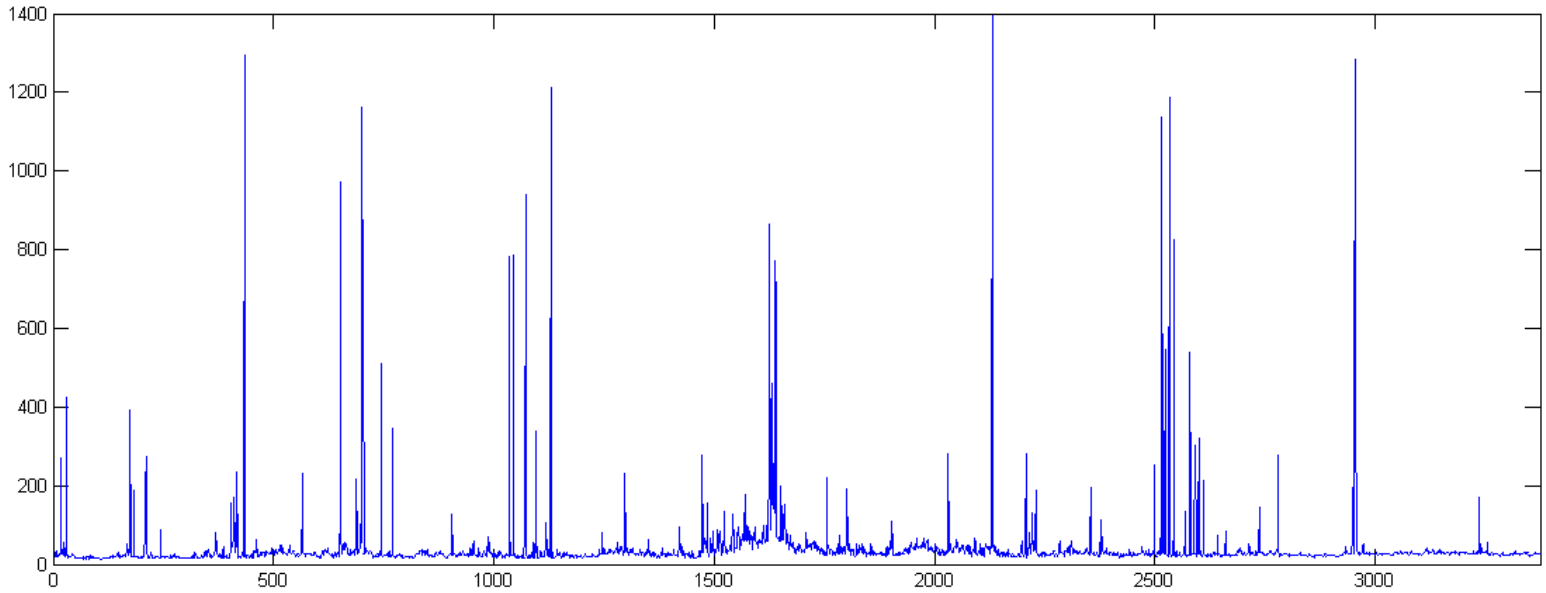


Electricity Prices - Stylized Facts

- Electricity is basically non-storable
- Prices show seasonality and mean-reverting behavior (Schwartz, 1997)
- Heteroscedasticity (Duffie & Gray, 1995)
- Electricity prices exhibit extreme volatility and price spikes (Weron, 2006; Bierbrauer et al, 2007)
- Generally complex relationship between spot and futures markets, e.g. backwardation, contango markets and significant risk premiums (Stulz, 2003)
- Standard models for price behavior of financial assets need to be adjusted / extended to fit electricity price behaviour

Electricity Prices in Australia

Spot price behavior (daily)



Daily electricity spot prices for NSW market (01.01.2003 - 25.03.2012)

Electricity Prices in Australia

- Australian residential electricity prices are the fourth lowest of all OECD countries (ABARE 2008)
- Australian average household spend 2.4% of income on electricity bills
- Australia's electricity consumption is predominantly fuelled by coal-fired power plants
- Electricity spot prices can range from -$1,000 / MWh to $12,000 / MWh

Emission Intensity in Australian Electricity Markets

- Australian emission per unit of GDP are 0.78kg of carbon dioxide equivalent in comparison to 0.43kg of carbon dioxide equivalent in OECD (IEA, 2009)
- The average emission intensity of the NEM in Australia is currently 0.94 tonnes CO_2 per MWH (Simshauser & Doan, 2008)
- Intensities vary significantly across states, e.g. 1.23 t CO_2 / MWH for Victoria, 0.32 t CO_2 / MWH in Tasmania
- In comparison the European average is 0.35 t CO_2 / MWH

Futures Trading in the NEM

- Delivery periods for exchange traded futures in Australia are quarterly (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) and yearly
- Futures contracts are available in states of NSW, VIC, SA and QLD
- There are base load (24 hours) electricity futures and peak load (7am-10pm) electricity futures contracts available
- Contracts are priced in AUD based on delivery of 1 MW of electricity during the whole contract period

Electricity Futures Markets

Futures contracts in electricity markets

- In contrast to classical forward contracts, electricity forwards / futures refer to **delivery over a period** rather than a fixed point in time
- The **forward premium** as the difference between the forward price and the (expected) future spot price represents compensation for facing the risk of uncertainty in prices during the delivery period
- Storage of spot is not possible (only indirectly in water reservoirs)

Electricity Futures Markets

Ex-ante and ex-post futures premium

- Futures premium is simply calculated as the difference between futures and spot price

$$\pi = F_{t,[T1,T2]} - S_{[T1,T2]}$$

- **Ex-ante futures premium:** use expected (model based) spot price at point in time $t<T_1$ and compare it to quoted futures price at some point in time $t<T_1$
- **Ex-post futures premium:** use realized spot price during the period $[T_1,T_2]$ and calculate premium by comparing realized spot to futures quote at some point in time $t<T_1$

Electricity Futures Markets

Results on risk premiums in electricity markets

Previous studies on electricity forward premium:

- **Negative and significant ex-ante premium** using one-month futures in PJM and CALPX market (Bessembinder & Lemmon, 2002, JF)
- **Positive** and significant **ex-post premium** in the EEX (Redl et al, 2009, EE) using monthly and yearly futures contracts
- **Positive** and significant **ex-post premium** in the NEM (Handika & Trück, 2012) using quarterly futures contracts for NSW, QLD, SA and VIC

The Australian Carbon Policy Mechanism

Some facts

- Carbon tax comes into effect on July 1, 2012 with an initial price of $23
- Approximately 500 Australian companies will be required to acquire and surrender carbon permits.
- Various emissions will not be covered, e.g. agricultural and land sector emissions; emissions from fuel used by households for transport, emissions from the combustion of bio fuels and biomass
- Initial estimated cost of the plan is $6-7 billion per annum (assuming a 0.7% CPI increase in 2012/2013 and a reduction in GPD of 0.1%)

The Australian Carbon Policy Mechanism

More facts

- Cap will be set by the Government during the flexible price period as to the amount of greenhouse gases that may be emitted during each compliance year
- Annual caps of the first, five years of the ETS flexible price period will be announced by 31 May 2014
- Price floor and price ceiling will be set for at least the first three years of ETS to avoid uncertainty in the market for investors and liable companies
- Price floor will be initially set at $15, price ceiling will be set at $20 above the expected international price for 2015-16

Impact of Carbon Prices on Electricity Prices

Results for Europe and Australia

- Experience from EU-ETS suggests that expectation about carbon price was added to electricity futures prices
- Mixed results on relationship between carbon and electricity spot prices (Bunn & Fezzi, 2009; Nazifi & Milunovich, 2010)
- Strong relationship between carbon futures and electricity futures prices (Gronwald et al, 2011)
- For Australia, simulation studies on carbon pass-through suggest a range from 17% (McLennan Magasanik Associates 2006), 100% (ROAM Consulting 2008), up to more than 300% (Simshauser & Doan 2009)

Empirical Analysis

The Data

- The model for the spot price behavior in regional markets is calibrated based on daily price observations from 2003-2012
- Futures contracts are available in states of NSW, VIC, QLD and SA operated by NEMMCO
- We consider futures quotes from d-cypha trade for baseload futures contracts Q2-Q4 2012, Q1 2013 and yearly contracts for 2012, 2013 and 2014
- Expected increase in electricity prices is calculated based on carbon price and average emission intensities per MWh electricity and for each regional market individually

Empirical Analysis

Modeling spot price behavior

- A common approach is to split the observed system prices P_t into a deterministic part f(t) that comprises all kinds of seasonal behavior and a purely stochastic component S_t which represents the only source of uncertainty in prices:

$$P_t = f(t) + S_t$$

- Seasonality is often modeled using constant step functions (Lucia and Schwartz, 2000), sinusoidal functions with trend (Bierbrauer et al, 2007), Wavelets (Weron, 2006), sinus with additional EWMA component (De Jong, 2006) etc.

Empirical Analysis

Modeling spot price behavior

- For the stochastic component a variety of models have been suggested including e.g.
  - mean-reversion models
  - stochastic models with jumps
  - GARCH type models
  - regime-switching models
- Models are applied as (i) pure time series models or (ii) allowing for explanatory variables such as demand and weather etc.

Empirical Analysis

Modeling spot price behavior

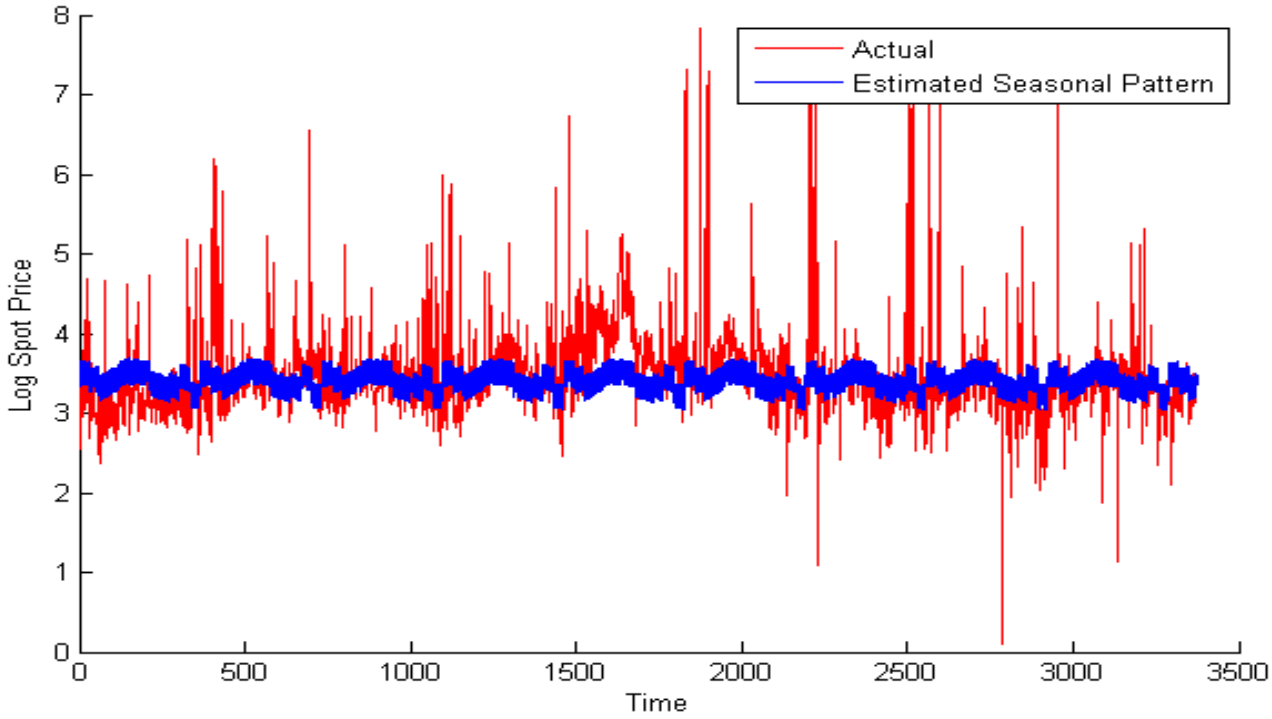
- Due to the extreme volatility in Australian electricity markets, we model log prices instead of the original spot price
- We fit a combination of trend, constant step functions and sinus to model the seasonality in each regional market

$$f(t) = \alpha + \beta \cdot t + d \cdot D_{day} + m \cdot D_{mon} + \gamma \cdot \sin\left((t+\tau)\frac{2\pi}{365}\right)$$

- To model the stochastic component we use a two-stage regime switching model allowing for mean-reverting price behavior in the ‘base regime’ and higher volatility and price levels in the ‘spike regime’

Empirical Analysis

Modeling the spot price behavior



Log Spot Prices and estimated seasonal pattern for SA market

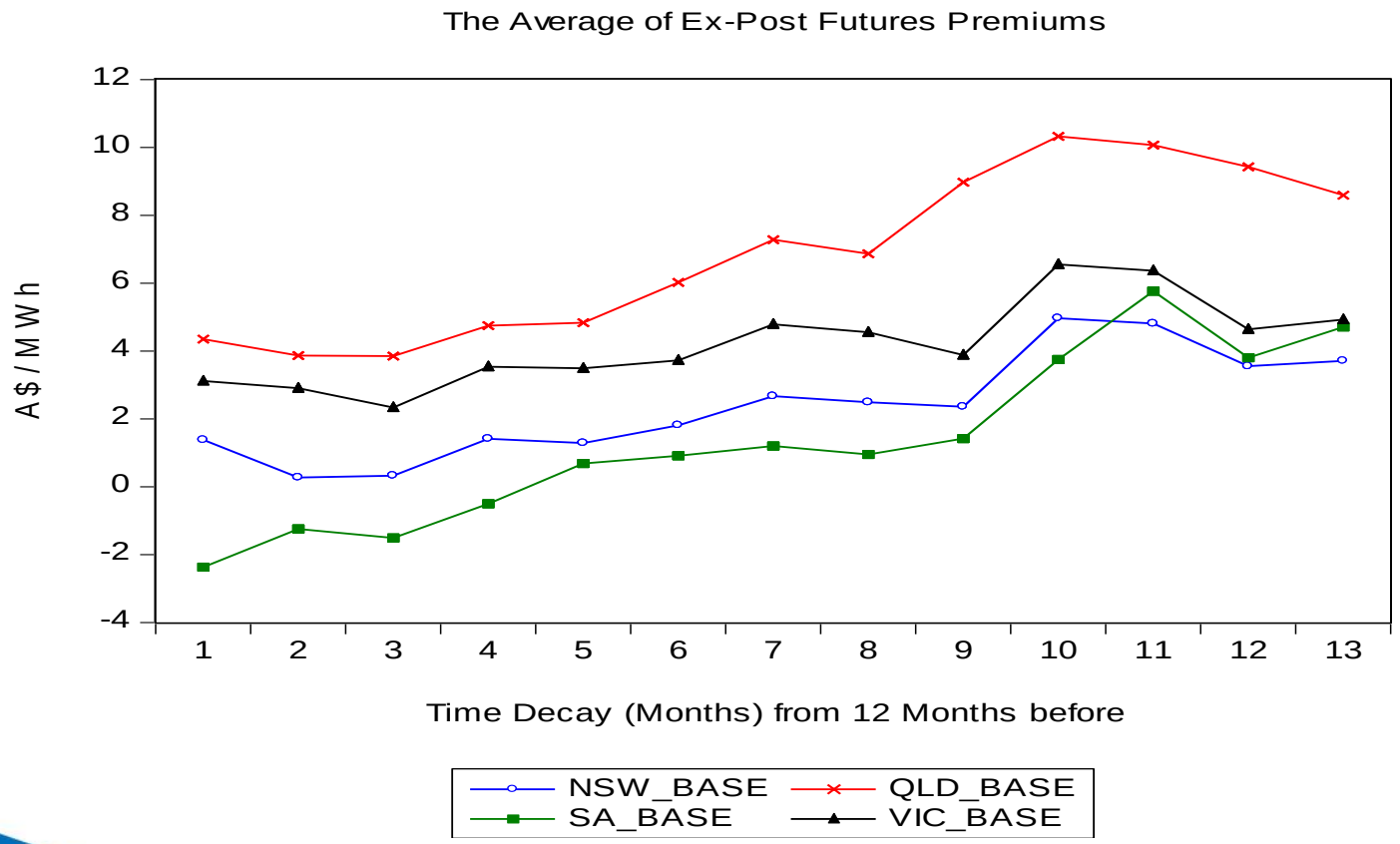
Empirical Analysis

Historical Realized Risk Premiums (Seasonal effects)

State	NSW	QLD	SA	VIC
Base	5.76	6.00	3.94	3.73
Peak	10.26	11.01	9.13	5.73
Q1 (Base)	11.81	15.57	8.37	10.91
Q2 (Base)	4.40	4.27	-1.33	-0.42
Q3 (Base)	7.40	5.60	3.94	6.25
Q4 (Base)	-0.93	5.48	2.67	5.95

Empirical Analysis

Historical Realized Risk Premiums (Maturity effects)



Empirical Analysis

Emission Intensities

State	Emission Factor	Additional Cost (2012-2013)	Output (TwH)
NSW	0.90	$20.70	73.4
QLD	0.89	$20.47	59.3
VIC	1.23	$28.29	56.1
SA	0.72	$16.56	14.3
TAS	0.32	$7.36	8.5
Average	0.94	$21.62	

Empirical Analysis

Actual Futures Quotes 25.03.2012 (Base Load)

State	NSW	QLD	SA	VIC
Q1/2012	$25.85	$30.00	$26.15	$24.45
Q2/2012	$31.25	$28.00	$27.00	$27.25
Q3 / 2012	$54.40	$49.30	$47.50	$49.00
Q4 / 2012	$55.35	$51.25	$52.50	$48.65
Q1/ 2013	$64.35	$64.10	$71.75	$62.20
Cal 2012	$41.78	$39.70	$38.35	$37.40
Cal 2013	$58.00	$54.59	$56.50	$52.65
Cal 2014	$59.24	$54.89	$61.84	$53.63

Empirical Analysis

Calculating a premium for the carbon price

- We assume the following relationship between futures quotes and expected spot prices:

$$F_{t,[T1,T2]} = E(S_{[T1,T2]}) + \pi_{R[T1,T2]} + \pi_{C[T1,T2]}$$

- Futures quotes $F_{t,[T1,T2]}$ are taken from D-Cypha trade
- Expected spot price $E(S_{[T1,T2]})$ simulated from spot price model
- Risk premiums $\pi_{R[T1,T2]}$ are calculated as median of historical ex-post risk premiums (2003-2011)
- Additional premium for carbon price $\pi_{C[T1,T2]}$ is calculated

Empirical Analysis

Calculating the Carbon Tax Premium

State	NSW	QLD	SA	VIC
Q2/2012	$1.30	-$1.25	$1.03	-$1.51
Expected	$0	$0	$0	$0
Q3 / 2012	$22.10	$17.44	$13.16	$22.95
Q4 / 2012	$18.63	$23.53	$16.53	$28.58
Q1/ 2013	$19.92	$19.14	$12.39	$21.71
Expected	$20.70	$20.47	$16.56	$28.29
Cal 2013	$14.37	$17.02	$9.95	$17.35
Expected	$21.22	$20.98	$16.97	$29.00
Cal 2014	$15.72	$18.58	$13.05	$18.33
Expected	$22.30	$22.05	$17.84	$30.47

Empirical Analysis

Results on premium for carbon price

- Our model yields an appropriate fit to nearest-term futures quotes Q2 2012 that are not affected by carbon price
- We find that the estimated pass-through cost of carbon is in its expected range (between 75%-115%) for the near-term futures contracts Q3/2012, Q4/2012 and Q1/2013
- For yearly contracts with delivery in 2013 and 2014 the estimated pass-through cost is clearly lower and only between 60%-80% of what could be expected based on regional emission intensities

Empirical Analysis

Possible reasons

- Risk premiums tend to include a compensation for the risk of price spikes and/or high levels electricity prices.
- In recent periods (Q1/2011-Q1/2012)
  (i) only very few price spikes could be observed in Australian electricity markets, while
  (ii) Q1/2012 prices were on an extremely low level
- As a result current futures risk premiums and market expectations on seasonal patterns might be lower than assumed in this study.

Some issues to consider

Regulatory and other issues

- Concerns about ‘double-dipping’ with respect to AFMA addendum that allows retailers to pass through any additional costs due to changes in law as an addition to the negotiated price of OTC deals
- Experience from European EU-ETS shows that carbon price was passed on to consumers despite the fact that >90% of allowances were given away for free
- Setting caps too generous for ETS (from 2015 onwards) might lead to a crash in trading prices (see Phase I of EU-ETS) and scheme not to be effective in terms of reducing emissions

Conclusions & Future Work

- One of the first studies to investigate the impact of forthcoming carbon tax on actual futures prices in Australian electricity markets
- We find that after controlling for risk premiums in electricity futures markets, there is still a significant (anticipated) increase in prices by market participants
- However, estimated pass-through costs of carbon are generally lower than what could be expected based on regional emission intensities
- Additional sensitivity tests with respect to futures premiums / estimated model for spot prices might provide more insights in explaining this anomaly