The Renewable Energy Certificate Market and Energy Transition in Australia

[early/preliminary analysis]

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Introduction: GCM

- GCM: 100 jurisdiction have RO/PS. Not all RO/PS's are tradable
- Carrots and sticks or carrots vs sticks
- **Sticks**: Carbon/emissions markets can be economy wide and could cover other GHGs (e.g. biogenic from agriculture)
- **Carrot**: GCM incentivize renewables
  - Energy sector carbon emissions (essentially)
  - GCM vs feed in tariffs
- Devil in the detail
  - Obligation on generators (portfolio standard= PS) = additional cost (invest in RES or buy certificates)
  - Obligation on retailers (RO) = additional revenue source for RES generators
- Other use of certificates – green tariff markets; voluntary markets (net zero scope 2 commitments)
- Complementary?
  - UK RO alongside CM
- Relevant in a post subsidy would? Only consistent policy in Australia….

Motivation: Australia

- the highest per capita GHG from coal power and is a net exporter of two-thirds of its coal, crude oil, and natural gas (Morton,2021; DCCEEW,2022b).
- longest history of implementing a REC market since 2001 (Andrews, 2001);
- rather liquid market compared to the EU REC markets (DCCEEW, 2022a; Hulshof, Jepma, & Mulder, 2019)
- in an environment of climate inaction of the federal government (due to political division) accompanied with an appeal for more ambitious climate policies from the public and state governments: how robust a REC pricing mechanism can be to promote emissions reduction in such an environment?

Introduction – paper overview

What

- **Pricing efficiency:** RQ (1) Whether the REC price change is driven by the change in emissions or emissions intensity from the energy consumption?
- **Environmental Effectiveness:** RQ (2) Whether the change in emissions or emissions intensity from the energy consumption in turn responds to the REC price change?

Why

- effectiveness & efficiency matters as REC has been primary climate policy for Australia

How

- FDL ARDL models: two-way relationship between REC returns and Emissions and Emissions intensities over 2011-2021

Contribution

- Analyses of the REC market remain limited (Coulon et al., 2015).
- no study tests the effectiveness of the REC pricing mechanism (in Australia)

Key Findings

1. 1) **Pricing efficiency:** The emissions and emissions intensity positively affected the LGC prices before the Carbon Pricing Mechanism (CPM) in a monthly relationship and during and after the CPM in a weekly relationship.

2. 2) **Environmental effectiveness:** For all the subperiods, the LGC prices negatively affected the emissions but not the emissions intensity.

3. 3) suggestion of substitutional effect of the CPM on the LGC mechanism – indicated by Structural break and in a monthly relationship during the CPM period between the emissions intensity and the LGC prices.

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2. Australian Emissions Profile

- Emissions from the electricity and stationary energy sectors: > 40% of the emissions profile
- power generation primarily from coal, followed by other non-renewable sources.
- Dash for GAS, state differences (Tasmania and SA are very green), high residential PV

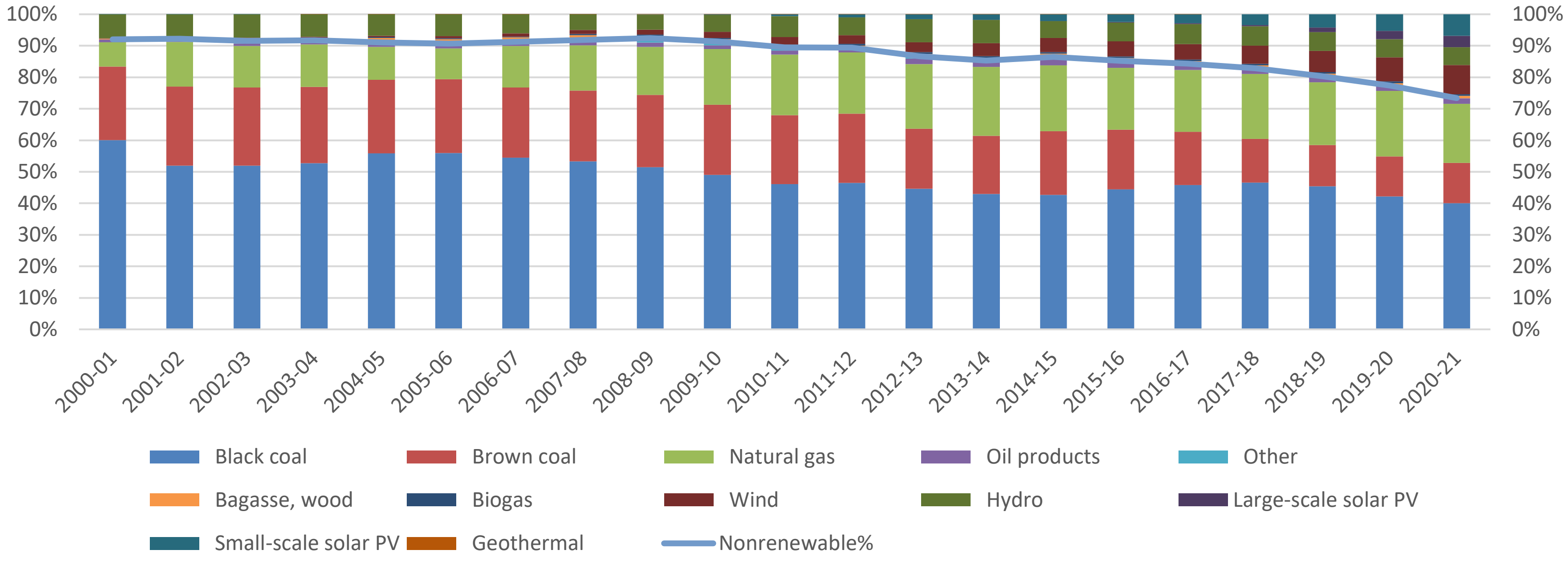

Figure 2: Australian Energy Mix 2000-2021

Source: Department of Climate Change, Energy, the Environment and Water

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Policies: RET

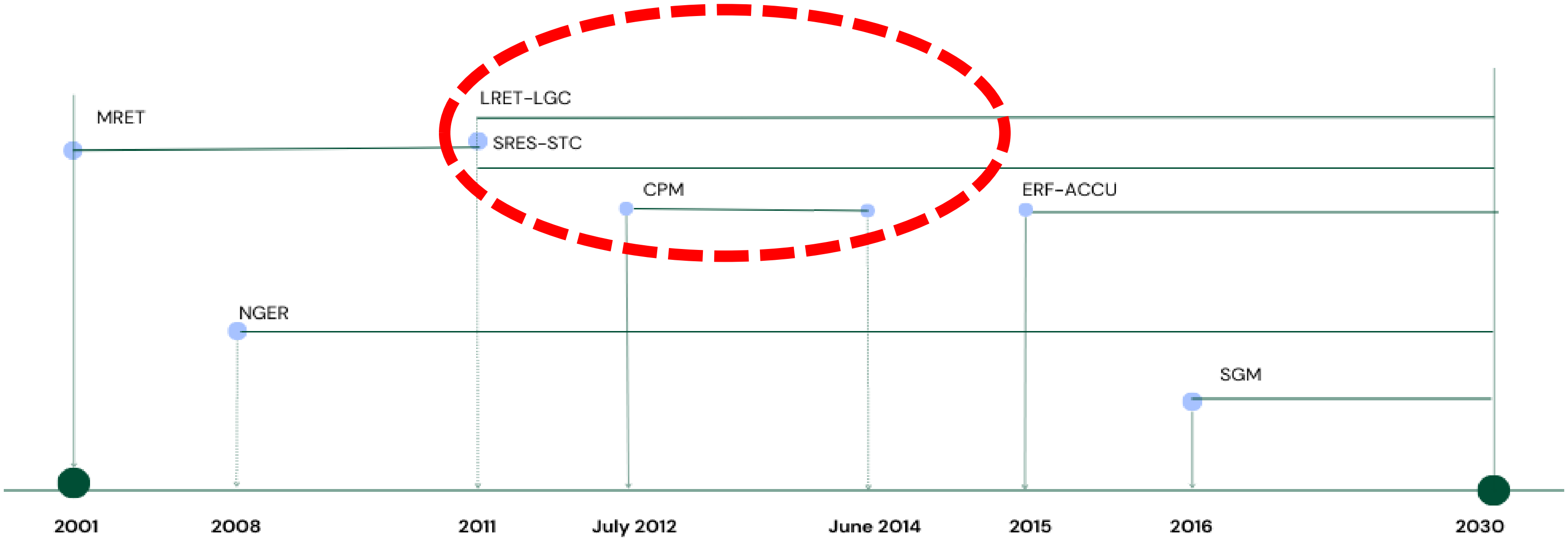
- State and federal: FIT (state/solar), Green investment bank,
- 2008 to date - NGERs: National Greenhouse and Energy Reporting scheme
- 2012 to 2014 - CPM: Carbon Pricing Mechanism (July 2012- June 2014)
- 2018 to date - ERF: Emissions Reduction Fund – reverse auction where govt. buys offsets (ACCU: Australian Carbon Credit Unit)
- SGM: Safeguard Mechanism – soft cap (use of adjustable 'baseline') on emissions for large facilities emitting GHS (Scope 1 emissions)
  - Due to concerns of business as usual via offserts (ACCU) of questionable interity

RET

- 2001 Obligation on retailers
- Amended 2009 (Rudd); 2011 (Gillard); 2015 (Abbott); and 2017 (Turnbull).
- 33,000 gigawatt hours (GWh) by 2020
- Allocated to retailers via the Renewable Power Percentage

Australian National Climate Policies

- Mandatory renewable energy target (MRET) started in 2001 and since 2011 has been split into Large-scale Renewable Energy Target (LRET) and Small-scale Renewable Energy Scheme (SRES).
- LRET mandated a Renewable Power Percentage (RPP) and SRES a small-scale technology percentage (STP). These standards determine the number of large-scale generation certificate (LGC) and the small-scale technology certificate (STC) an electricity retailer is liable for. One LGC or STC is equivalent to one megawatt hour (MWh) of renewable energy generated by the accredited renewable energy power station.
- The carbon pricing mechanism (CPM) started to operate in July 2012 but was repealed in July 2014. It (“carbon tax”) predetermined carbon cost every year and covered nearly 60% of Australia’s carbon emissions.



Literature and Hypotheses Development

- The pricing of environmental assets can be greatly affected by policy and regulatory events (Alberola et al., 2008; Benz & Trück, 2006; Christiansen, Arvanitakis, Tangen, & Hasselknippe, 2005; Diaz-Rainey & Tulloch, 2018; Kerr, Ormsby, & White, 2021) and the CPM repeal is a significant climate policy event that took place in Australia (see Maryniak, Trück, & Weron, 2019; Nazifi, Trück, & Zhu, 2021; O'Gorman & Jotzo, 2014).

H1: LGC returns experienced a structural break following the news that PUP confirmed its support of the CPM repeal on June 25th 2014.

Literature and Hypotheses Development

- Australian Financial Market Association (2021) points out that the REC price should be driven by certificate demand and supply, a perspective from which Chevallier (2011) and Liao et al.(2023) also investigated in the Emissions Trading Scheme. Thus, if Australian REC market is effective in promoting energy transition:

H2 **Pricing efficiency**: Emissions or emissions intensity from energy dispatched have a significant and positive effect on LGC prices.

Mechanism

- higher emissions implies greater demand for LGC’s

Literature and Hypotheses Development

- Literature that investigates the effectiveness of a climate policy from the perspective of a climate policy's association with emissions reduction: O'Gorman & Jotzo (2014), Best et al. (2020), Martin & Saikawa (2017), Schmalensee & Stavins (2017), Bjørn et al. (2022)

H3 **Environmental effectives**: LGC prices have a significant and negative effect on emissions or emissions intensity from energy dispatched.

Mechanism

- Higher prices (and returns) leads to investment in RES and reductions in emissions]
    - Unlikely captured in weekly or monthly regression
- Higher prices leads to clean Substitution – use lower carbon fuels or dispatchable renewables (batteries; hydro)

Definition of Variables (2011/06/01- 2021/12/31)

	Description	Source
LGC_t	Australia Large-scale Generation Certificate spot prices in AU$/MWh	Bloomberg
GHG_t	Emissions from energy consumption in tons of CO2-e in the National Electricity Market	Australian Energy Market Operator
$DISP_t$	Electricity dispatched in the National Electricity Market	Australian Energy Market Operator
$GHGINT_t$	Carbon Dioxide Equivalent Intensity Index in tons of CO2-e /MWh of the energy dispatched for consumption in the National Electricity Market	$\boldsymbol{GHGINT_t = GHG_t/DISP_t}$

Methodology

- finite distributed lag (FDL) model for RQ1:

$$RLGC_t = \delta_0 + \Sigma_{q=1}^{Q}\delta_{1,q}\Delta E_{t-q} + \delta_2 * During + \delta_3 * After + \Sigma_{q=1}^{Q}\delta_{4,q}(During * \Delta E_{t-q}) + \Sigma_{q=1}^{Q}\delta_{5,q}(After * \Delta E_{t-q}) + \epsilon_t, \quad \textbf{(1)}$$

- autoregressive distributed lag model (ARDL) model for RQ2:

$$\Delta E_t = \delta_0 + \Sigma_{p=1}^{P}\delta_{1,p}\Delta E_{t-p} + \Sigma_{q=1}^{Q}\delta_{2,q}RLGC_{t-q} + \delta_3 * During + \delta_4 * After + \Sigma_{q=1}^{Q}\delta_{5,q}(During * RLGC_{t-q}) + \Sigma_{q=1}^{Q}\delta_{6,q}(After * RLGC_{t-q}) + \epsilon_t, \quad \textbf{(2)}$$

$RLGC_t$: the LGC returns

ΔE : the change in emissions (emissions intensity)

ΔE_{t-p} : the lag terms of the change in emissions (emissions intensity) at the order of p determined by BIC criterion

During (After): the dummy variable that is equal to one during (after) the CPM period and zero otherwise.

ϵ_t is the independent random error term.

- Approach: weekly baseline (Cotton&De Mello, 2014) and monthly regression; subperiod analysis

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Result Highlights

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Table 2 Structural Break Test: Day after Repeal becomes clear

Table 2 presents the structural break test done on daily LGC returns by employing Zivot-Andrews (1992) test which accompanied a unit root test in the presence of a structural break in the intercept. Lag structures for the underlying unit root tests are selected using AIC and t-statistics corresponding to H0: LGC returns have a unit root.

Daily LGC returns					
	Minimum t-statistic	Observation	p<=1%	p<=5%	p<=10%
$SBlgc$**(June 25th, 2014)**	-19.791	801	-5.34	-4.8	-4.58

Table 3 Weekly Effect of Emissions and Emissions Intensity

	Model (1)		Model (2)
$VARIABLES$	$RLGC_t$	$VARIABLES$	$RLGC_t$
ΔGHG_{t-1}	-0.006	$\Delta GHGINT_{t-1}$	0.004
	(0.058)		(0.082)
ΔGHG_{t-2}	-0.063***	$\Delta GHGINT_{t-2}$	-0.248**
	(0.021)		(0.118)
$During$	-0.005	$During$	-0.004
	(0.004)		(0.004)
$During * \Delta GHG_{t-1}$	0.012	$During * \Delta GHGINT_{t-1}$	0.145
	(0.090)		(0.192)
$During * \Delta GHG_{t-2}$	0.199***	$During * \Delta GHGINT_{t-2}$	0.406**
	(0.068)		(0.201)
$After$	0.002	$After$	0.003
	(0.003)		(0.003)
$After * \Delta GHG_{t-1}$	0.019	$After * \Delta GHGINT_{t-1}$	-0.024
	(0.071)		(0.114)
$After * \Delta GHG_{t-2}$	0.119**	$After * \Delta GHGINT_{t-2}$	0.248*
	(0.050)		(0.143)
$Constant$	-0.001	$Constant$	-0.002
	(0.003)		(0.003)
$Observations$	548	$Observations$	548

Pricing efficiency during and after CPM in line with H2

Table 4 Monthly Effect of Emissions and Emissions Intensity

$VARIABLES$	Model (1) $RLGC_t$
ΔGHG_{t-1}	0.344**
	(0.166)
ΔGHG_{t-2}	0.217
	(0.169)
$During$	-0.009
	(0.016)
$During * \Delta GHG_{t-1}$	-0.406
	(0.255)
$During * \Delta GHG_{t-2}$	0.020
	(0.236)
$After$	0.008
	(0.015)
$After * \Delta GHG_{t-1}$	-0.191
	(0.227)
$After * \Delta GHG_{t-2}$	-0.110
	(0.247)
$Constant$	-0.005
	(0.011)
$Observations$	124

$VARIABLES$	Model (2) $RLGC_t$
$\Delta GHGINT_{t-1}$	0.890***
	(0.247)
$\Delta GHGINT_{t-2}$	1.412***
	(0.515)
$\Delta GHGINT_{t-3}$	0.096
	(0.310)
$During$	-0.014
	(0.015)
$During * \Delta GHGINT_{t-1}$	-1.182*
	(0.655)
$During * \Delta GHGINT_{t-2}$	-1.556**
	(0.739)
$During * \Delta GHGINT_{t-3}$	-0.357
	(0.694)
$After$	0.002
	(0.013)
$After * \Delta GHGINT_{t-1}$	-0.376
	(0.506)
$After * \Delta GHGINT_{t-2}$	-0.580
	(0.786)
$After * \Delta GHGINT_{t-3}$	-0.299
	(0.495)
$Constant$	0.001
	[illegible]

Sign switches for monthly regression

Substitution effect in longer regression?

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Environmental effectiveness

Table 5 Weekly Effect of LGC Returns on Emissions and Emissions Intensity

Panel A Emissions

VARIABLES	ΔGHG_t
ΔGHG_{t-1}	-0.609***
	(0.054)
ΔGHG_{t-2}	-0.480***
	(0.061)
ΔGHG_{t-3}	-0.283***
	(0.054)
ΔGHG_{t-4}	-0.129***
	(0.041)
$RLGC_{t-1}$	$\boxed{\text{-0.282**}}$
	(0.140)
$RLGC_{t-2}$	-0.022
	(0.267)
During	0.000
	(0.007)
$During * RLGC_{t-1}$	0.197
	(0.180)
$During * RLGC_{t-2}$	0.063
	(0.290)
After	0.000
	(0.006)
$After * RLGC_{t-1}$	0.223
	(0.153)
$After * RLGC_{t-2}$	0.040
	(0.269)
Constant	-0.001
	(0.006)
Observations	546

Panel B Emissions Intensity

VARIABLES	$\Delta GHGINT_t$
$\Delta GHGINT_{t-1}$	-0.505***
	(0.044)
$\Delta GHGINT_{t-2}$	-0.364***
	(0.061)
$\Delta GHGINT_{t-3}$	-0.222***
	(0.052)
$\Delta GHGINT_{t-4}$	-0.158***
	(0.052)
$\Delta GHGINT_{t-5}$	-0.126***
	(0.045)
$RLGC_{t-1}$	-0.144
	(0.107)
$RLGC_{t-2}$	-0.199
	(0.158)
During	0.001
	(0.003)
$During * RLGC_{t-1}$	0.069
	(0.115)
$During * RLGC_{t-2}$	0.169
	(0.165)
After	0.001
	(0.003)
$After * RLGC_{t-1}$	0.149
	(0.110)
$After * RLGC_{t-2}$	0.176
	(0.160)
Constant	-0.001
	(0.003)
Observations	545

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Conclusion

Conclusion

1) Pricing efficiency H2: The emissions and emissions intensity positively affected the LGC prices before the Carbon Pricing Mechanism (CPM) in a monthly relationship and during and after the CPM in a weekly relationship.

2) **Environmental effectiveness H3**: For all the subperiods, the LGC prices negatively affected the emissions but not the emissions intensity.

3) suggestion of substitutional effect of the CPM on the LGC mechanism – indicated by Structural break and in a monthly relationship during the CPM period between the emissions intensity and the LGC prices.

Next Steps

- Theory/mechanisms e.g. hypothesis substitution between CPM/REC
- **Other test: BP multiple structural breaks**
- **Pricing efficiency**
  - More lags in weekly regression so week and month regressions can be reconciled
  - Controls, ACCU, weather etc
- **Environmental effectiveness**
  - Controls
    - Economic activity – GDP
    - Economic efficiency – Total Factor Productivity
  - Regressions at levels rather than returns [esp. for RQ2/H3 enviromental effectiveness]
  - Are limited environmental effectiveness results driven by dash for gas or distributed RES (solar FIT)?
    - REC returns on 1) Large RES absolute levels of installed capacity; Large RES % installed capacity (not use generation)

Thank you

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Carbon tax or price

Carbon pricing will add costs to non-renewables (fossil fuel generation) sources raising their costs. Therefore, renewables are relatively better off.

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t + (V_t . C_t)}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

$$V_t = volume\ of\ fuel\ used\ (note: F\ is\ cost\ not\ volume\ of\ fuel)$$

$$C_t = cost\ of\ carbon\ per\ unit\ of\ volume\ (V_t)$$

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LCOE with GCM

- Similar to FIT but in this case have $G_t = green\ certificate\ price$. This will vary based on demand and supply for green certificates, so they provide less certainty that FIT and will therefore not lower I_t as much.

- Note: Where the obligations falls on *retailers* (**Renewable purchase obligation**), then generators benefit from G_t for each MWh of green generation. When the obligation is on *generators* (**Renewable Portfolio Standard**), it is the excess G_t over and above their obligation that can be sold.

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t - (E_t . G_t)}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$