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## General equilibrium models and uncertainty in environmental policies: implications for Australia

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## **General equilibrium models and uncertainty in environmental policies: implications for Australia**

### **Abstract**

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# **General Equilibrium Models and Uncertainty in Environmental Policies: Implications for Australia**

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## 2- Aims and Significance of Study



- To study the effects of policies on a whole economy, general equilibrium models have been broadly used since they can embrace all sectors and markets in an economy.
- We review the literature on **computable general equilibrium (CGE)** and **dynamic stochastic general equilibrium (DSGE)** models in environmental economics.
- The contribution of CGE models in Australian environmental policy analysis is significant (Asafu-Adjaye, 2004; Clarke and Waschik, 2012; Asafu-Adjaye and Mahadevan, 2013; Fraser and Waschik, 2013; Meng *et al.*, 2013; Adams *et al.*, 2014; Meng, 2014).

## 2- Aims and Significance of Study



- The Australian emissions pricing system:
- the Clean Energy Programme under the Prime Ministership of Julia Gillard in 2011 including a carbon tax period from 1 July 2012 to 30 July 2015 following by an emissions trading scheme.
- under the Prime Ministership of Kevin Rudd: the tax period would finish one year earlier, on 30 July 2014.
- under the Prime Ministership of Tony Abbott: the carbon pricing system was abolished from 1 July 2014. The government introduced the Emissions Reduction Fund program from 13 December 2014 in which the government funds emissions reduction activities.

## 2- Aims and Significance of Study



Uncertainties relating environmental policies:

**1. environmental uncertainty** arising from unknown geological and environmental factors.

- the life of carbon in the atmosphere
- the contribution of GHGs to climate change and global warming
- the sensitivity of the earth to global warming
- the level and timing of the damages due to pollution

In Australia, the annual average temperature would increase by 2.8 to 5.1°C by the end of this century (CSIRO and the Australian Bureau of Meteorology, 2015).

## 2- Aims and Significance of Study



### 2. economic uncertainty related to:

- the social economic costs of emissions abatement, the costs of climate change damage and the trade-off between these two expenses and other factors which can affect the future of this trade-off such as
  - substitution between fuels
  - the progress of backstop technology
  - the arrival of new, cleaner technology

In Australia, the progress of renewable energy technology can significantly affect the approaches policy makers can follow to achieve emissions targets since the production sector heavily relies on fossil fuels, e.g. 86.9% of Australian electricity was generated by fossil fuels in 2012-13



## 2- Aims and Significance of Study



- Dissou and Karnizova (2012) discuss that macroeconomic uncertainty in environmental policies should be considered, since, firstly, it would result in fluctuations in consumption which would influence the costs of emissions policies; secondly, it is known as the main factor of a quantity versus a price emissions policy since Weitzman (1974).
- In order to track the effects of uncertainties on the economy over time, DSGE models can be applied.



### 3- Methodology

- **Conceptual Issues relating to CGE and DSGE Modelling:**
- Both CGE and DSGE models are based on micro-foundations containing similar micro principles:
  - 1) utility maximisation by households
  - 2) profit maximization by firms
  - 3) market clearing: all markets are in equilibrium.
- Both models assume rational behaviour by different economic agents and, thus, they are less likely to be subject to the Lucas critique (Lucas, 1976).
- The Lucas critique is a criticism of econometric models which evaluates historical data in order to predict the effects of a change in a policy without recognizing the optimal decision rules of economic agents.



### 3- Methodology

- *CGE models*
- the antecedents to DSGE models
- CGE models generally include four features:
  1. the focus of the model is on equilibrium resource allocation patterns
  2. assumes perfectly competitive markets
  3. the production side is represented by a profit maximising producer subject to technology constraints who chooses the optimal supply of a product and demand for factors.
  4. the consumption side is shown by a representative utility maximising household who chooses the optimal supply of factors and demand for a product (Pezzey and Lambie, 2001).



### 3- Methodology

- Following these four steps the outcome of a CGE model will be a system of equations:

...

- For parameterization, CGE models mostly employ calibration, using a transaction table which is usually an input-output table or a social accounting matrix contains (Dejuan *et al.*, 2013; Guo *et al.*, 2014; Hosoe, 2014; Okuyama and Santos, 2014).



### 3- Methodology

- The structure of a DSGE model is similar to that of a CGE model.
- The main difference is that agent optimizations take place within a **deterministic environment in a CGE model** while in a **DSGE model the environment is stochastic due to uncertainties**, usually specified as random shocks occurring in the model.
- There are two schools of DSGE models, real business cycle (RBC) and New-Keynesian.
- RBC models were first introduced by Kydland and Prescott (1982) to investigate if real shocks are the main source of business cycle fluctuations.
- Adding friction on the monetary side, specifically price and wage adjustment, and monopolistically competitive markets to RBC models led to the second school of DSGE models, New-Keynesian by Rotemberg and Woodford (1997).



### 3- Methodology

- For parameterization early DSGE models usually employed calibration, but new parameterization procedures were developed including Bayesian estimation, generalised methods of moment estimation, full-information maximum likelihood estimation and matching VAR and DSGE dynamic responses to structural shocks.
- \* The progress made in DSGE modelling made it an appropriate tool for fiscal and monetary policy analysis:
  - the Federal Reserve Board's SIGMA model
  - The Central Bank of Chile MAS model

	CGE	DSGE
Advances over time	<ul style="list-style-type: none"> <li>• <b>From static to dynamic models:</b> to show the time path of policy changes</li> <li>• <b>Development of computer programs</b> (such as GAMS, MPSGE and GEMPACK): this facilitate researchers to run large scale CGE models</li> </ul>	<ul style="list-style-type: none"> <li>• <b>From perfectly competitive markets</b> (in RBC models) <b>to monopolistically competitive markets</b> (in NK models): adding friction, specifically price and wage adjustment, and monopolistically competitive markets to make it appropriate for monetary policy analysis</li> <li>• <b>From calibration to estimation</b> in parameterization: including Bayesian estimation, generalised methods of moment and full-information maximum likelihood. This makes DSGE models fit to actual data.</li> </ul>
As Macroeconomics Models	<ul style="list-style-type: none"> <li>• Deterministic</li> <li>• Static/ dynamic</li> <li>• Perfectly competitive markets</li> <li>• Calibration for parameterization</li> </ul>	<ul style="list-style-type: none"> <li>• Stochastic</li> <li>• Dynamic</li> <li>• Perfectly competitive markets (in RBC models) and monopolistically competitive markets (in NK models)</li> <li>• Calibration and estimation for parameterization</li> </ul>
As Environmental Models (mostly)	<ul style="list-style-type: none"> <li>• Deterministic</li> <li>• Static/ dynamic</li> <li>• Calibration for parameterization</li> <li>• Large-scale multi-sectoral models</li> </ul>	<ul style="list-style-type: none"> <li>• Stochastic emphasising real shocks</li> <li>• Dynamic</li> <li>• Calibration for parameterization</li> <li>• Small-scale models with integrated sectors</li> </ul>

Year	Author	Model	Type of Model	Region	Scale	Findings
1993	McDougall	ORANI-E	Comparative Static	National	Multi-sectoral	An energy tax can be an effective alternative to a carbon tax by leading to fuel switching
1998	Kennedy	MEGABARE	Dynamic	International	Multi-regional (including Australia), Multi-sectoral	Comparing with a carbon tax, an emissions trading scheme can lead to lower carbon leakage and, thus, lower economic costs.
1999	Brown et al.	GTEM	Dynamic	International	Multi-regional (including Australia), Multi-sectoral	Meeting Kyoto targets with an international emissions trading system would be less costlier with less carbon leakage and thus more effective compared to without such a system
2000	Adams et al.	MMRF-Green	Dynamic	National	Multi-regional (6 states and 2 territories in Australia), Multi-sectoral	Adams (2007) finds that the costs of an emissions trading system depend on the abatement target and the associated permit price and recycling the revenue to the household would moderate the welfare effects.
1992	McKibbin and Wilcoxon	G-Cubed	Dynamic	International	Multi-regional (including Australia), Multi-sectoral	McKibbin et al. (2010) show that the impacts of the Copenhagen Accord's commitments on consumption or GDP loss are different across countries and are affected by their economic situation in the future.
2011	Commonwealth of Australia Treasury	The Treasury Model (which is a combination of different models)	Dynamic	National/ International	Multi-regional (including Australia, and different regions in Australia), Multi-sectoral	The Australian GNI per capita in 2050 increases by an average rate of 1.1 and 1 per cent per year in the core and high price policy respectively compared to 1.2 per cent without an environmental policy.





## 4- Background

- The literature on environmental policy comparison under uncertain conditions began with Weitzman (1974), followed by many other researchers (Hoel and Karp, 2002; Pizer, 2002; Newell and Pizer, 2003; Quirion, 2005; Fell *et al.*, 2012) who have applied a **partial equilibrium approach** to investigate the role of uncertainty, usually about abatement cost, in environmental policy.
- In a **static stochastic general equilibrium** model, Kelly (2005) investigates the effects of productivity shocks on environmental policy in a static framework.
- \* Investigating environmental economics under a type of **uncertainty** and in a **dynamic general equilibrium** model is still in its primary stage, involving the limitations that the early DSGE models had over three decades ago.

Year	Author	Uncertainty	Region	Main (Theoretical) Contribution	Findings/ Policy Implications
2011	Fischer and Springborn	TFP	US	Introducing DSGE model (RBC) in environmental economics under intensity target policy and emissions pricing policies	<ul style="list-style-type: none"> <li>Both emissions tax and cap result in the same outcomes although the tax policy leads to greater volatility.</li> <li>Intensity target result in higher output, employment and capital compare to a cap and a tax policy.</li> </ul>
2012	Heutel	TFP	US	Testing flexible emissions pricing policies where the government can set the tax (or cap) at the beginning of each period, adding asymmetric information	<ul style="list-style-type: none"> <li>An optimal policy should be pro-cyclical: stringent during recessions and gentle during expansions.</li> <li>Under asymmetric information, the variation of the tax policy is significantly greater than the quantity policy.</li> </ul>
2012	Dissou and Karnizova	TFP and sector-specific technology	US	Developing a multi-sectoral model to investigate the sectoral and aggregate effects of emissions pricing	<ul style="list-style-type: none"> <li>Although the emissions permit policy imposes less volatility, it can lead to asymmetries in economic responses to shocks.</li> <li>The welfare effects of each policy depend on the origin of the shocks.</li> </ul>
2012	Hassler and Krusell	TFP	Global	Extending the RICE model to a stochastic one	<ul style="list-style-type: none"> <li>Levying an oil tax in oil-producing countries can improve the climate while it has no climate consequences in the oil-consuming countries.</li> <li>The economic effects of such taxes in oil-producing countries are significant, especially when the proceeds of the taxes recycle in a lump-sum manner to the payer countries.</li> </ul>
2013	Angelopoulos et al.	TFP and pollution technology	US	Adding a pollution technology shock measured as emissions per unit of output	<ul style="list-style-type: none"> <li>An optimal environmental policy is pro-cyclical when an economic shock occurs, and counter-cyclical in the case of an environmental shock.</li> </ul>
2014	Roach	TFP and the energy price	US	Developing a New-Keynesian model with the assumption of monopolistic competition and friction, testing the effects of energy shocks	<ul style="list-style-type: none"> <li>An optimal tax should be pro-cyclical</li> <li>The tax revenue should be recycled to the household in both scenarios.</li> </ul>
2014	Golosov et al.	the long-run value of the scale	Global	Developing a new DSGE model without any structural shock,	<ul style="list-style-type: none"> <li>The damage is determined by three factors: discounting, the sensitivity of damage and the structure of carbon depreciation in</li> </ul>



## 4- Background

The limitations of environmental DSGE models:

1. mostly emphasise real shocks only, ignoring other economic and environmental shocks. This issue is also pointed to by Fischer and Heutel (2013) who conclude that other types of uncertainties should be added beside productivity to the environmental RBC models.
2. calibration
3. As a result of calibration, they focus on forecasting deviations from the steady state of macroeconomic variables rather than the level of such variables.
4. The size, usually one integrated sector, while an appropriate environmental policy analysis requires a multi-sectoral macroeconomics models.



## 4- Background

- Constructing large-scale multi-sectoral DSGE models can tailor these models to environmental analysis since the imposed economic costs and the optimal outcome of environmental policies varies across sectors
- the current environmental DSGE models are similar to early DSGE models and further development is required to make DSGE as a solid, efficient modelling tool in environmental economic analysis.
- For Australia, in particular, the literature of DSGE models for quantitative policy assessment remains limited to a few studies (Jaaskela and Nimark, 2011; Robinson, 2013; Rees, 2013).



## 5- Results: Implications for Australia

- investigating the relationship between Australian emissions and business (TFP or foreign shocks)
- The policy implications of such studies would be significant by representing how an environmental policy should be adjusted to business cycles.
- improving the empirical results of the existing CGE models by specifying different shocks to them to investigate the sectoral responses.
- simulating the effects of unexpected environmental changes which can be done by developing a DSGE model including the special environmental features of Australia.
- Exploring the limitations and other issues of these models within the context of Australian environmental policy analysis and Australian policy makers can learn a lot about the outcome of their policies along the way.



*Thank you*