

UPGEM: A DYNAMIC COMPUTABLE GENERAL EQUILIBRIUM (CGE) MODEL OF THE SOUTH AFRICAN ECONOMY FOR FORECASTING AND POLICY ANALYSIS

*Methodology and assumptions behind the
partnership for market readiness carbon tax study
for South Africa*

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Carbon Tax Modelling Workshop
10 November 2016*

INTRODUCTION TO CGE MODELLING

CGE modelling is a challenging field. It requires mastery of economic theory, meticulous preparation of data and familiarity with underlying accounting conventions, knowledge of econometric methods, and an understanding of solution algorithms and associated software for solving large equation systems. However, the most important requirement is the ability to communicate. **CGE modelling is primarily about shedding light on real-world policy issues.** For CGE analyses to be influential, modelers must explain their results in a way that is comprehensible and convincing to their fellow economists, and eventually to policy makers.

While CGE modelling is challenging, it is also rewarding. CGE models are used in almost every part of the world to generate insights into the effects of policies and other shocks in the areas of trade, taxation, public expenditure, social security, demography, immigration, technology, labor markets, environment, resources, infrastructure and major-project expenditures, disasters, and financial crises. CGE modelling is the only practical way of quantifying these effects on industries, occupations, regions and socioeconomic groups.

Peter B. Dixon and Dale W. Jorgenson
Handbook of Computable General Equilibrium Modeling

WHAT IS UPGEM?

- Large-scale dynamic economic **model** designed to provide quantitative estimates of the **economy-wide** effects of policy proposals
- The UPGEM database, in combination with the model's rigorous theoretical specification, describes the main real inter-linkages in the South African economy
- The theory of the model is then, essentially, a set of equations that describe how the values in the database move through time and move in response to any given policy shock
- CGE models such as UPGEM represent a significant improvement over input-output models by allowing for **price-induced behaviour** and **resource constraints**

UPGEM DATABASE STRUCTURE

		<i>ABSORPTION MATRIX (USE TABLE)</i>						
		1	2	3	4	5	6	7
		PRODUCERS	INVESTORS	HOUSEHOLD	EXPORT	GENGOV	STOCKS	TOTAL
	SIZE	IND	IND	HOU	1	1	1	ALL USERS
BASIC FLOWS	COMxSRC	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS	V0BAS BASIC
MARGINS	COMx SRCxMAR	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	N/A	V0MAR MARGINS
INDIRECT TAXES	COMxSRC	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	N/A	V0TAX TLSP
BAS + MAR + TAX = PUR VALUES	COM	V1PUR INTERMED USE	V2PUR INVESTMENT	V3PUR PRIV CONS	V4PUR EXPORTS	V5PUR PUB CONS	V6BAS STOCKS	TOTAL COM DEMAND
LABOUR COSTS	OCC	V1LAB						
PRODUCTION TAXES	1	V1PTX						
CAPITAL RENTALS	1	V1CAP						
V1PUR + V1PRIM = TOTAL COST	1	TOTAL IND COSTS						

		<i>PRODUCTION MATRIX (SUPPLY TABLE)</i>				
SIZE	IND	1	1	1	ALL SOURCES	
COM	MAKE SUPPLY TABLE	V0IMP IMPORTS	V0MAR MARGINS	V0TAX TLSP	TOTAL COM SUPPLY	
1	TOTAL IND SALES					

<i>EMISSIONS</i>	
SIZE	IND
COMx SRC	CO2

<i>TARIFFS</i>	
SIZE	1
COM	V0TAR

UPGEM EMISSIONS DATABASE

- The energy and emissions database linked to the model's core economic database implies the **input-output-emissions** relationship for each industry in the model
- The energy and emissions inventory for UPGEM is based on Blignaut et al. (2005) and Seymore et al. (2014) and was developed using emission factors from various South African sources, including DEA, which are in line IPCC default factors
- Fugitive emissions were not captured in the database

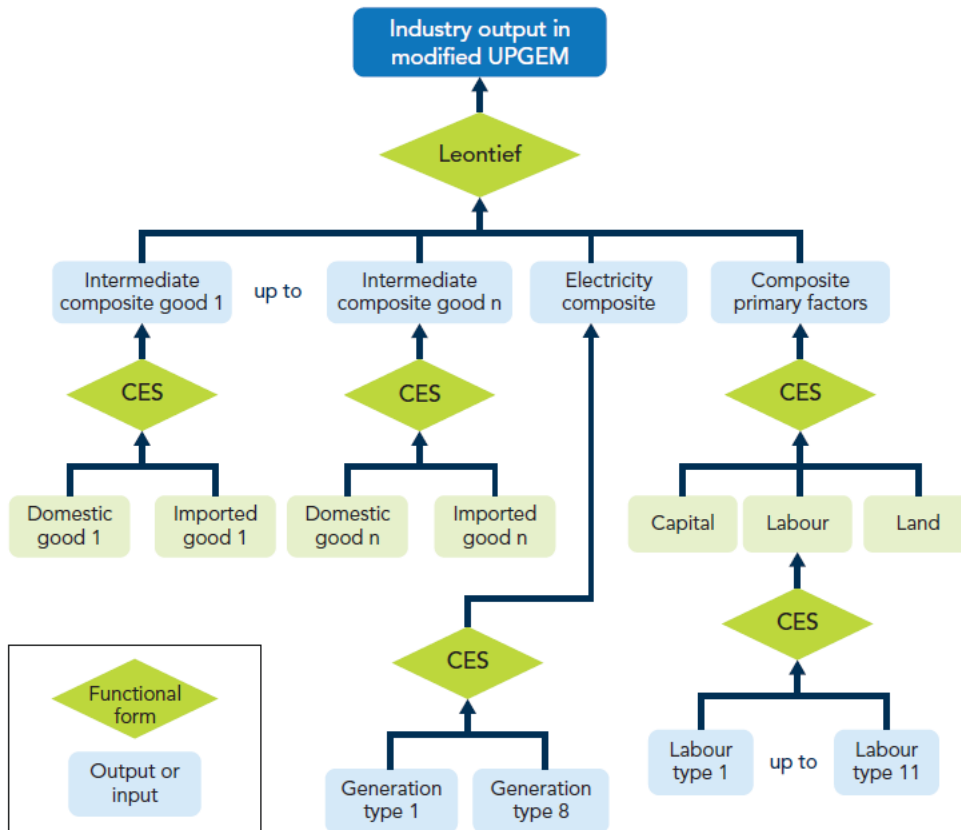
UPGEM THEORETICAL STRUCTURE

- The theoretical structure of UPGEM is based on the well-documented **MONASH** model developed by the **Centre of Policy Studies**
- Industries minimise costs subject to input prices and a constant returns to scale production function
- Households maximise a Klein-Rubin utility function subject to their budget constraint
- New industry-specific capital are constructed as cost-minimising combinations of domestic and imported commodities
- Export demand is inversely related to the foreign-currency price
- Government demand and the details of direct and indirect taxation are also recognised in the model

UPGEM THEORETICAL STRUCTURE

- In policy simulations, the labour market follows a lagged adjustment path where wage rates respond over time to gaps between demand and supply for labour across each of the different occupation groups
- Disequilibrium in the labour market over the short to medium term is therefore allowed
- Capital accumulation is specified separately for each industry and linked to industry-specific net investment in the preceding period; investment in each industry is positively related to its ERoR
- Fiscal account dynamics relates public sector debt to debt incurred during a particular year and interest payments on previous debt; adjustments to the national net foreign liability position are related to the annual investment/savings imbalance, net asset revaluation, and remittance flows during the year

UPGEM PRODUCTION STRUCTURE



- Industries in UPGEM combine various intermediate composite goods, an electricity composite good and a primary factor composite in fixed proportion
- For each top-level composite in the production recipe, **CES sub-nests** allow price induced substitution between imported and domestic versions of each good, electricity generation types, primary factors and labour types
- The **electricity** composite sub-nest distinguishes various electricity generation technologies

UPGEM SIMULATION BASICS

- Our aim was to **isolate and measure** the impact of introducing the proposed carbon tax policy on the economy
- A good way to do this is to compute the differences between a scenario in which the tax was imposed – the policy simulation – and a counterfactual business-as-usual scenario in which the tax did not occur – the baseline scenario
- Results are then reported as **percentage change deviations** over time between the first ‘baseline’ run and the second ‘policy’ run
- Great care must be taken in converting policy run results to their levels values as they are sensitive to baseline forecast assumptions

KEY ASSUMPTIONS: BASELINE

- Main baseline scenario based on available projections (in 2014) for selected macroeconomic variables up to 2030
- Alternative baseline scenario accounts for recent economic slowdown
- Due to endogeneity concerns, we did **not** make any explicit assumption or projection regarding potential changes to the electricity generation-mix in the baseline
- We also did **not** make any explicit assumptions regarding technical change or efficiency gains of clean technologies relative to fossil fuel based sources in the electricity generation-mix
- These assumptions dictate that the electricity generation-mix and the input-output-emissions relationship specified in the base data will remain largely **unchanged** over the baseline forecast period

KEY ASSUMPTIONS: BASELINE

- In principle, two key variables determine the level of emissions projected in the baseline: how much we will produce (GDP), and at what level of technology and efficiency
- Given the assumptions imposed on the baseline forecast, emissions grow in line with projected GDP, which explains why the main baseline scenario generates such high emissions growth over the forecast period (see figure 1)
- The most consequential assumption we make in the baseline, in terms of its impact on the policy results (both in $\% \Delta$ deviation and levels terms), is that we do not allow renewable technologies to become cheaper or more efficient over time

KEY ASSUMPTIONS: POLICY CLOSURE

- Variables that we believe will not be directly influenced as a result of the policy shock are set as exogenous, that is, they do not deviate from their baseline path despite the introduction of the carbon tax
- Naturally exogenous variables in the policy run typically include technical change variables, tax rates, shift variables such as the positions of foreign export demand curves, and variables that force certain economic relationships or behaviours to hold in the long-run
- The policy shock must be applied to an appropriate exogenous variable as identified in the simulation design phase based on the policy brief, in this case a **tax on specific carbon-emitting energy inputs** (coal, gas, petroleum)

TAX POLICY DESIGN

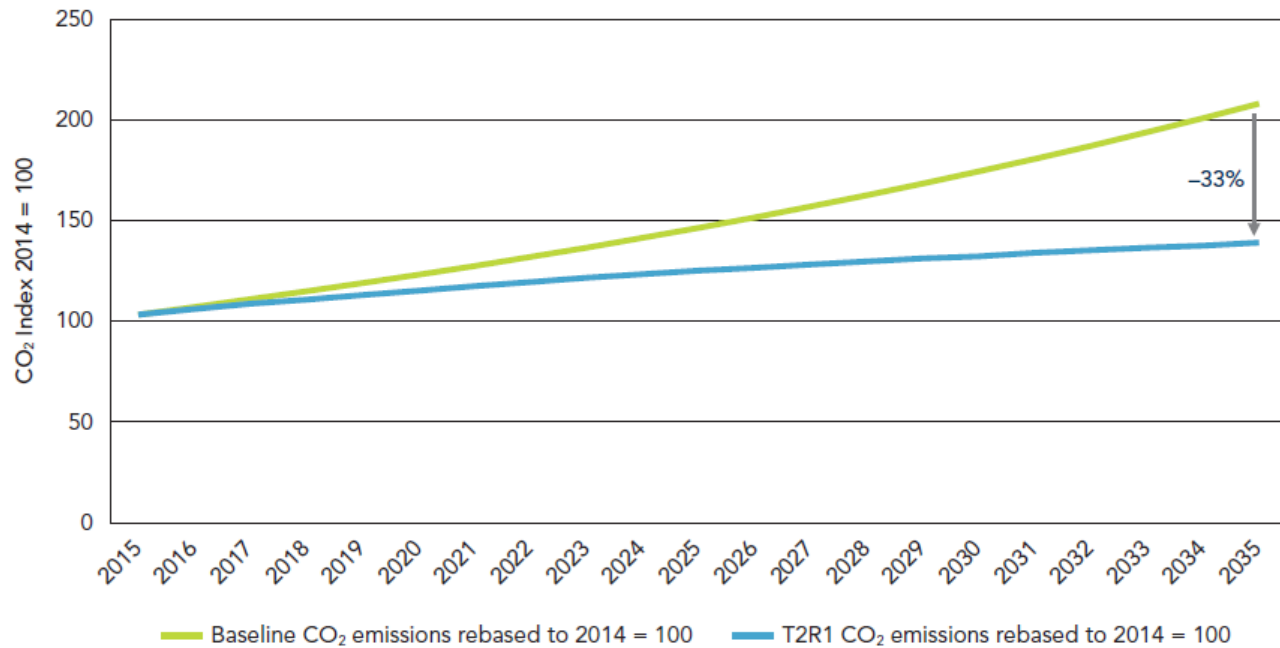
- All policy scenarios modelled are based on a carbon tax of R120/tCO₂ equiv. (before any exemptions) being imposed on all industries that use three specific fuel inputs – coal, gas and petroleum
- The 60% to 70% tax-free allowance, which includes the basic and trade-exposure exemptions, was modelled
- Performance offset and carbon budget allowances were not modelled
- Different closure settings were used to control how the tax revenue was **recycled** back into the economy, with various recycling schemes tested

TAX POLICY DESIGN

- The T2 scenario captures all the main tax design elements in the **Carbon Tax Policy Paper** with gradual removal of tax-free allowances from 2021 but exemption for the agricultural sector maintained throughout
- The R1 recycling scheme broadly targets industries/production via an output-based rebate, whilst other schemes (R2 to R5) focus more narrowly on households and renewable energy producers, with expected results
- By looking at selected policy results, particularly for the T2R4 scenario, the role of certain modelling assumption can further be highlighted and interrogated

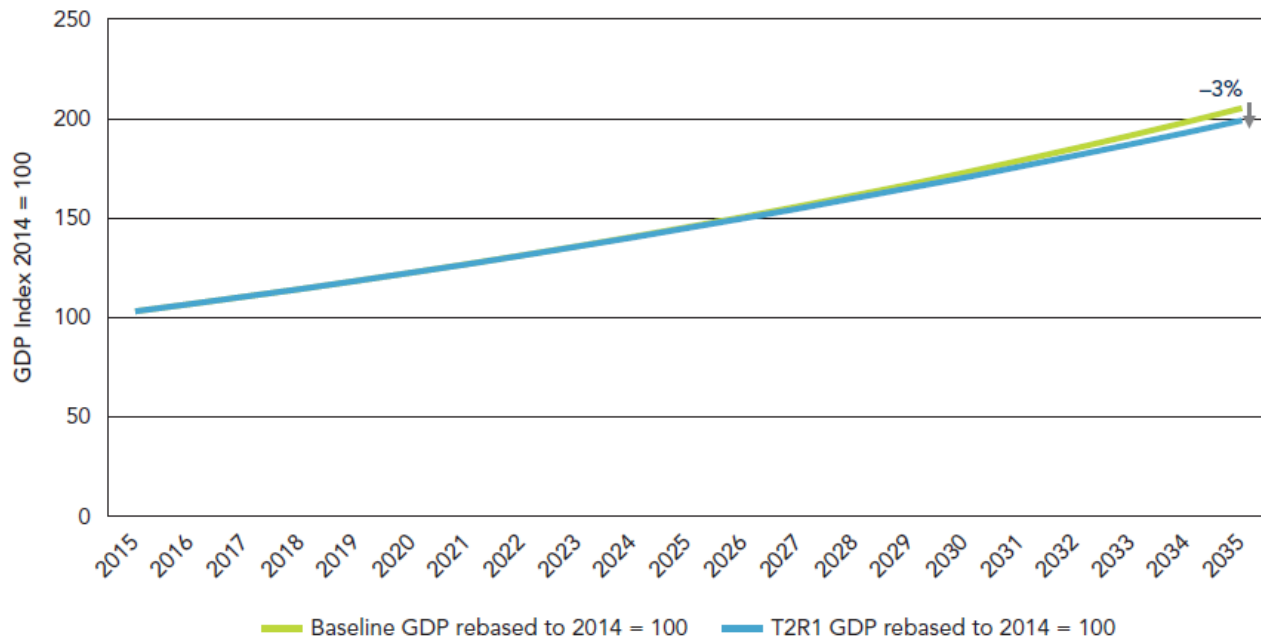
RESULTS: EMISSION REDUCTIONS

FIGURE 1. In scenario T2R1, emissions in 2035 are expected to be 33 percent lower in 2035 than under the baseline assumptions



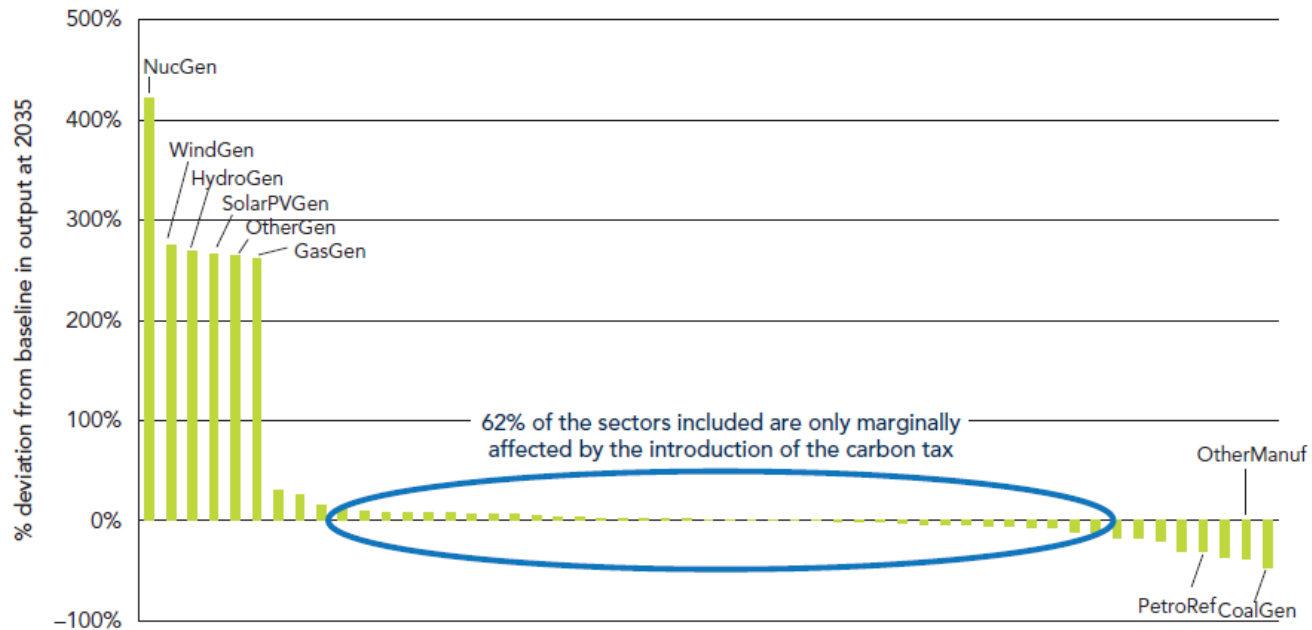
RESULTS: GDP GROWTH

FIGURE 2. In the context of the expected growth of the economy, the impact of the carbon tax is small (T2R1 scenario)



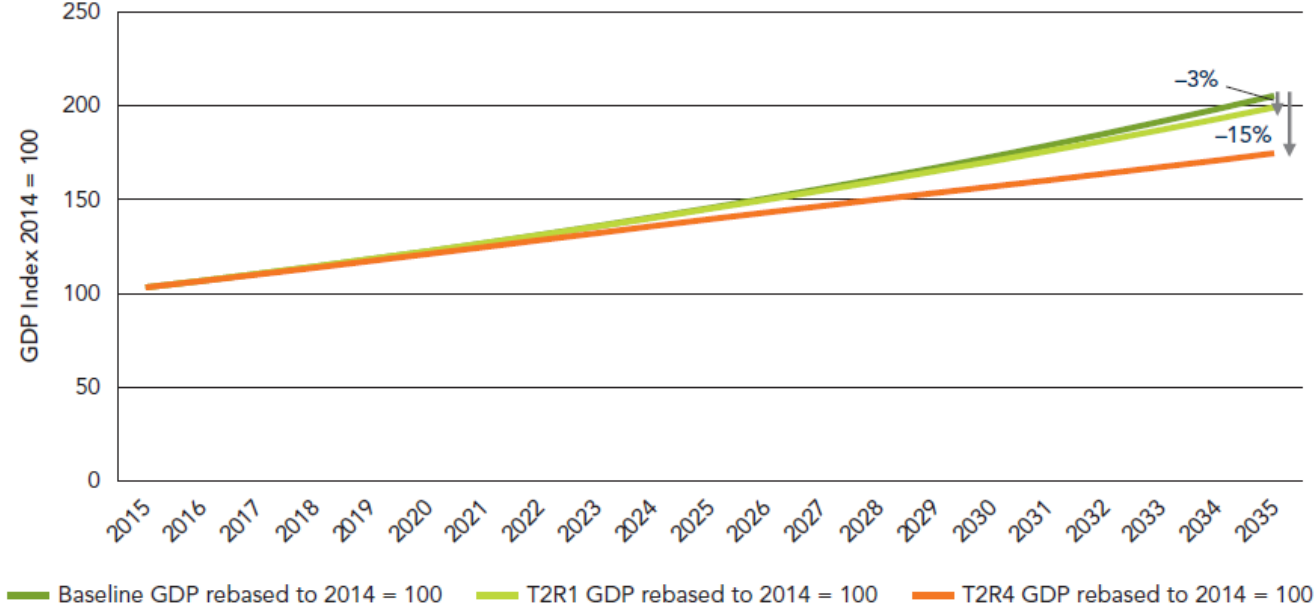
RESULTS: INDUSTRY OUTPUT

FIGURE 4. The impact of the tax, in terms of expected change in output in 2035 relative to the baseline, is small for most sectors



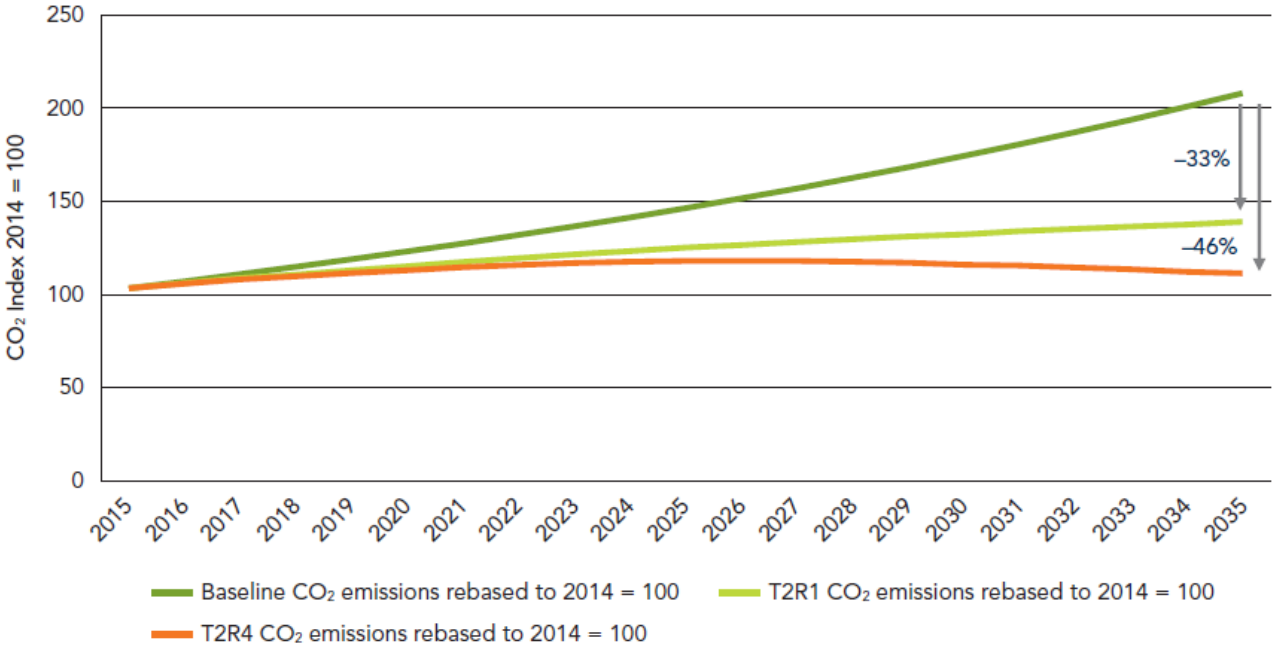
RESULTS: TAX RECYCLING CHOICES

FIGURE 8. Broad revenue recycling schemes result in smaller deviations from baseline growth



RESULTS: TAX RECYCLING CHOICES

FIGURE 9. By focusing tax revenue recycling on the renewable sector emissions can be lowered further



KEY POINTS TO REMEMBER

- Why are we doing this? To internalise the world's biggest externality and create the necessary incentives for change!
- Without even considering the benefits of counteracting climate change or efficiency gains in renewable technology, the effects of the carbon tax on most macroeconomic and industry-level variables are minimal in the long run
- When interpreting policy results, it is important not to confuse $\% \Delta$ deviation with levels outcomes, for example, to place the impact of the carbon tax into perspective, even the worst affected industry (coal) will still be larger in absolute terms in 2030
- Concerns about relative competitiveness are best overcome through appropriate policy design, and growing international action on climate change

THANK YOU



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