Welfare Consequences of Government Budget Closure Assumptions Under New Environmental Policies*

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Abstract

Computable General Equilibrium (CGE) models are commonly used tools for benefit-cost analysis of energy and environmental policy, and are used for regulatory analysis in federal agencies. Newer subsidy-based policies that generate costs to the government budget have potentially complicated the analysis of estimating the costs and benefits of environmental policies and have resurfaced questions related to the welfare and distributional consequences of closure and financing assumptions in CGE models. In this paper, we ask what are the overall welfare and distributional consequences of different closure assumptions across a range of CGE models with different dynamic behavior (static, recursive, perfect foresight) and policies (taxes, subsidies, standards)? We answer this question using data from the Wisconsin National Data Consortium (WiNDC) in a series of numerical modeling scenarios that aim to disentangle the welfare implications from alternative closure assumptions and policy types.
JEL Codes: TBD.

Keywords: computable general equilibrium; emissions cap; clean energy subsidies; clean energy standard; government budget closure

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1 Introduction

Computable General Equilibrium (CGE) models are a commonly used tool for assessing the economy-wide impacts of energy and environmental policy and is used for regulatory analysis at the U.S. Environmental Protection Agency (EPA). With recent legislation in the United States setting aside significant funding to induce clean energy investments through subsidies, using CGE models to analyze environmental regulations and policies in the energy sector has been potentially complicated by government budget impacts. In a CGE modeling setting, the government budget is typically fixed and subject to some type of closure rule (e.g., lump sum). While analysis of environmental policy in this modeling framework has always been subject to government closure assumptions, the potentially significant amount of resource shifts stemming from interactions with new subsidy-based policies have led to questions about the welfare consequences of these closure rules. In this paper, we assess the implications of closure and financing assumptions on welfare and distributional consequences across a range of environmental policies and CGE modeling types.

We use WiNDC (Wisconsin National Data Consortium) based CGE models of the United States economy to simulate the effect of alternative closure assumptions for environmental policies that have a positive (taxes), negative (subsidies), or indirect (regulatory standards) impact on the government's budget. We first model alternative closure rule assumptions in a static setting. We compare modeling outcomes when policy induced government deficits or revenues must be paid off or reallocated in the period that they occur (e.g., through lump sum or tax related mechanisms) with modeled outcomes that allow for government budget imbalances to be deferred to a later date. In this latter case in the static model, deferring repayment of policy induced government budget imbalances effectively removes the closure assumption from the short-run welfare effect of the given policy. We then model the same sets of simulations in a dynamic context under alternative temporal assumptions. We consider model simulations that not only capture alternative repayment mechanisms, but also the timing of the transfer (i.e., deferring the repayment of government debt to a later date within the model horizon). In a dynamic CGE model setting with a long enough model horizon, we can explicitly grapple with the welfare implications on the timing of debt repayment as opposed to simply deferring repayment to outside of the model domain as in the static framework. We model the same sets of environmental policies and closure rules with both perfect foresight and myopic dynamic CGE models to understand the role of anticipatory effects in the welfare implications of our considered scenarios.

This work is intended to be informative to regulators, modelers, and analysts deciding on closure assumptions and to clarify how assumptions affect overall welfare and distributional outcomes in CGE models.

2 Methodology

We explore the effect of budget closure assumptions through a set of scenarios that we describe with a scenario matrix (see figure 1). The scenario matrix has three dimensions: i) model template, ii) policy instrument class, iii) closure rule. For each model template we simulate different closure rules for each policy instrument class. This section describes the three dimensions of the scenario matrix.

2.1 CGE Model Template

The CGE model template is constructed using the 2017 WiNDC blueNOTE energy-environment benchmark dataset. The WiNDC benchmark is aggregated to a single U.S. region, 5 household income quintiles, 11 industrial sectors, and calibrated to a steady-state investment growth path.[1] We construct three models based on our CGE model template that differ by temporal treatment: a static model, recursive dynamic model, or Ramsey-based perfectly foresighted model. For comparability across model variants, where possible, we ensure a consistent set of model assumptions and employ the same benchmark economic dataset. Energy commodities coal, natural gas, crude oil, and refined oil are among those demanded by firms and households along with associated CO2 emissions. The electricity sector is further disaggregated into clean and dirty production using electricity generation data from the State Energy Data System (SEDS).[2] Primary fuel and clean electricity production sectors employ a fixed-resource factor that is calibrated to ensure upward-sloping supply. The benchmark economy also accounts for existing taxes and subsidies on capital income, labor income, production, consumption, and imports.

The US is a small-open economy with international trade categorized by an Armington composite of foreign and domestic varieties. Household consumption and sectoral production are modeled using nested constant elasticity of substitution (CES) functions in the calibrated-share form. Each production sector employs a combination of intermediate goods, capital, labor, and a fixed resource factor to produce output. Capital markets are perfectly mobile across sectors within the US, but immobile internationally — capital is in-elastically supplied at the national level. Labor is restricted to the same mobility assumptions as capital, however it is supplied through a time endowment that can be used for either labor or leisure — household labor supply is elastic at the national level. Each household consumes a bundle of commodities and leisure.

Full consumption, the composite household consumption index consisting of goods and leisure is used to measure welfare and distributional effects. Households consume this index using income generated from their time (labor and leisure), capital, and resource endowments as well as government transfer payments. Two types of government transfer payments exist, those that exist in the benchmark economy and those that arise due to a counterfactual policy and associated government budget closure rule. In each model, the US government is subject to a closure rule, but is generally responsible for collecting tax revenues and dispersing subsidies, transfers to households, and consuming for the public good.

[1] The steady-state growth path is defined by a depreciation rate of 5%, interest rate of 4%, and growth rate of 2%. The underlying social accounting matrix is re-calibrated to align capital demands and investment according to our steady-state assumptions.

[2] The existing electricity sector is disaggregated based on the renewable energy generation share of total generation. Then fossil fuel inputs are moved from the clean- to dirty-side and capital input moved from the dirty- to clean-side to balance.

These model templates differ in their treatment of capital investment. All else equal, the static and recursive models assume a constant marginal propensity to save (CMPS) function. The static model is just a base-year solve of the recursive model. The recursive model updates the capital stock between solve years via an accumulation function, whereas the Ramsey model optimizes around the present value of final consumption with investment and capital stock accumulation embedded into the intertemporal optimization problem.

2.2 Policy Instrument Class

Three policy instrument classes are considered that differ by their impact on the government's budget. We use carbon pricing to proxy for policies that have a direct positive effect on the government's budget, a clean energy subsidy that has a direct negative effect on the government's budget, and clean energy standard that is representative of policies that only impact the government's budget through indirect means (e.g., changes in tax revenues through shrinking or expanding industries). Figure 2 describes three policy instruments chosen to reflect a policy instrument class, respectively. All of these policies are levied against the electricity sector and are designed to target the same raw policy value of $50 billion USD in the model base year. We chose to hold direct policy balancing costs consistent (rather than model emissions equivalency) to better assess a given policy's effect across closure assumptions.

The first row shows the carbon pricing mechanism which is modeled as an emissions cap (CAP) set to produce a pre-specified revenue target. The revenues generated create a government budget surplus that is balanced with a closure rule. The second row shows the clean energy standard (CES) set to produce a pre-specified net clean subsidy target. The CES implicitly balances direct revenues and costs via a net-subsidy to clean electricity production (non-CO2 emitting generating technologies) and a net-tax on dirty electricity production (CO2 emitting generating technologies), but produces an indirect effect on the government budget which is balanced with a closure rule. A clean energy standard is a natural proxy for many of the technology or emissions-based regulatory standards in the United States, where installation or use of pollution control equipment is required as part of the standard but has no direct impact on the government's budget. The use of a CES standard considers a case that only indirectly impacts government revenues and costs while maintaining some level of consistency in the size of the policy shock across modeling scenarios. The last row shows the subsidy-based mechanism which is a clean energy subsidy (CLSUB) set to produce a pre-specified raw target value of $50 billion USD in the base year. The subsidy-induced budgetary shortfall is balanced by a closure rule.

2.3 Budget Closure Rules

To complete description of our policy experiment, each policy instrument must be paired with a government budget closure assumption described in figure 3. Each of these closure rules is effectively a government budget neutrality constraint that ensures the government budget is balanced via a chosen balancing variable. Specifically, this balancing variable is endogenously adjusted to maintain a fixed level of government commodity demand. Closure options assumed in this study can generally be categorized as a variant of a lump sum transfer, changes to a pre-existing market distorting tax rate, changes to government spending, or changes to the deficit/surplus.

The budgetary effects of the policy instruments in figure 2 can be broken into two components: i) direct balancing, which reflects the revenue or cost directly attributable to the policy itself (i.e., \$50 billion USD in the CAP and CLSUB scenarios); ii) indirect balancing, the indirect effect of the policy on the government budget after taking the direct policy value into account -– any additional balancing required to maintain budget neutrality. For the CAP and CLSUB policies, the budget closure constraints imply that direct and indirect balancing are covered by the same closure mechanism. While it is possible to model different combinations, we chose to combine them to reduce dimensions of the scenario matrix. The CES policy provides a special case that allows us to isolate the effects of different indirect balancing mechanisms since only the indirect portion of the policy is covered by the closure rule. Figure 1 reports the scenario matrix. We refer to this scenario matrix when discussing results in later sections.

3 Core Closure Results

In this section, we discuss the welfare and distributional results associated with the core model closure assumptions (i.e., all but debt financing closures), first within the static model and then across model templates. These core closure rules ensure balance in each period over the modeled horizon.

Figure 4 shows the changes in welfare, distributional impacts, and changes in emissions for the static model across policy instruments and closure assumptions relative to a business as usual baseline (BaU). The horizontal axis contains the respective scenario from the scenario matrix in "policy_closure" format. The left vertical axis contains the percentage change in total welfare[3] and by household (columns) as well as the percentage change in the Gini coefficient (dots). An increase (decrease) in the Gini coefficient indicates the policy is regressive (progressive). The right vertical axis shows the percentage change in electricity sector co2 emissions (line).

The overall welfare effects are negative, except for the clean subsidy cases where policy costs are unaccounted for (CLSUB_JPOW and CLSUB_TRNFX). The extreme differences shown in these deficit/surplus cases highlight the need for a careful consideration of the timing of budgetary balancing and the use of debt instruments. The lowest income groups are subject to large relative swings in equivalent variation (EV) as a dollar of extra income has a larger percentage impact for lower income groups. The highest income group also seems to be noticeably sensitive. This also be could be due to the lack of diversification in income sources with most of HH1's income derived from government transfer payments and HH5's from capital income.

Under the emissions cap, lump-sum equal redistribution to households (CAP_LSPTAX) is pro-

[3] Equivalent variation (EV) is the welfare measure and does not include avoided damages from co2 emissions. EV is the amount consumers would be willing to pay to avoid the policy counterfactual.

gressive indicated by the negative Gini coefficient delta and confirmed by the negative sloped profile of the sequential household welfare columns. The opposite is true of the clean subsidy case with equal lump sum tax (CLSUB_LSPTAX) where the Gini coefficient delta is positive and positive sloped profile of the sequential household welfare columns. In theory, the LSGINI closure instrument could be used to force distributional equivalence between the emissions cap and clean subsidy with little cost to overall welfare. Overall, most policies show a regressive trend.

Based on the CES results – a special case that isolates indirect balancing effects – the indirect policy balancing seems to have only small effects across closures. These can be meaningful effects in extreme cases where the lowest income groups bear the burden (benefit) of the tax (transfer). Also, the pattern of the Gini coefficient for the CES_LSGINI, CES_LSITAX, and CES_LSPTAX indicates that the CES results lead to an indirect budget surplus.

The clean subsidies still appear regressive under the JPOW and TRNFX closures, which isn't necessarily expected. While the subsidies lower the cost of electricity to consumers, they also cause a large positive shock to the economy and induce a shift towards capital intensive technologies. This positive shock causes non-energy commodity prices to rise which negatively effects household budgets. The combined effect of income shifting more towards capital returns and rising non-energy prices induces a regressive effect.

Given identical direct raw policy targets of $50 billion USD, the CAP achieves the most emissions reductions, the CES next most, followed by the CLSUB cases. This speaks to each policy's ability to achieve a level of emissions reductions given a fixed dollar amount that it can use to tax or subsidize. However, when taken in the context of average abatement cost in USD/ton of co2 this observation is less clear. Figure 6 shows average cost of co2 abatement in USD/ton of CO2 – calculated as the raw equivalent variation in USD divided by electricity sector emissions avoided in tons.[4] Comparing the policies for each closure results in an ambiguous policy ranking. In most cases, the cap achieves emissions reductions at the lowest average cost. However, for the KTAX closure, the CLSUB case achieves emissions reduction at lowest average cost. The CLSUB case beats the CES case in many instances as well. While interesting, average abatement cost is not the preferred metric for assessing cost-effectiveness; a proper comparison would force emissions equivalency between these policies, a comparison outside the scope of this paper. The variability here does indicate the importance of properly capturing the distortionary behavior of the tax system, specifically related to income taxes and potential interactions of other closures such as those on capital and labor supply. All things considered, certainly figure 4 suggests that the closure rule is not a main determinant of emissions reductions.

Figure 7 shows the change in total welfare, Gini coefficient, and emissions across model templates. Figure 7 only shows emissions from the static model as they are grouped very tightly across model templates – the model template and closure rule are not major determinants of emissions reductions. The total welfare effects move in the same direction across model templates but are more pronounced in most cases for the dynamic templates. The Gini coefficients are very tightly clustered for the static

[4] Similar trends exist when using economy-wide emissions instead of electricity sector emissions

and recursive models but the Gini coefficient for the Ramsey model deviates quite significantly. The Ramsey Gini coefficient is generally more regressive except in the CAP_KTAX and CLSUB_TRAN cases. Comparing the KTAX closure for the CAP and CLSUB cases, the change to the capital tax rate is driving the more progressive benefit in the CAP and more regressive cost to the CLSUB for the Ramsey model due to more elastic capital supply (QC??).

Figure 7 indicates that income tax revenue recycling is preferred to lump sum for the CAP, but that revenue recycling via labor tax reductions are preferred to capital tax reductions, which is contrary to the findings of recent literature.[5] This is likely due to interactions with factor market closure and relative elasticity of capital supply versus labor supply. In the literature, capital supply is assumed to be relatively elastic and overtaxed relative to labor supply leading the model to prefer recycling cap revenues with capital tax reductions. However, due to relatively inelastic capital supply our core cases indicate labor tax reductions to be preferred to capital tax reductions. In the CLSUB cases, this behavior drives a preference towards an increasing capital tax rate over labor tax rate.[6]

4 Debt Closure Results

TBD.

5 Discussion

TBD.

Acknowledgements

TBD.

[5]The ranking of capital vs labor tax recycling needs further investigation to ensure the model is better parameterized or to better understand the assumptions or economic forces driving this behavior.

[6]See appendix for a static counterfactual with perfectly elastic capital supply – shows capital tax recycling preferred to labor tax recycling under a cap, and the opposite under a clean subsidy.

References

6 Figures

Scenario Matrix - Static, Recursive, Ramsey

Closure Rule	Policy Instrument: CAP	CES	CLSUB
JPOW	CAP_JPOW	CES_JPOW	CLSUB_JPOW
TRNFX	CAP_TRNFX	CES_TRNFX	CLSUB_TRNFX
KTAX	CAP_KTAX	CES_KTAX	CLSUB_KTAX
LTAX	CAP_LTAX	CES_LTAX	CLSUB_LTAX
LSGINI	CAP_LSGINI	CES_LSGINI	CLSUB_LSGINI
LSITAX	CAP_LSITAX	CES_LSITAX	CLSUB_LSITAX
LSPTAX	CAP_LSPTAX	CES_LSPTAX	CLSUB_LSPTAX
TRAN	CAP_TRAN	CES_TRAN	CLSUB_TRAN

Figure 1: Scenario Matrix

Policy Instrument	**Coverage**	**Description**
CAP	Electricity	Emissions cap set to produce a pre-specified revenue target. The revenue from the CAP creates a budget surplus balanced with a closure rule.
CES	Electricity	Clean energy standard set to produce a pre-specified revenue target. The CES implicitly balances direct revenues/costs via a net-subsidy to clean and net-tax on dirty but produces an indirect effect on the budget which is balanced with a closure rule.
CLSUB	Electricity	Ad-valorem clean subsidy set to produce a pre-specified raw $ target value. The subsidy-induced budgetary shortfall is balanced by a closure rule.

Figure 2: Policy Instrument Class Descriptions

Closure Rule	Balancing Variable	Description of closure assumption
BAU	Irrelevant	Business as usual - closure is irrelevant due to benchmark calibration
JPOW	Deficit/surplus	Deficit/surplus balances the budget with no intention to repay or distribute to households
TRNFX	Govt Spending	Govt spending balances the budget but does not affect household utility
KTAX	Capital income tax rate	Increase/decrease in capital income tax rate to balance budget
LTAX	Labor income tax rate	Increase/decrease in labor income tax rate to balance budget
LSGINI	Lump-sum tax/transfer	Lump-sum tax/transfer to households maintains a target Gini coefficient and government budget balance
LSITAX	Lump-sum tax/transfer	Lump-sum tax/transfer to households proportional to household income share of total income balances budget
LSPTAX	Lump-sum tax/transfer	Lump-sum tax/transfer in equal payments to each household - population-based - to balance budget
TRAN	Transfer payments	Proportional adjustment to benchmark transfer payments maintains budget balance

Figure 3: Closure Descriptions

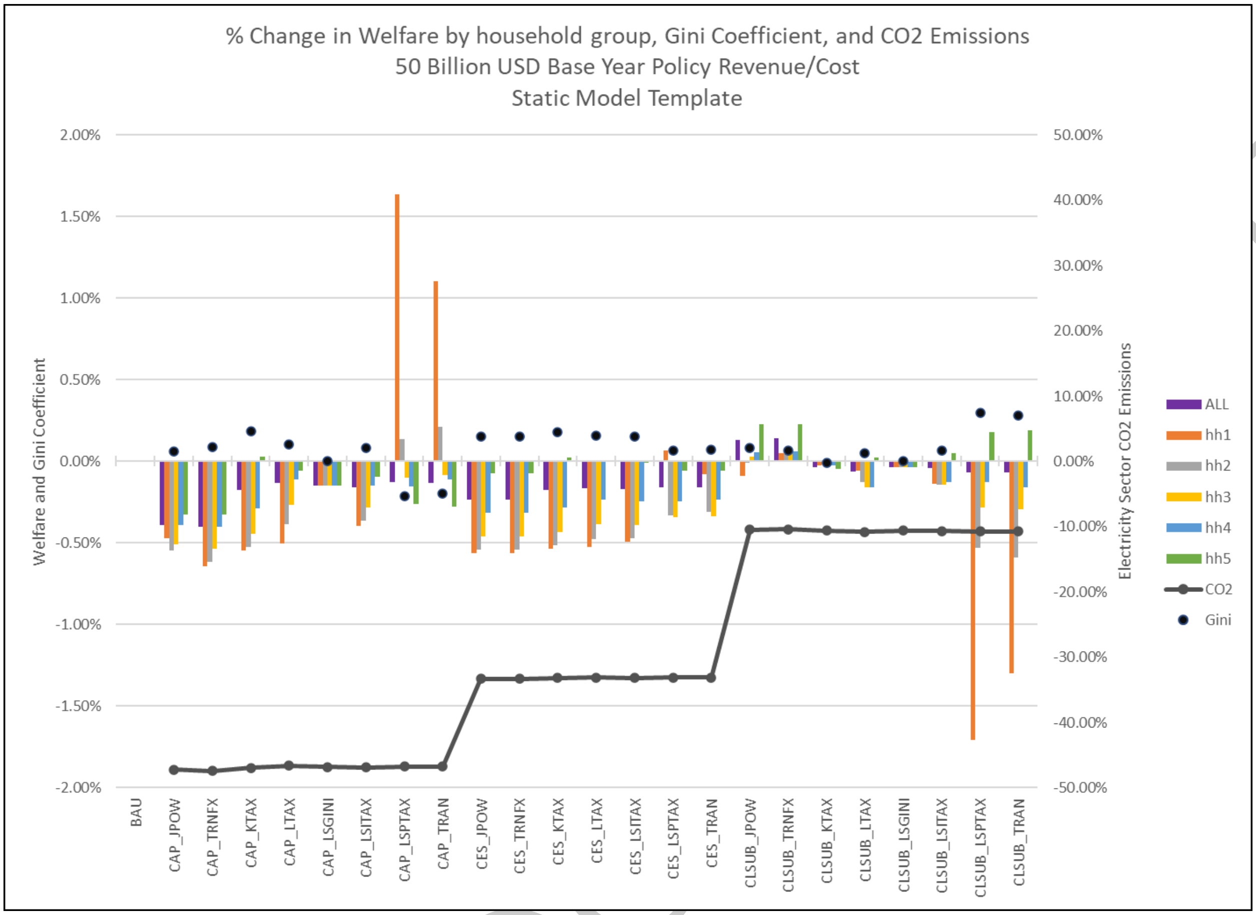

Figure 4: Static model welfare and distributional comparison

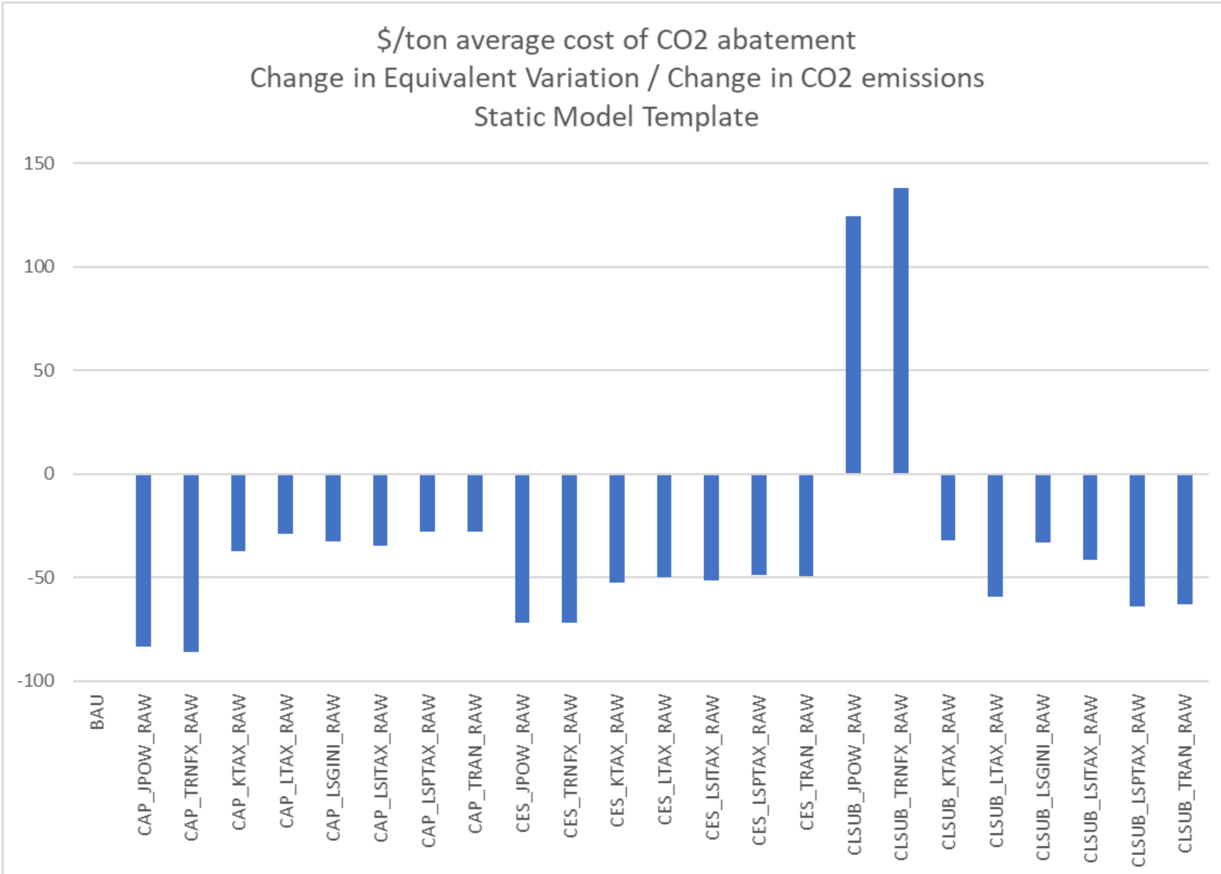

Figure 5: Static model average cost of co2 abatement

Static - $/ton average cost of CO2 abatement

	CAP	CES	CLSUB
JPOW	-83.32	-71.95	124.59
TRNFX	-86.28	-71.95	137.88
KTAX	-37.45	-52.80	-32.04
LTAX	-29.17	-49.76	-59.15
LSGINI	-32.64		-33.13
LSITAX	-34.74	-51.76	-41.32
LSPTAX	-27.94	-49.16	-64.04
TRAN	-28.19	-49.34	-62.96

Figure 6: Static model average cost of co2 abatement

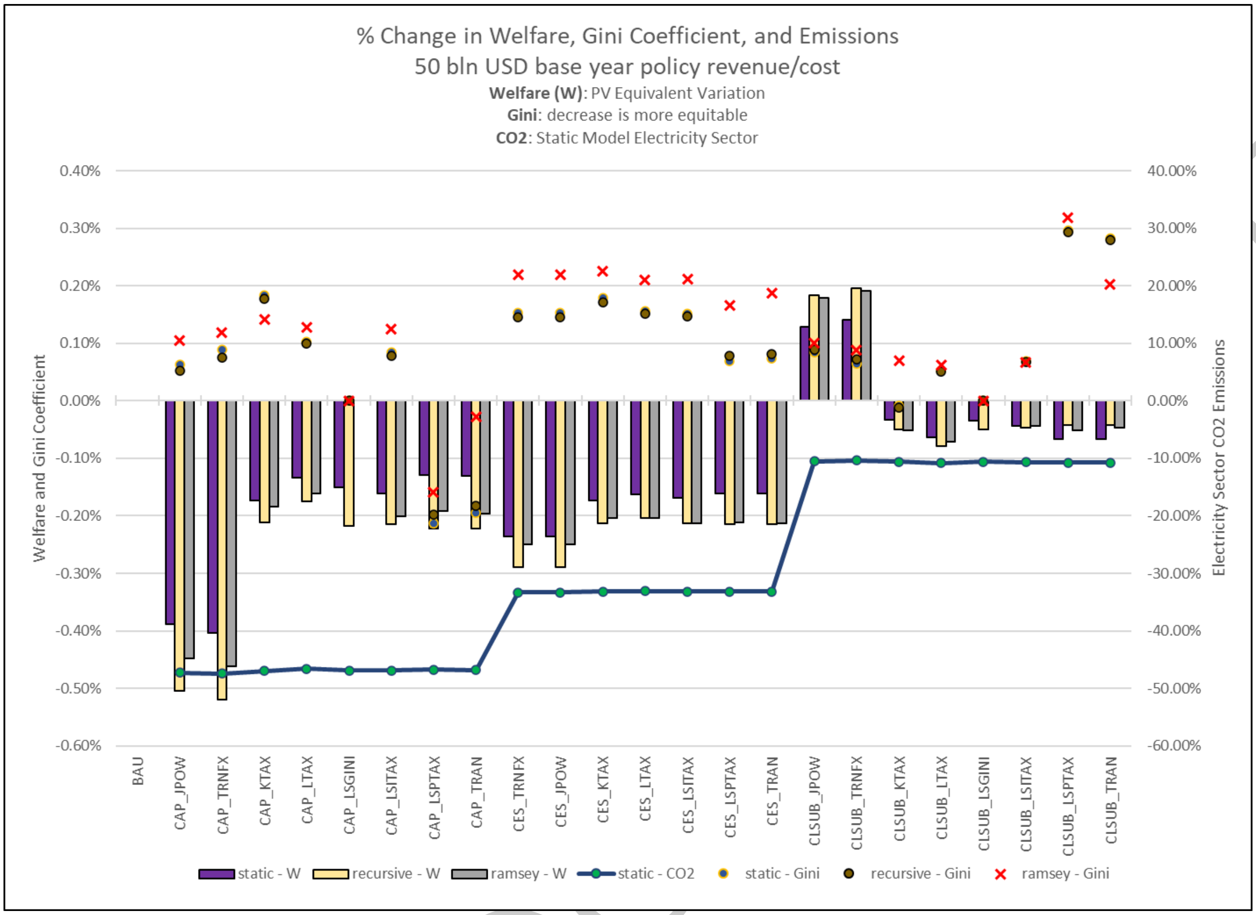

Figure 7: Core closure scenario comparison

A Select Nesting Diagrams

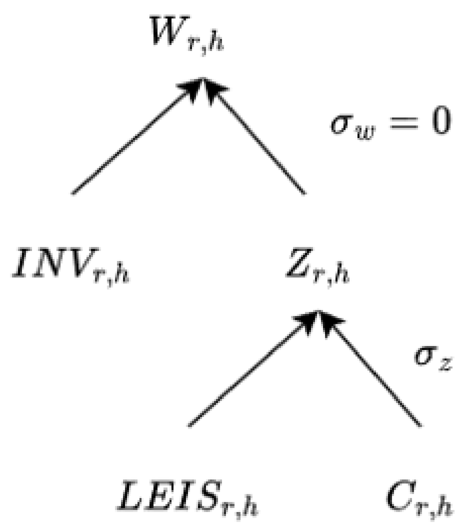

Figure 8: Household Consumption and Savings Nesting

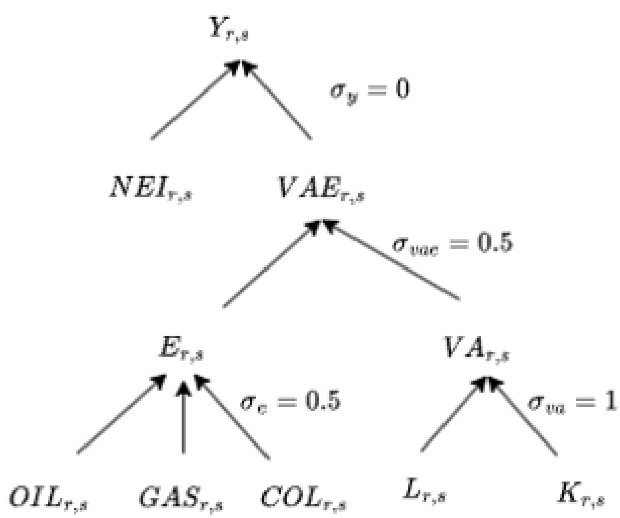

Figure 9: Non-electricity Production Nesting

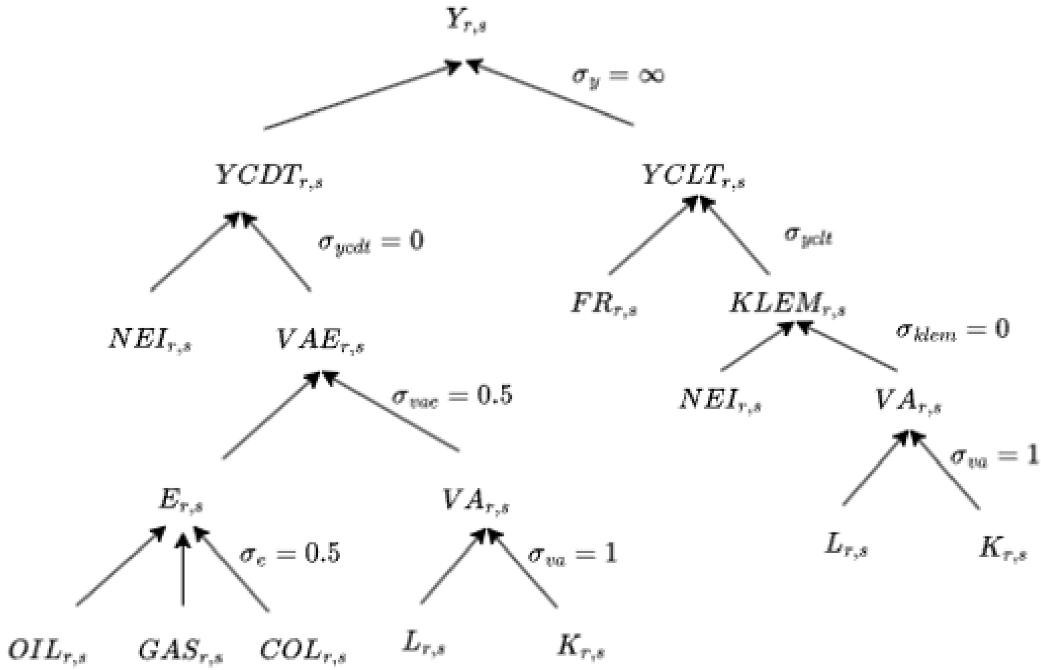

Figure 10: Electricity Production Nesting