Economy-wide impacts of output-based permit allocations in emissions trading schemes

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Abstract

Emissions trading schemes (ETSs) in many jurisdictions offer a free output-based allocation (OBA) of emissions permits to selected energy-intensive sectors to reduce the burden of emissions pricing. Most analyses of the impact of OBAs relative to grandfathering or auctioning permits focuses on the US economy. This paper examines the economy-wide impacts of OBAs using a stylized model that is calibrated economies with different relative sizes of energy-intensive sectors while other factors are held constant. The results show that OBAs lead to larger increases in carbon prices and welfare costs from reducing emissions (1) the larger the relative size of sectors that receive OBAs, (2) the tighter the emissions cap. We also find that some emissions reduction targets are infeasible when the size of sectors that receive OBAs is sufficiently large. Jurisdictions considering OBAs should carefully consider the economy-wide impacts of this allocation method before enacting policies.

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1. Introduction

Emissions Trading Scheme (ETSs) are a key policy mechanism to reduce greenhouse gas (GHG) emissions in many jurisdictions. In ETSs, emissions permits are commonly auctioned or allocated for free either by grandfathering them or offering an output-based allocation (OBA). Under a grandfathering allocation, firms receive a certain number of permits each year. When there is an OBA, firms receive a certain number of permits per unit of output. Free OBAs are typical offered to emissions insensitive trade exposed (EITE) firms to compensate them for increased costs and/or reduce leakage.

As is well known, an OBAs provides an implicit subsidy that increase the output and emissions from firms that receive them relative to when permits are auctioned or grandfathered (Fischer and Fox, 2007). This is because more emissions from sectors that receive OBAs means that other sectors must increase their abatement to meet the ETS cap on emissions, which requires a higher carbon price. Ultimately, this results in higher welfare costs of meeting emissions constrains when there is OBA relative to grandfathering or auctioning.

Several studies have investigated the economic impacts of OBAs – see Quirion (2022) for a review of this literature. Böhringer et al. (2012) and Böhringer et al. (2014) show that border carbon adjustments are better at addressing competitiveness concerns for EITE sectors than OBA. Böhringer et al. (2017) analyse the efficiency of policies to alleviate competitive disadvantages on EITE sectors due to carbon pricing. They find that protective measures can alleviate competitive concerns in EITIE facing carbon prices, they increase the cost of climate policy. In comparing alternative measures, they find that OBAs increase the welfare costs of reducing emissions compared to both energy intensity standards and carbon intensity or standards.

Böhringer et al. (2023) compare the impacts of OBA with those from abatement-based rebating (where permits are, effectively, allocated to firms based on additional abatement), and intensity-based rebating (where permits are allocated to firms based on their emissions intensity relative to a performance benchmark). They find emissions abatement in EITE sectors is up three times higher when there is abatement-based or intensity-based rebating relative to when there is an OBA.

Fischer and Fox (2007) examine how OBA can address second-best efficiency issues from pre-existing labour taxes relative to grandfathering. The authors find that, relative to grandfathering, OBA results in lower prices for consumption goods. The lower prices increase the cost of leisure and result in lower deadweight loss from labour taxes when there is OBA instead of grandfathering. In their simulations, this gain outweighs the distortions due the higher carbon price under OBA.

Many studies – including all of those cited above – analyse the US economy; however, this country does not have a national ETS (or carbon price), but ETSs have been enacted in 37 jurisdictions and are under development or consideration in 24 other administrations (World Bank, 2024). Consequently, this paper explores the impacts of OBAs under alternative economic structures. Specifically, we vary the size of EITE sectors (which receive an OBA) in the economy in a stylized economy-wide model while holding other factors constant. We estimate how OBAs impact the emissions price, sectoral output, GDP, and welfare relative to when permits are auctioned.

The emissions price and the welfare cost of reducing emissions are higher under OBA than auctioning/grandfathering in all parametrizations of our model. We find that the increases in the carbon price and welfare costs of reducing emissions is higher (1) the larger the relative size of EITE sectors in the economy, (2) the higher the allocation rate (free permits per unit of output), and (3) the tighter the emissions cap. The results also show that OBAs may also make it impossible to meet a desired emissions cap and conditions that increase the welfare costs of OBA also make it more likely for this to happen. We conclude that the economy-wide impacts of output-based permit allocations should be carefully considered by policymakers when setting ETS rules.

This paper has three further sections. The next section details the modelling framework used for our analysis. Section 3 presents and discusses results from the simulation exercises. The final section concludes.

2. Modelling framework

The economy-wide model

To examine the impact of OBA allocation in a simplistic setting, we construct a stylized economy-wide model. Each sector in the model is perfectly competitive and sector specific resources are used to represent resource rents in some sectors. Final goods and services are consumed by a representative agent that encompasses private and government consumption and investment. To focus on the within-economy impacts of OBAs, the model considers a closed economy and there are no taxes or subsidies in the benchmark model.

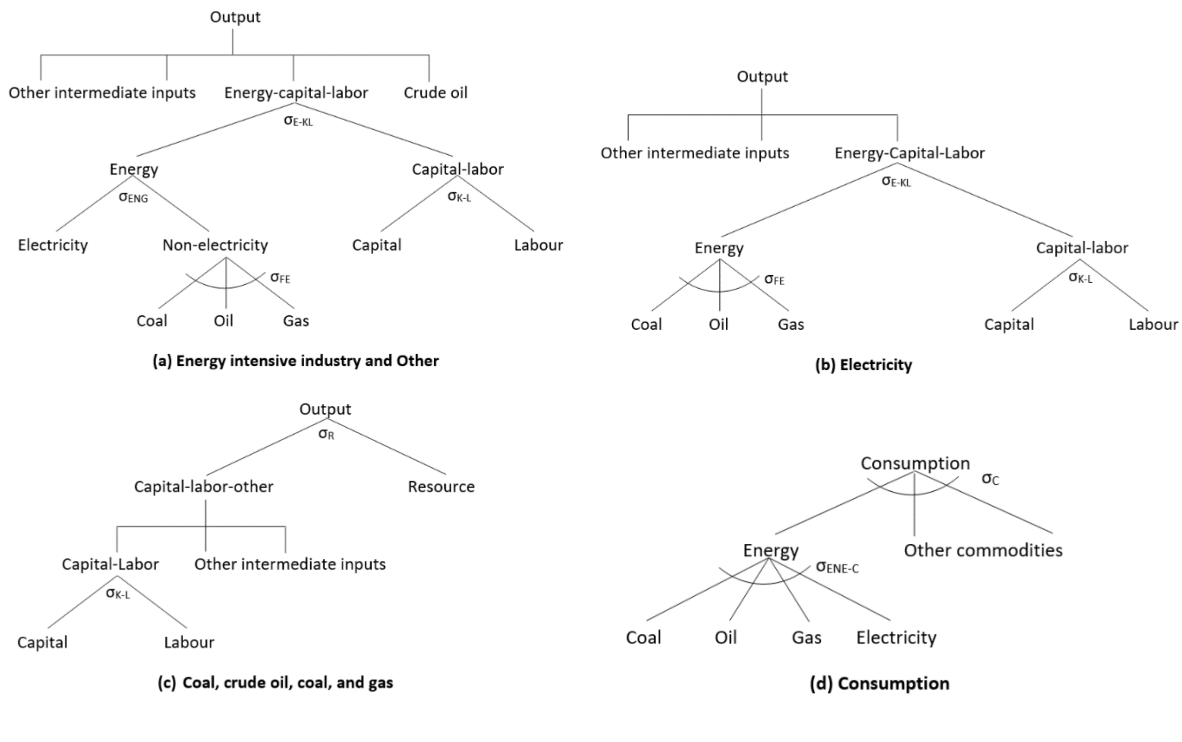
The base version of the model is calibrated to approximate the US economy. Sectors in the model are listed in Table 1. The model includes three primary energy sectors (coal, crude oil, and gas), two secondary energy sectors (refined oil and electricity). The rest of the economy classified as either energy -intensive industry (EINT) or other production. Primary factors in the model include capital, labour, coal resources, crude oil resources, and gas resources. The base social accounting matrix in displayed in Appendix A.

Table 1. Sectors in the CGE model.

	CO_2 Emissions (mt)	Output ($b)	Value added (b$)	Emissions intensity
Coal	3	42	22	0.078
Crude oil	4	299	130	0.015
Gas	78	99	60	0.791
Refined oil		375	17	-
Electricity	1677	351	167	4.779
Energy-intensive industry	232	971	282	0.239
Other production	1508	32209	19403	0.047

Each sector produces output by assembling primary factors and intermediate inputs using constant elasticity of substitution (CES) functions. The production nest for the EINT and Other sectors is shown in panel (a) of Figure 1. Emissions abatement options in these sectors include substitution among fuels, substitution between fuels and electricity, and substitution between aggregate energy and a capital-labour composite.

Figure 1. Production and consumption nesting structures.



Note: Vertical lines signify a Leontief structure where the elasticity of substitution is zero. σ_R = 0.6, $\sigma_{K\text{-}L}$ = 1, $\sigma_{E\text{-}KL}$ = 0.5 in the electricity sector and 0.6 in other sectors, σ_{ENG} = 0.5, σ_{FE} = 1, σ_C = 0.3 and $\sigma_{ENE\text{-}C}$ = 0.5.

Panel (b) of Figure 1 sketches the production nest for electricity. Producing electricity with fewer emissions is achieved by using less CO_2-intensive fuels and/or substituting capital-labour inputs for fuels. The model does not explicitly represent low-carbon electricity options, such as wind and solar, but deployment of such options is captured by producing electricity using more capital-labour and less fuels. A key nest in the production of coal, crude oil, and gas (Figure 1, panel c) is the CES function that combines a sector-specific resource and inputs. This allows the model to represent a graded resources with increasing marginal costs for mining activities.

Panel (d) of Figure 1 outlines the consumption nest of the representative agent. In this nest, there are substitution possibilities among fuels and electricity and between aggregate energy and other commodities. Elasticity values used in the production and consumption nest are listed in the notes to Figure 1 and are informed by Chen et al (2016).

Specifying an ETS and the allocation of emissions permits

An ETS is specified in the model by requiring producers in sectors included in the ETS to surrender an emission permits for each tonne of CO_2 emissions from the use of fossil fuels. For, say, coal, this is modelled by combining coal purchases and emission permits in a Leontief nest. For sectors included in the ETS, this coal-permit composite then replaces coal inputs in the in the production functions described in Figure 1.

Two approaches for assigning emissions permits are considered in the model: (1) grandfathering of permits to all included sectors, and (2) an OBA allocation to the EINT sector and grandfathering of permits to other included sectors. When all emissions permits are grandfathered, the supply of permits enters as an additional endowment in the model, with the endowed quantity equal to the cap on emissions.

When there is an OBA for the EINT sector, this sector jointly produces the EINT commodity and emissions permits in fixed proportions. The number of permits produced per unit of output is determined by the benchmark allocation rules (discussed below). There is also an endowment of permits to represent grandfathering of permits to other sectors. The number of permits grandfathered is determined endogenously in each simulation so that quantity of emissions permits grandfathered plus the number of permits ‘produced’ by the EINT sector is equal to the (exogenous) emissions cap.

Scenarios

All scenarios in the modelling analysis implement an ETS that covers (only) the electricity and EINT sectors (henceforth known as ETS sectors). The scenarios differ with respect to (1) rules for allocating emissions permits, (2) the reduction in emissions from ETS sectors relative to the benchmark, and (3) the share of EINT emissions in total emissions from ETS sectors. As noted above, we consider two alternative rules for allocating emissions permits: grandfathering permits to both the EINT and electricity sectors, and an OBA allocation to the EINT sector and grandfathering of permits to the electricity sector. For ease of reference, we henceforth refer to former as "grandfathering" and the later as "OBA". The allocative baseline (free allocation per unit of output) for OBA simulations is equal to direct emissions in the EINT sector plus indirect emissions from electricity used by the EINT sector.

The scenarios simulate proportional reductions in emissions from ETS sectors relative to the benchmark, denoted φ, of 10%, 20%, 30%, 40%, 50%, and 60%. We calibrate the model to SAMs with the following EINT emissions shares in total ETS emissions, denoted α: 0.12, 0.2, 0.3 and 0.4. To consider all combinations proportional reductions in ETS emissions (φ values) and EINT emission shares, we simulate 48 scenarios.

3. Results

Results for alternative energy intensive emission shares and reductions in emissions from ETS sectors are presented in Table 2. When there is a 20% emissions reduction and $\alpha = 0.12$, the carbon price per tonne of CO_2 is $25.59 when EINT permits are grandfathered and $25.62 when there is an OBA allocation of EINT permits (a 0.1% increase). Emissions from ETS sectors is the same under both allocation methods by design. Under these settings, moving from grandfather EINT permits to an OBA allocation results in a larger welfare loss, more EINT emissions, and fewer electricity emissions, as expected. However, these changes represent small proportion changes – for example, the welfare loss increases by 0.02% when there is an OBA and the change in electricity emissions is only visible at two or more decimal places. When EINT sectors account for 40% of benchmark ETS emissions ($\alpha = 0.4$) and ETS emissions are reduced by 20%, changes due to OBA are larger than when $\alpha = 0.2$. For example, moving from auctioning to an OBA allocation increases the carbon price by 2.3% and the welfare loss by 2.0%.

Table 2. Stylized model results for alternative allocations of EINT permits for alternative emissions reductions and EINT shares.

	Grandfathering	**OBA**	**Grandfathering**	**OBA**
	$\boldsymbol{\alpha = 0.12}$		$\boldsymbol{\alpha = 0.4}$	
	20% reduction in emissions from covered sectors			
CO2 price ($/t)	25.59	25.62	33.71	34.48

Welfare change (B$)	-4.353	-4.354	-8.23	-8.39
EEI emissions (Mt)	207.8	207.9	986.3	990.0
Electricity emissions (Mt)	1,319.8	1,319.8	1,249.6	1,245.9
ETS emissions	1,527.6	1,527.6	2,235.9	2,235.9
Implicit output subsidy	-	1.0%	-	1.7%
		40% reduction in emissions from covered sectors		
CO2 price ($/t)	84.38	84.58	119.65	126.71
Welfare change (B$)	-23.542	-23.551	-46.890	-49.005
EEI emissions (Mt)	175.6	175.7	807.6	816.8
Electricity emissions (Mt)	970.1	970.0	869.3	860.1
ETS emissions	1,145.7	1,145.7	1,676.9	1,676.9
Implicit output subsidy	-	3.2%	-	6.1%

Larger emissions reductions lead to higher emissions prices and larger welfare losses but also increase the impacts of OBA permit allocations relative to grandfathering. For example, when permits are grandfathered and $\alpha = 0.2$, the carbon price required for a 40% reduction in emissions is \$84.38/tCO_2 (compared to\$25.59 for a 20% emissions reduction), and an OBA of permits increases the carbon price by 0.2% (compared to 0.1% for a 20% emissions reduction).

The largest OBA impacts in Table 2 are when ETS emissions are reduced by 40% and $\alpha = 0.4$. In this scenario, moving from an OBA to grandfathering increases the permit price by 5.9% and the welfare loss by 4.5%.

To explore the impacts of OBAs in more detail, the carbon price and the welfare cost for alternative (feasible) emissions reductions and EINT emission shares are display in Figures 2 and 3, respectively. The results reinforce those in Table 2: OBA allocation results in larger increases in the carbon price and larger welfare costs and the impacts are larger (1) the larger the reduction in emissions, and (2) the larger the share of EINT emissions in the ETS.

The simulations also reveal that increasing the share of EINT emissions has a larger impact than increasing the emissions cap. For example, when the share of EINT emissions is 0.2 and there is a 40% reduction in emissions, OBA increases the welfare cost of the ETS by 0.7%. Increasing the EINT share by 50% (to 0.3) increases the welfare of cost of OBA to 3.0% and increasing the emissions reduction by 50% (to 60%) the increases welfare cost to 2.3%.

The model is unable to solve when emissions are reduced by 60% and share of EINT emissions is 0.3 or 0.4, or when the emissions are reduced by 50% and the share of EINT emissions is 0.4. This reveals that when the EINT sector accounts for a notable share of emissions and receives an OBA allocation, deep emissions cuts are not feasible. The largest solvable impacts of OBA are when the EINT sector accounts for 30% of emissions and emissions are reduced by 50%. In this simulation, OBA increases the carbon price by 6.9% and the welfare cost by 5.3%.

Figure 2. Carbon price changes for alternative EINT emissions shares.

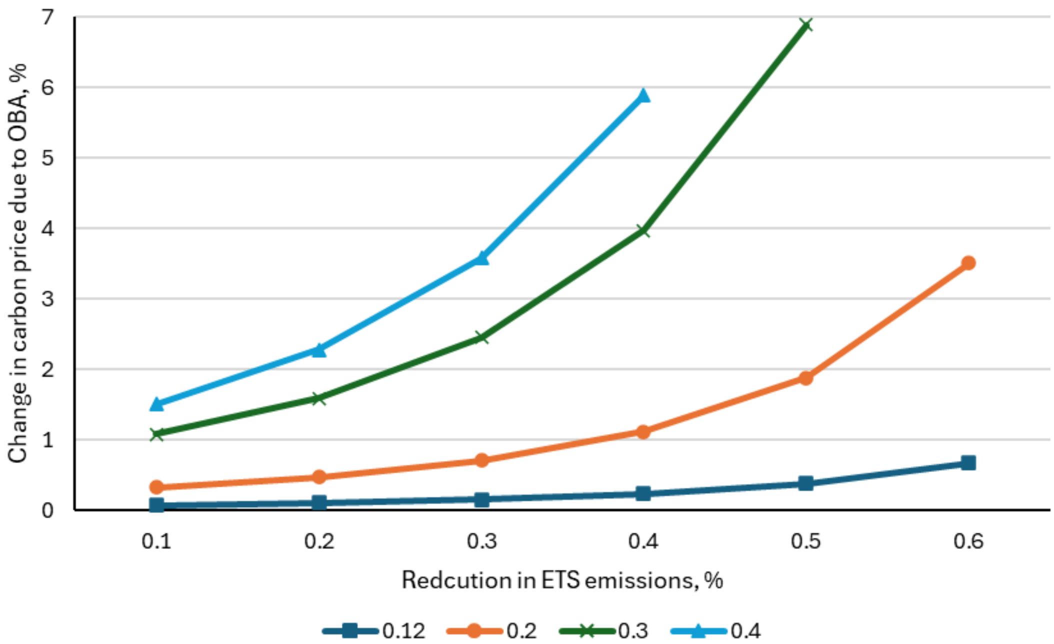
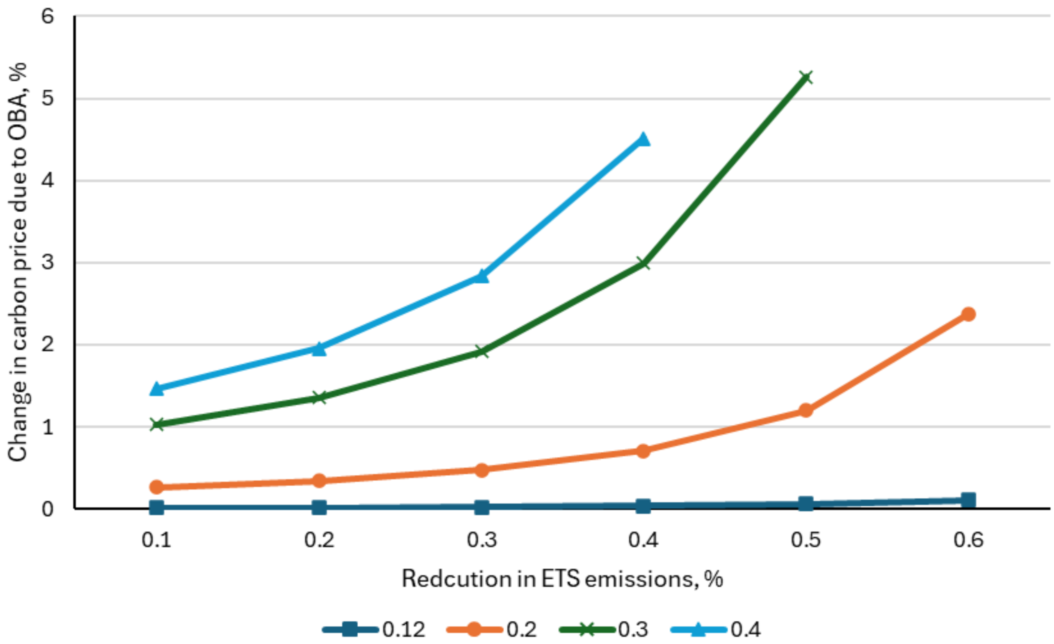


Figure 3. Changes in welfare costs for alternative EINT emissions shares.



4. Conclusions

ETSs in many junctions offer free OBAs of emissions permits to reduce impacts on sectors that are energy-intensive and exposed to international trade. It is well known that, absent other distortions, OBAs increase both the carbon price and welfare of reducing emissions. Most studies that analyse the economy-wide impacts of OBAs consider the (aggregate) US economy. To evaluate the impact of OBAs in a more general setting, we developed a deployed a stylized economy-wide model that allowed us to vary the relative size of sectors that receive OBAs while keeping other factors constant. Our results show that, relative to auctioning or grandfathering, OBA increases carbon prices and the welfare costs of reducing emissions are larger the greater the relative size of sectors that receive OBAs. These increases are exacerbated for tighter emissions cap. We also found that when sectors that receive OBAs are relatively large the model is unable to solve for emissions targets that are sufficiently stringent. Overall, our results show that the economy-wide impacts of OBA should be carefully evaluated before deciding on the appropriate policy mix, and that countries will need to move away from OBAs to achieve deep emissions cuts consistent with long-term climate pledges, such as net zero emissions targets.

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Appendix A

Table A1. Social Accounting Matrix for the CGE mode, billions of USD.

Output/Input	Sector							
	Coal	**Crude Oil**	**Gas**	**Oil**	**Electricity**	**EINT**	**Other**	**Household**
Output	41.52	299	99	375	351	971	32209	
Gas			-5	-18	-33	-14	-21	-8
Electricity		-3	-3	-8	-23	-28	-228	-58
Oil	-0.5	-1	-1	-22	-4	-35	-190	-121.5
Coal	-0.02				-38	-1	-1	-1.5
Crude Oil				-298				-1
EINT						-277	-665	-29
Other	-19	-165	-30	-12	-86	-334	-11701	-19862
Capital	-8	-79	-36	-20	-115	-186	-9183	9627
Labor	-4	-15	-9	3	-52	-96	-10220	10393
Resource	-10	-36	-15					61