Carbon Pricing Policy Design and Revenue Management: Economic Models and Policy Practice

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1. INTRODUCTION

Over the past 25 years, a growing number of countries have adopted policies that place a price on the emissions of carbon dioxide (CO_2) and other greenhouse gases. Regardless of whether such carbon pricing is implemented through taxes or emissions trading schemes (ETS), these policies can raise substantial amounts of public funds. Carbon taxes raise revenues directly, and firms can be required to purchase emissions permits to comply with an ETS. How should the revenues raised by carbon pricing policies be managed? This chapter surveys both the economic models and the policy approaches that have been used to address this question from the perspectives of economic efficiency, equity, and political feasibility. First, public finance models typically find that the most efficient policy would create a revenue-neutral 'tax-swap' that (i) lowers tax rates that fall on capital income (e.g., corporate income taxes) and (ii) uses the carbon revenues to make up for the lost revenues.. Recycling the revenues through labor income tax cuts ranks second, whereas rebating the revenues directly to households as lump-sum payments entails the largest efficiency costs. In contrast, based on equity considerations, lump-sum rebates can be preferable over labor tax reductions in addressing the regressivity of carbon prices. In contrast, an ETS that gives emissions permits to firms for free and cuts corporate income taxes at the same time is likely the most regressive option, but would compensate industries and thus achieve political feasibility at the lowest cost.

In practice, the countries and regions that have successfully implemented carbon pricing policies to date have employed various combinations of these revenue-recycling mechanisms. Indeed, many policies mandate a mix of revenue uses, such as rebates to low-income households along with income tax cuts for households and industry. Two features of observed policies stand out as indicative of the importance of political economy considerations. First, most ETS programs provide generous free permit allocations to firms. Second, many policies tie revenues directly to climate-related spending, such as clean energy programs. However, from an efficiency perspective, the funds for these programs should be raised through the least distortionary mix of broad-based tax instruments. Overall, however, the policy practice of carbon pricing revenue management has commonly struck a balance between efficiency, equity, and political considerations.

2. THEORY AND ECONOMIC MODELS

2.1 Efficiency

2.2.1 Carbon Taxes

A rich literature has studied different carbon tax revenue recycling options from the perspective of economic efficiency. These studies typically compare the effects of using carbon pricing revenue to reduce different distortionary taxes (labor income taxes, corporate income taxes, etc.) or to be rebated as a lump-sum.[1] A remarkable feature of these studies is the consistency of the efficiency rankings of different revenue recycling options across models. This is likely the case because the theoretical prediction for optimal policy is clear: carbon revenues should be used to decrease those taxes that impose the largest deadweight loss on the economy. That is, carbon pricing revenues should be used to offset the pre-existing taxes with the highest *marginal cost of public funds* (MCF).

The MCF measures the welfare cost of raising an additional dollar of government revenue from a given tax.[2] For example, Baylor and Beausejour (2004) estimate that the MCF in Canada is 1.32 for personal income taxes and 1.37 for corporate income taxes. These results imply that the efficiency costs of raising another dollar in tax revenues are $0.32 for personal income taxes and $0.37 for corporate income taxes. In this setting, a marginal dollar of revenues should thus be used to reduce corporate rather than personal income taxes, as this would yield a higher efficiency gain. Importantly, it should be noted that the imposition of carbon prices is likely to change the MCF of other taxes in the economy. For example, by increasing energy prices, carbon taxes can increase the cost of consumption goods, thereby decreasing the real wage. If labor markets were already distorted by income taxes, then this additional decrease in the returns to labor can exacerbate the deadweight loss from labor taxes by further reducing labor supply. In other words, if carbon taxes decrease employment, they can thereby exacerbate the efficiency costs of pre-existing labor income taxes.[2] Analogous arguments apply to capital income and other taxes. Overall, the most efficient use of carbon pricing revenue is thus to reduce the tax rates with the highest marginal deadweight loss with the climate policy in place. That is, carbon pricing revenues should be used to counter-act the efficiency costs they create.

Both theoretical models of optimal distortionary taxation (in the Ramsey tradition) and related computable general equilibrium (CGE) models often find that the most distortionary taxes are those that fall on capital income (e.g., corporate income taxes), intermediate goods, or those taxes that have a narrow base. In contrast, the least distortionary taxes tend to be those falling on the consumption side of the economy, such as labor income taxes or consumption taxes, as well as taxes with a broad base (see, e.g., Chari and Kehoe, 1998; Ballard, Shoven, and Whalley, 1985; Goulder, 1995). Consequently, climate policy revenue recycling recommendations based on these models follow along similar lines, namely that capital income tax reductions should typically yield the highest efficiency gains, followed by labor and consumption taxes, and with lump-sum rebates as the least favorable option.[3] Intuitively, lump-sum transfers have a MCF of 1.00 as they are pure transfers between households and the government. There is thus no efficiency gain associated with returning climate policy revenues to households in lump-sum rebates. To the contrary, since these rebates increase households' incomes but do not increase the returns to working (i.e., real after-tax labor income), lump-sum rebates can create a pure income effect that reduces labor supply, thereby again exacerbating the welfare costs of labor income taxes. For this reason, they are generally found to be a less efficient revenue recycling option than tax cuts.

Table 1 summarizes the findings from several CGE models that have simulated the impacts of carbon taxes imposed under different revenue recycling scenarios. Indeed, these studies generally find the largest positive effects on GDP or welfare (Equivalent Variation, EV) from using carbon tax revenues to reduce capital income taxes, with labor taxes ranking second, and with lump-sum rebates as the costliest choice in terms of economic efficiency.

Table 1: Carbon Tax Impacts Across Revenue-Recycling Scenarios: Economic Modeling Results

Study	Initial Carbon Tax	Welfare/Outcome	Revenue Recycling		
	$/MT CO_2	Measure	Capital Income	Labor Income	Lump-Sum
Barrage (2014)[a]	$165 or $195 ($2005)[e]	EV $\%\Delta C_t\ \forall t$	+1.09%	+0.73%	
Carbone et al. (2013)[b]	$30 ($2012)	GDP (by 2035)	+1.00%	-0.5%	-3.5%
Goulder (1995)[c]	$92[e] ($1990)	Gross EV/$ revenue	-0.279	-0.374	-0.516
Jorgenson et al. (2013)[d]	$20 in 2020 ($2005)	Avg. EV/full wealth	+0.216	-0.080	-0.051
	$10 in 2020	Real GDP (2010-50 avg.)	+0.2%	-0.1%	-1.0%
	$50 in 2020	Real GDP (2010-50 avg.)	+0.4%	-0.7%	-3.7%
Jorgenson and Wilcoxen (1996)	$55[e] in 1990 $238 in 2020	Real GNP (by 2020)	+1.10%	-0.69%	-1.70%

[a] Avg. capital income tax cut is -9% (from 41.41% to 38.59%), and avg. labor income tax cut is -1.1% (from 36.58% to 36.17%).
[b] Table 1, Figure 1. Tax cuts decrease marginal rates by same percentage-point amount in every bracket, equaling avg. change. Avg. capital tax cut -4.823%, avg. labor tax cut -1.413%, avg. lump-sum rebate $876.44 per adult per year.
[c] Marginal taxes on labor and capital cut -0.9% (for labor from 23.01% to 22.81%, for dividend interest from 22.89% to 22.72%, for accrual-equivalent tax on capital gains from 5.72% to 5.68%).
[d] Avg. tax rate cuts range from -5.2% ($10 tax) to -19.8% ($50 tax) for labor taxes, and -11.1% to -40.3% for capital income.
[e] Converted by the author from dollars per ton carbon (as reported in the study) into dollars per ton CO_2.

2.1.2 Emissions Trading Schemes

While the revenue-raising potential of carbon taxes is clear, the corresponding considerations in emissions trading schemes warrant further discussion. From a fiscal perspective, an emissions trading scheme can be designed to be formally equivalent to a carbon tax (abstracting from uncertainty considerations[4] as described by Weitzman (1974) and the subsequent literature). Consider a government seeking to reduce carbon emissions from business-as-usual (BAU) level Q^{BAU} to Q^*. On the one hand, this reduction can be achieved by a carbon tax $\$\tau$ set equal to the aggregate marginal abatement cost MAC evaluated at Q^*. This tax will generate revenues worth $\$\tau \cdot Q^*$ paid by firms on their residual emissions. On the other hand, the government could impose an ETS restricting emissions to $\bar{Q}=Q^*$. Since firms will abate and trade permits until their marginal abatement costs are equated, the equilibrium permit price will be $p^*=\$\tau=MAC(Q^*)$. Figure 1 illustrates the resulting revenue equivalence:

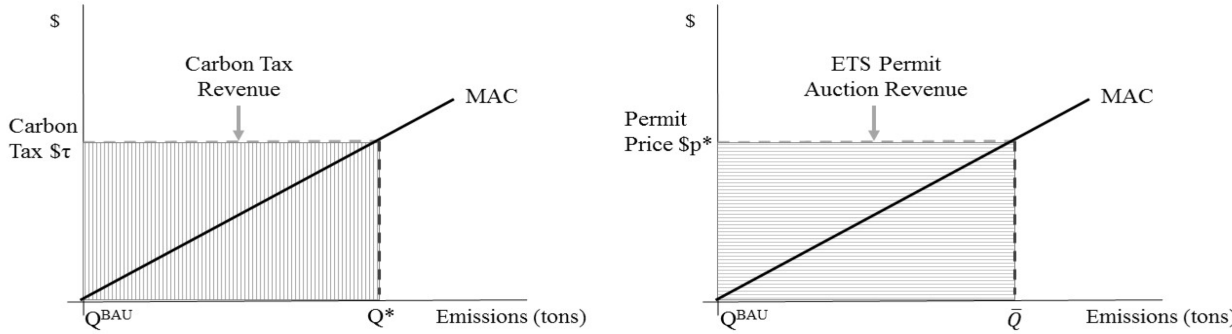

Figure 1: Revenue Equivalence of Carbon Tax and ETS with 100% Permit Auctioning

Importantly, an ETS can thus generate the same amount of public revenues as a carbon tax *if all emissions permits were auctioned off* to firms by the government. However, a much more common practice is for governments to give out the majority of permits for free. As discussed below, free permit allocations amount to a rent transfer to firms. In representative agent models - where the household owns the firms - this rent transfer can be shown to be formally equivalent to a lump-sum rebate of carbon pricing revenues to households. That is, an ETS with free permits is equivalent to a virtual emissions tax with lump-sum revenue rebates (see, e.g., Goulder, Parry, Williams, and Burtraw, 1999). Consequently, the efficiency costs of an ETS with non-auctioned permits correspond to those of lump-sum revenue recycling as outlined in Table 1. Conversely, the most efficient ETS would auction 100 percent of permits and use the revenues to cut taxes that fall on capital income (e.g., corporate income taxes).

2.2 Equity

2.2.1 Carbon Taxes

One of the most important equity-based concerns about carbon taxes is that they are regressive. For example, Hasset, Mathur, and Metcalf (2009) estimate that the burden of a carbon tax relative to income for households at the bottom decile of the income distribution would be between 1.25 and 5.3 times higher than the burden for the top decile, depending on the year and measure of income. However, these estimates do not consider the recycling of carbon tax revenues. A number of studies have shown that carbon pricing policies can be made *distributionally neutral* through appropriate revenue usage. Metcalf (2007) proposes an *environmental earned income tax credit* that would offset payroll taxes paid up to a limit. He studies the effects of a tax of $15 per ton CO_2 in 2003 with a rebate capped at $560 per worker. The cap makes the tax credit progressive, offsetting 73 percent of payroll tax payments for workers earning $5,000 per year but only 4 percent of payroll taxes for workers earning $90,000 per year. In line with other studies, Metcalf (2007) estimates that the gross effects of a carbon tax would be regressive. However, the *net* effects of the tax after rebates would be close to distributionally neutral. Alternatively, using the revenues to provide households with lump-sum rebates of $274 would make the policy fully progressive. Overall, Metcalf thus concludes that, while carbon taxes may be regressive in isolation, they can easily be designed to be distributionally neutral (or even progressive).

Studies exploring the distributional impacts of gasoline taxes have found similar results.

West and Williams (2004a) estimate demand for gasoline, leisure, and other goods among different household types.[5] The authors then consider an increase in gasoline taxes to $1.39 per gallon, the optimal overall tax as suggested by West and Williams (2004b). While they find that the tax is regressive in isolation, its net incidence depends on how the revenues are used. On the one hand, the tax could be made essentially progressive by rebating revenues to consumers in a lump-sum fashion. Indeed, the transfers more than offset the gasoline cost increase for the bottom quintile of the income distribution. However, this policy entails the largest efficiency costs. In contrast, using revenues to reduce labor income taxes - specifically through an equal percentage-point cut in all income tax brackets - mitigates the regressivity and reduces the efficiency costs (relative to lump-sum rebates), thus arguably presenting an attractive potential compromise.

Bento et al. (2009) estimate a multi-market model of U.S. vehicle and driving demand and supply to study the effects of a $0.25 per gallon gasoline tax increase. They consider three revenue recycling scenarios: lump-sum rebates, income-based (proportional to households' income shares), and VMT-based (proportional to households' baseline share of vehicle miles traveled). It should be noted that the model is not designed to consider revenue recycling through reductions in distortionary taxes, such as labor income taxes. Consequently, the authors can only consider different types of lump-sum transfers. However, the computed gasoline tax welfare impacts include general equilibrium effects such as changes in vehicle prices and carmaker profits. Despite the difference in the model and study focus, the authors also find that standard lump-sum revenue recycling more than offsets the regressivity of the gasoline tax. Lower income groups are made better off as they receive a larger share of tax revenues than their share of gasoline tax payments. With income-based rebates, the welfare effects of the tax are U-shaped when plotted across income deciles. Intuitively, this is because medium income households have the highest ratio of miles driven - and thus gasoline taxes paid - relative to income. An income-based rebate thus compensates them relatively less than households on either extreme of the income distribution. Finally, VMT-based rebates render the gasoline tax increase close to distributionally neutral, although higher income households are made slightly worse off. Overall, however, the study's results thus imply once again that lump-sum rebates can be used to mitigate or even reverse the regressivity of gasoline taxes.

Finally, prior work on carbon pricing revenues in the electricity sector has found broadly similar results, but raised its own set of complications and caveats. For example, Burtraw, Walls, and Blonz (2009) compare the use of emissions trading permit auction revenues to provide free allocations to electricity and natural gas local distribution companies with rebating the value of this effective subsidy to households directly. With the exception of the top income decile, most households are better off with the lump-sum rebate than with the electricity subsidy. However, the distribution of welfare impacts depends on nuances such as whether utilities pass through the free permit values through decreases in variable or fixed electricity charges, as well as on whether households respond to such price changes differently (rationally).

2.2.2 Emissions Trading Schemes

In theory, carbon emissions trading schemes could raise the same amount of revenues as carbon taxes by auctioning off emissions permits (see Figure 1). In this case, the distributional effects of competing policy options are in line with those predicted for carbon taxes. For example, Burtraw, Sweeney, and Walls (2009) model five revenue recycling options for a U.S. cap and trade program. They find that the policy can be made progressive if revenues are rebated to households in lump-sum, or through an expansion of the Earned Income Tax Credit. In contrast, the policy remains regressive if permit auction revenues are used to reduce income or payroll taxes.

In reality, at least some emissions permits are commonly given out for free. This policy has two main implications for the distributional effects of an ETS. First, the forgoing of revenues limits a government's ability to implement tax and rebate policies to mitigate the regressive effects of energy price increases associated with the ETS. Second, the benefits of free permits may accrue to shareholders of firms receiving these rents. The extent to which equities are more likely to be owned by wealthier households may thus further exacerbate the regressivity of an ETS. Several studies have quantified these effects.

Dinan and Rogers (2002) study the distributional effects of an ETS designed to reduce U.S. carbon emissions by 15 percent. They compare two permit allocation schemes: free distribution (where the government re-captures 45 percent of the resulting rents as "residual revenue" through income and profit taxation) and full auctioning (where the government captures 100 percent of the rents, as with a carbon tax). The authors also consider three competing revenue recycling schemes: corporate tax cuts, payroll tax cuts, and lump-sum rebates. The results suggest that the gross costs of the climate policy are regressive. In line with other studies, full auctioning of permits with lump-sum rebates could eliminate this regressivity. However, all other policies considered remain regressive. In particular, free permit allocation renders the ETS regressive even with lump-sum rebates of the residual revenues raised through income and profit taxes, costing households in the bottom quintile of the income distribution an estimated 0.4 to 4.2 percent of annual income, compared with a cost of -0.5 to 0.0 percent for households in the top quintile. The regressivity is most severe with free permits and residual revenues used to reduce corporate income taxes, costing bottom quintile households an estimated 2.4 to 6.2 percent of annual income, compared with -0.6 to -1.2 percent for top quintile households.

Parry (2004) finds similar results in studying an ETS that would reduce U.S. carbon emissions from the electricity sector by 10 percent. He estimates that the gross burden of the policy would amount to $106 for households at the bottom quintile of the income distribution and $406 for households in the top quintile. However, the profit income resulting from free permit allocations and the associated rents would yield $370 for top quintile households but only $24 for bottom quintile households. The reason for this discrepancy is that, based on the Consumer Expenditure Survey, he estimates that top income quintile households own 53 percent of stockholdings (within the CEX sample), compared with only 3.5 percent for lowest income quintile households. Parry also considers that the government can re-capture 35 percent of the permit rents through income and profit taxation. However, even after lump-sum distribution of these revenues, the ETS remains regressive: the net burden amounts to 0.061 percent of income for households in the bottom quintile, compared with a -0.063 percent burden (or net gain) for households in the top quintile. In contrast, a carbon tax (or an ETS with 100% permit auctioning) with lump-sum revenue recycling would be progressive, yielding an estimated net cost of -$109 for households in the bottom quintile, compared with a cost of $191 for the top quintile.

Metcalf (2007) also considers an ETS with free permits in his analysis. He finds that such a policy would be "decidedly regressive," decreasing households' disposable income the most for the lowest income deciles, and increasing income for only the two top deciles.

Overall, free permit allocation in an ETS thus appears to greatly increase the regressivity of the policy across income groups, even if some rents are re-captured through income taxation and distributed to households in lump-sum payments. Unfortunately, this finding creates an important dilemma for policy makers, as such partially free permit allocations and rent transfers to shareholders are precisely what would be needed to render an ETS distributionally neutral from the perspective of affected industries, as described in the next section.

2.3 Political Feasibility

Lack of political feasibility is one of the largest obstacles to the enactment of climate policies. In turn, one of the key determinants of the political feasibility of different policies is the distribution of their impacts across industries (Bovenberg and Goulder, 2001; Bovenberg, Goulder, Jacobsen, 2008). Policy revenues can be used to modify these impacts in several ways, including corporate tax cuts, transfers, and by giving out free permits in the context of an emissions trading scheme (ETS). As discussed above, the distribution of free permits constitutes a rent transfer to firms. Intuitively, the creation of an ETS effectively restricts output, causing prices to rise. However, with free permits, firms do not face an associated increase in production costs, thus earning rents through the free permit allocation (Bovenberg and Goulder, 2001). Despite the efficiency costs of this policy (see above discussion of Goulder, Parry, Williams, and Burtraw, 1999), its potential value in enhancing the political feasibility of an ETS is evident.

Bovenberg and Goulder (2001) employ a dynamic computable general equilibrium model of the U.S. economy to study the effects of a carbon pricing policy on output, after-tax profits, and equity values of firms under competing revenue recycling and industry compensation schemes. In particular, they consider policy adjustments that would protect regulated industries from adverse effects on their equity values or overall tax bills. More formally, they consider policies that achieve either "equity-value neutrality" - implying that the real value of the most vulnerable industries remains unchanged by the announcement and enactment of the climate policy - or "tax-payment neutrality," ensuring that an industry's overall tax payments (from carbon taxes, corporate taxes, indirect labor taxes, etc.) remain unchanged. These distributional goals are achieved through either (i) industry-specific corporate tax cuts, (ii) lump-sum transfers to industry-specific capital, or (iii) inframarginal carbon tax exemptions, which are equivalent to an ETS with some free permit distribution.

The study's most significant finding is that compensation for the most vulnerable industries could be achieved at little to no efficiency cost. Consider, for example, a carbon pricing policy that recycles all revenues through personal income tax (PIT) reductions, against a policy that first ensures equity-value neutrality through industry-specific corporate income tax adjustments, and then uses the remainder of the revenue for PIT reductions. Perhaps surprisingly, the policy that achieves equity-value neutrality is *more efficient* than the standard policy. That is, the gross efficiency costs are \$60.00 per ton CO_2 emissions with the standard policy, but only \$46.90 per ton with vulnerable industry compensation through targeted corporate income tax reductions. Intuitively, this is because corporate income taxes are more distortionary than personal income taxes, and consequently this effective tax swap improves overall efficiency. Similarly, a policy using lump-sum payments to affected industries achieves equity-value neutrality with only a minor gross efficiency cost increase (\$61.40 per ton CO_2) compared to the all-PIT reduction policy (\$60.00 per ton). Finally, free permits appear to be an effective and low-cost way of achieving some distributional neutrality. The estimated share of emissions permits that must be given out for free to achieve equity-value neutrality is only 4.3 percent in the coal industry, and 15 percent for oil and gas. The associated gross efficiency costs of \$64.60 per ton CO_2 compare favorably with those of the standard policy raising and using 100 percent of revenues to reduce personal income taxes (\$60.00 per ton).

It is important to note that more generous free permit allocation schemes - such as those commonly observed in practice - create significantly higher efficiency costs. For example, a policy granting firms 90 percent of their base year business-as-usual emissions as free ("grandfathered") permits each year increases the gross efficiency costs to \$77.40 per ton CO_2. Such policies are also predicted to *increase* equity values in the most vulnerable industries, notably coal and oil and gas, thus arguably overshooting the goal of industry compensation.

The authors also consider industry compensation to achieve tax-payment neutrality. Importantly, the tax cuts or transfers required to achieve such neutrality are considerably larger than those needed for equity-value neutrality. Intuitively, this is because supply in the most vulnerable industries is quite elastic, implying that energy sector firms can pass on most of their tax burdens to consumers. Consequently, a tax-payment neutrality policy overcompensates firms relative to the true economic burden of the climate policy. However, the efficiency costs of even this generous compensation policy compare favorably (\$61.10 per ton CO_2) with those of a fully PIT revenue recycling scheme as long as tax-payment neutrality is achieved through targeted corporate income tax reductions.

Overall, the key finding of Bovenberg and Goulder's (2001) study is thus that climate policies can be designed to protect profits in the most vulnerable industries at minimal additional efficiency costs. The most efficient policy would use industry-specific corporate income tax cuts to achieve equity-value efficiency; however, distributing modest amounts of free permits to key industries in an ETS can achieve the same goal. While political feasibility adjustments remain an important area for future research, some subsequent studies have found similar results. Bovenberg, Goulder, and Gruyter (2005) find that, while the share of permits that must be freely allocated to compensate firms is increasing in the emissions reductions target of the policy, this share remains below 50% for a wide range of targets and parameters. Similarly, Burtraw, Palmer, Bharvirkar, and Paul (2002) find that it would cost only 7.5% of the value of auctioned emissions allowances to compensate electricity generators for the losses to their asset values due to the imposition of an ETS in the electricity sector (see also Burtraw and Palmer, 2008).

2.4 Theory Summary

Many economic models of fiscal policy and carbon pricing produce similar conclusions on the rankings of different revenue usage schemes in order to achieve a given policy objective. However, *across* policy objectives, the rankings of preferred policies differ starkly. Policy makers consequently face a trade-off between efficiency, equity, and political feasibility.

For example, from the perspective of economic efficiency, the preferred policy would be a carbon tax (or an ETS with 100 percent auctioned permits) with revenues recycled fully in cuts on taxes that fall on capital income, such as corporate income taxes. Rebating revenues as lump-sum payments to households would yield the lowest efficiency gains. In contrast, from the perspective of equity, such lump-sum rebates would be the best policy. The least equitable or most regressive policy would be an ETS with free permits and residual revenue recycled through corporate income tax cuts. However, partially free permits and targeted corporate income tax cuts would be the least costly choice to ensure industry compensation, and thus political feasibility.[6] While economic models can thus provide guidance to policy makers, they generally do not yield a unique “best” revenue recycling method that would hold across competing policy objectives.

Table 2: Carbon Pricing Revenue Usage in Policy Practice

			Percentage of Carbon Pricing Revenues* Allocated to:								
Location	**Carbon Policy**	**Year**	**Tax Rate Reductions**			**Lump-Sum Transfers**		**Program Expense**		**General Gov't Fund**	**Free Permits**
			Income			Households	Industry	Green	Low Inc.		
			Personal	Corp.	Payroll			Tech.	Energy		
Australia	Tax/ETS	2013/14[a]	✓(26%)*			✓ (25%, Targeted)	✓(1.7%, Targeted)	✓ (14%)	✓(1.5%[c])	✓	✓(48%)
British Columbia	Tax	2013/14	✓ (20%)	✓(36%)		✓ (22%, Targeted)					
Denmark	Tax	2000[d]			✓(82%)			✓ (19%)			
France	Tax	2016[e]			✓(75%)	✓ (Targeted)		✓			
Iceland	Tax	2010								✓(100%)	
Ireland	Tax	2010						(✓15%[f])		✓(100%)	
Japan	Tax	2012						✓(100%)			
Norway	Tax	2007								✓(100%)	
Portugal	Tax	2015	✓(100%)								
Quebec	ETS	2015						✓			✓
Sweden	Tax	2009								✓(100%)	
Switzerland	Tax	2015				✓(41%, General)	✓(25%, General)	✓ (33%)			
RGGI[g]	ETS	2015	Member states have authority over permit auction revenues. Majority of aggregate funds spent on energy efficiency, clean and renewable energy, household energy bill assistance, etc.								✓(31%)
EU	ETS	2013	Member states have authority over permit auction revenues. EU Directive requests that "at least 50%" be used for climate and energy related purposes.								✓(60%)

* Percentage indicates approximate share of carbon pricing revenues in indicated year allocated to a given purpose. Shares may not add to 100 due to other spending or shortfalls.
[a] Calculations based on projections from Australian Government's 2011 "Clean Future Final Plan" as summarized by Carl and Feldor (2012). Expenditures may exceed or fall short of revenue raised. For 2013/14, more revenues were allocated than projected to be raised through the carbon pricing scheme (Carl and Feldor, 2012). [b] Figure excludes government buyouts of inefficient coal-fired power plants, as their value is included in coal industry assistance through free permits. [c] Includes all *household* energy efficiency expenditures.
[d] Percentage of total revenue from taxes on both CO_2 (€277 mil.) and SO_2 (€42 mil.). Note that total expenditures included some additional categories (e.g., funds for self-employed) and exceeded revenues slightly in 2000 after adjustments (Danish Energy Authority). [e]*Projected* revenue usage, with details on spending besides competitiveness (payroll) tax credit (CICE) still to be determined (Elbeze, 2014). [f] While €50 million from the estimated carbon tax revenues of €330 million were designated for energy efficiency programs (Irish Government, 2010), these funds are not generally earmarked as such (ICMM, 2013). [g]Regional Greenhouse Gas Initiative, an ETS of the electricity sector across a group of northeastern U.S. states.
Sources: Swiss Bundesamt für Umwelt, European Commission, Government of British Columbia Budget and Fiscal Plan 2015/16-2017/18, Parliament of Australia, ICMM (2013), Carl and Fedor (2012), International Energy Agency, RGGI, Govt. of Iceland, Govt. of Ireland Annexes to Summary of 2010 Budget Measure, Sumner, Bird, and Smith (2009), Governo de Portugal (2014), Pereira and Rodrigues (2015), Québec Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques.

3. POLICY PRACTICE

Over the past 25 years, a growing number of countries and regions across the world have adopted carbon pricing policies (for details, see, e.g., Sumner, Bird, and Smith, 2009; World Bank, 2014). The policy practice with regards to revenue usage varies greatly across jurisdictions, and often differs markedly from the recommendations of economic models. Table 2 summarizes revenue usage for a select sample of policies.

Three main insights and surprises emerge from these figures. First, the majority of policies use revenues for expenditure programs such as for clean and renewable energy technology, energy efficiency, and the environment. As noted above, economic models often exclude this revenue usage option. On the one hand, the calibration of government spending effects on the macroeconomy and/or directed technical change are highly controversial. On the other hand, standard public finance theory predicts that the best way to raise revenues for any program is through the least distortionary tax instrument. Depending on the level of carbon taxes, it may thus be preferable to raise the next dollar of revenue for clean energy subsidies from labor or consumption taxes. Intuitively, carbon taxes generally fall on intermediate inputs (energy) and are thus an undesirable tax base above and beyond externality levies (see, e.g., Goulder, 1995; also discussion in Barrage, 2014). In theory, clean energy subsidies should thus be set based on efficiency criteria (e.g., to correct market failures in R&D incentives) and financed out of general government funds. In reality, however, due to political economy frictions, it may be desirable to earmark some carbon pricing revenues for clean energy subsidies (see, e.g., Brett and Keen, 2000). In particular, if political economy frictions prevent an optimized provision of public goods from general funds, then it may be necessary to tie carbon pricing revenues to expenditures on clean energy research or other environmental programs in order to expand the provision of these goods.[7]

The second surprise is that, with the exception of British Columbia, none of the policies considered recycled carbon pricing revenues through capital income tax reductions, despite the consistent prediction from economic models that this would be the most efficient revenue usage.

Third, the main finding is that many countries appear to balance competing policy objectives. Most countries appear to split revenues across multiple uses so as to at least partly protect the interests of vulnerable households, industry, and the broader economy.

Many more countries have or are currently introducing carbon pricing policies, including large, emerging market economies such as China, Mexico, Chile, and South Africa. These carbon pricing schemes will undoubtedly play a critical role in building global climate resilience. The landmark Paris Agreement on climate change - reached in December 2015 at the 21st meeting of the Conference of the Parties to the United Nations Framework Convention on Climate Change - saw many countries pledging emission reduction targets supported by carbon pricing policies. Importantly, the world's largest carbon emitter – China – has already implemented pilot emissions trading schemes in several cities, and pledged its intent to build a nationwide ETS. Understanding the impacts of competing carbon pricing design elements will thus remain an important and policy-relevant area for future research in economics and climate resilience.

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NOTES

[1]In contrast, changes in the provision of public goods - such as using revenues to fund new infrastructure projects - are often not considered. On the one hand, the quantification of the economic benefits of increases in public spending are highly controversial. On the other hand, formally endogenizing government spending in the literature's workhorse dynamic taxation (Ramsey) models complicates the models considerably.

[2]This “tax interaction effect” is typically found to exceed the efficiency gains from optimized carbon tax revenue recycling (see, e.g., Goulder, 1995; Parry, 1995; Bovenberg and Goulder, 1996). In these and other standard Ramsey taxation models, a “double dividend” does therefore not arise without additional model features, such as untaxable rents (Bento and Jacobsen, 2007).

[3]While tax codes differ greatly across countries, the general finding that taxes falling on capital income (e.g., corporate income taxes) entail higher efficiency costs than those falling on labor emerges from studies estimating the MCF across several countries. See, e.g., the international MCF estimate review table in the Online Appendix of Barrage (2014) located at URL: http://lintbarrage.com/wp-content/uploads/2014/12/Barrage_2014_OnlineAppendix.pdf

[4]It should be noted that uncertainty is an important research frontier, both for economic analyses of climate policy in general (see, e.g., review by Burke et al., 2016) and for the study of fiscal-climate policy interactions in particular, where uncertainty has been largely abstracted from.

[4]Closely related concepts include the marginal excess burden, the marginal deadweight loss, and the marginal welfare cost of taxes. Though similar, the formal definition of these concepts can differ (see, e.g., Dahlby, 2008; Fullerton, 1991; Triest, 1990, and Snow and Warren, 1996).

[5]The authors estimate an Almost Ideal Demand System from Consumer Expenditure Survey data in order to account for households' (heterogeneous) demand responses to potential gasoline tax increases.

[6]It should be noted that the discussion in this paper and cited studies focuses on political feasibility in terms of industry asset values and profitability. In reality, feasibility is likely intertwined with other policy aspects, including its distributional impacts. Importantly, political feasibility may further depend on distributional effects along dimensions besides income, such as age or geography. I thank David Simpson for the insight that the delineation of “efficiency,” “distributional” and “political feasibility” objectives is thus “somewhat fluid and inexact.”

[7]I thank Kavi Kumar for this insight.

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