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ABSTRACT

I measure the industry impacts of an environmental tax reform where a carbon tax is used to finance full or partial corporate tax integration. I find that the industry impacts of such a reform are likely to be modest (in the sense of impacts on returns on equity).

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I. Introduction

In recent years environmental policy makers have shown a preference for cap and trade programs over taxes to bring about reduced levels of pollution. The success of the cap and trade program for SO_2 emissions under the 1990 Clean Air Act Amendments explains part of this shift in policy preferences.[1] But part of the preference for cap and trade programs has undoubtedly resulted from a general distaste in Washington for new taxes. Policy makers and environmental advocates have argued that cap and trade programs avoid the political stigma suffered by taxes and are more likely to be enacted by Congress. The Bush Administration's Clear Skies proposal, for example, relies on a cap and trade system to reduce emissions of sulfur dioxide, nitrogen oxides, and mercury from electric utility generators.[2]

Offsetting the political advantages of cap and trade programs relative to taxes are some practical advantages of environmental taxes. First, pollution taxes provide a measure of certainty to regulated firms. A carbon tax of $20 per metric ton of carbon, for example, ensures firms subject to the tax that they will pay no more than $20 per ton to emit carbon. A cap and trade program has no such assurance. The price paid for emissions under a cap and trade program depends on the market price of permits, a price that could fluctuate depending on economic conditions. Permit prices, according to a EPA website ranged from roughly $130 per metric ton to around $220 in 2003.[3]

Second, pollution taxes raise revenue for the federal budget while cap and trade programs - so far - do not. These revenues could help finance some of the tax reform initiatives currently under discussion by President Bush's Advisory Panel on Federal Tax Reform (Gleckman (2005)). While nothing precludes the federal government from

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[1] Ellerman et al. (2000) provides an overview of the SO_2 trading program.
[2] See the discussion of cap and trade programs in Chapter 9 of Council of Economic Advisors (2004).

selling emissions permits, the custom established under the Clean Air Act SO_2 and NO_x trading programs is to give the permits to firms in the regulated industries. In theory, tax based solutions and permit trading solutions can reach the same social optimum in the absence of uncertainty over marginal benefit and costs of abatement. But since tax revenue generated by Pigouvian taxes can be used to offset reductions from other sources, fundamental tax reform proposals could, in theory, be improved under some conditions if environmental taxes were included in the mix.[4]

The United States collects little in the way of revenue from environmental charges (including taxes) and the little that is collected is done so in an inefficient manner.[5] Considering environmental taxes at all levels (federal, state, and local), environmental taxes in the United States comprised 3.3 percent of total tax revenues in 2001.[6] By contrast, OECD countries as a whole collected 4.9 percent of taxes through environmental taxes. Denmark's environmental tax share, for example, was 10 percent in 2002; Germany's was 7.1 percent; the United Kingdom's was 7.5 percent. No country's environmental tax share in 2001 was lower than the United States' share.

Moreover, there is good evidence that existing levels of environmental taxation in the United States fall well short of their optimal levels. Parry and Small (forthcoming) note that the average level of taxation of gasoline in the United States is roughly $.40 per gallon while the optimal rate (taking into account pollution and congestion effects) is $1.01 per gallon. While there is widespread agreement that carbon emissions are

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[3] See the EPA's website http://www.epa.gov/airmarkets/trading/so2market/alprices.html.

[4] Cap and trade programs in which permits are handed out for free are equivalent to tax programs in which the tax revenues are rebated lump-sum (see Fullerton and Metcalf (2001) for a discussion of this point). Green tax reforms in which the environmental revenues are used to reduce distortionary taxes rather than returned lump sum in general have lower welfare costs (see, for example, Bovenberg and Goulder (1996)). This is an example of what Goulder (1995) calls a "weak double-dividend."

[5] See Fullerton (1996) for an overview of environmental tax policy and the high costs of collection. Francis (1999) notes the decreased use of some environmental taxes in the 1990s.

environmentally detrimental, estimates of social marginal damages are imprecise. An IPCC literature review by Pearce et al. (1996) found estimates ranging from $5 to $125 per metric ton of carbon with most estimates below $25 per metric ton. For discount rates between 3 and 5 percent, Tol (1999) found more precise estimates in the range of $9 to $23 per metric ton. Below I show that a carbon at the upper end of Tol's range would finance complete corporate tax integration.

In this paper, I identify the impact on industry of implementing a carbon tax to pay for full or partial corporate tax integration. I begin with a discussion of corporate tax reform and the link to a carbon tax. I then discuss my modeling approach and provide industry level impacts of a tax reform where a carbon tax finances corporate tax integration. In the conclusion, I consider various possible extensions to this study.

II. Background

The idea of a carbon tax combined with a reduction in existing taxes has been extensively studied. See, for example, Bovenberg and Goulder (1996) who consider cuts in the personal income tax financed by a carbon tax. The focus on a carbon tax is a natural one given that carbon emissions are mandated in the Kyoto Protocol to be reduced in the United States by 7 percent from 1990 levels in the years 2008-2012[7]. While the United States has declined to ratify the Kyoto Protocol, policy makers continue to discuss possible policy responses to rising greenhouse gas emissions.

Emissions of carbon dioxide (CO_2) in 1990 totaled 1,347 million metric tons of carbon and increased to 1,601 million metric tons in 2003, according to the most recent

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[6] The source for these and subsequent tax share numbers is the OECD Economic Instruments Database.

[7] The Kyoto Protocol actually mandates reductions in six "greenhouse gases:" carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. Carbon dioxide is by far the most significant of the six gases and I limit discussion to this gas. The text of the Kyoto Protocol along with explanatory documents can be found at http://www.unfccc.de.

report on greenhouse gas emissions from the Energy Information Administration (2004). While CO_2 emissions per dollar of GDP have tended to fall in the 1990s, emissions are 19 percent above 1990 levels and 27 percent above the target for emissions set in the Protocol. Thus a substantial effort would be required if the U.S. were to attempt to meet the target.

A carbon tax is an obvious policy tool to help achieve the goals set forth in the target. A natural question is what to do with the carbon tax revenue. Research by a number of economists has indicated that reducing the tax on capital income financed by environmental tax revenues would provide the greatest efficiency gains relative to other uses of the tax revenue.[8] Corporate tax integration is a way to reduce the tax on capital income.

Corporate tax integration is an effort to subject all income to a single income tax. The United States, like many countries, has a personal income tax and a corporate income tax and treats these two taxes as separate and distinct. Thus, income earned in the corporate sector can be subject to a tax first through the corporate income tax and then through the personal income tax. Such a system leads to a number of tax induced behaviors which can have significant efficiency impacts:

- Payout Behavior: the corporate income tax affects the decision to pay out after-tax profits in the form of dividends or to retain earnings within the corporation.
- Financing Behavior: the corporate income tax influences the decision to finance new investments with equity or debt.
- Corporate Organization: the corporate income tax affects the decision to organize businesses as corporations or partnerships.

[8] Bovenberg and Goulder (2002) cite a number of studies in their Table 4 that conduct a welfare assessment of environmental tax reforms. Most of the studies use revenues to cut the personal income tax but one study using the Jorgenson-Wilcoxen model uses revenues to cut capital income taxes. The welfare gains in the studies cited are highest for this policy reform. This is consistent with findings of Ballard et al. (1985b) and others that the marginal welfare cost of capital income taxes are higher than for personal income taxes.

A 1992 Treasury study on tax integration estimated annual efficiency losses from the current tax system (relative to an integrated system) ranging from $2.5 to $25 billion (in 1991 dollars).

Table 1 below provides some insight for these distortions. It shows the amount of tax paid on a dollar of earnings from an investment for different financing, organizational, and payout assumptions given tax rates in effect in 2005.

Table 1. Tax Rates on Marginal Profits

	General Tax Rate	Current Tax Rate
Corporate Dividends	$t_c + (1-t_c)t_d$	44.8%
Corporate Interest	t_i	35.0%
Corporate Retained Earnings	$t_c + (1-t_c)t_g$	37.6%
Non-Corporate Payouts	t_i	35.0%

The second column gives the general formula for the total amount of taxes paid on a dollar of pre-tax profits. There are four relevant tax rates: the corporate rate (t_c), the personal tax rate on dividends (t_d), or interest income (t_i), and the accrual equivalent tax rate on capital gains (t_g)[9]. To give a sense of the differences in taxation, I provide numerical results using a tax rate of 35 percent for the corporate tax and tax on interest income, 15 percent for the personal tax, and 5 percent for capital gains.

The table illustrates the various distortions. First, there is a bias against paying out dividends. Profits paid out as dividends are taxed at a rate of nearly 45 percent while retained earnings (leading to capital gains) are only taxed at 37.6 percent. Second, there is a bias against equity financing: a dollar of profits paid out in dividends incurs roughly 1 1/4 times the level of taxes on income paid out as interest. Third, there is a bias against

[9] This simplifies the analysis somewhat as I ignore various complicating factors including the alternative minimum tax, as well as the tax treatment of foreigners and tax exempt organizations. The accrual equivalent tax rate on capital gains accounts for the fact that capital gains are only taxed upon realization. Moreover, basis step-up at death further reduces the effective tax on capital gains.

the corporate organizational form. Corporate profits are taxed more heavily than non-corporate profits[10].

According to McLure (1979), interest in integrating the corporate and personal income tax systems increased in the 1960s and early 1970s for three reasons. First, there was widespread concern about the low rate of capital formation and it was thought that reducing the taxation of dividend income might encourage increased investment. Second, a number of European countries provided some form of dividend tax relief. Finally, a Canadian Royal Commission on Taxation report in 1967 argued that complete integration might in fact be feasible and not simply a conceptual idea.

Interest in tax integration was overshadowed in the 1980s by broad based income tax reform that culminated in the Tax Reform Act of 1986 (TRA86). Rather than fundamentally changing the tax system, TRA86 engaged in base broadening and rate lowering and the top marginal tax rate on personal income fell from 50 to 28 percent while the top corporate tax rate fell from 46 to 34 percent.

Let us next turn to the mechanics of tax integration. I'll look at two proposals in particular[11]. First, I'll consider full integration where corporate income is allocated to individual shareholders and subject to tax at the personal level. Second, I'll consider dividend tax exclusion at the personal level[12].

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[10] With these numbers, the bias goes away if all corporate after-tax profits are retained.

[11] This section draws in part on an excellent analysis of tax integration written by the U.S. Department of the Treasury (1992) (also summarized in Hubbard (1993)).

[12] McLure (1979) argues against this scheme and proposes instead a dividend deduction at the corporate level (similar to the interest deduction). The advantage of McLure's approach is that corporate income is taxed at the shareholder's tax rate rather than the corporate tax rate. It also eliminates the distortion between debt and equity financing (if basis adjustment for dividends paid is made). The 1992 Treasury report considered but rejected this approach on the grounds of cost and implementability.

1. Shareholder Allocation Prototype

The Shareholder Allocation Prototype (SAP) comes close to a "pass-through" (complete) integration plan that achieves all the goals of a textbook integration of the two income taxes. The SAP approach retains a corporate income tax but passes all corporate income, taxes, and credits through to shareholders. In effect, the corporate income tax serves as a withholding tax.

In brief, the SAP preserves the corporate income tax as a "withholding" tax and allocates corporate income and taxes to shareholders. To see how the SAP works, consider the following simple example. A corporation has $100 of taxable income, pays $35 in corporate taxes, and has $65 in after-tax profits which it can either distribute to shareholders (as a dividend) or keep as retained earnings. The purpose of the SAP is to tax the shareholder on the $100 of taxable income at the shareholder's tax rate rather than to tax income distributed as dividends or retained (and thus leading to capital gains). Let's assume for the moment that the entire $65 of after-tax profits is paid out as a dividend. The first important characteristic of the SAP is that dividend income is not taxable at the personal level (since the goal of the SAP is to tax corporate income, not corporate distributions). Rather than taxing dividend income, the SAP subjects the entire $100 of corporate income to taxation at the personal level. Just as a worker receives a W-2 form from an employer detailing wages paid and taxes withheld, a shareholder would receive a "corporate W-2" detailing income earned and taxes withheld. In this example, the shareholder would report $100 of taxable income on his personal income tax and receive a tax credit for the $35 of taxes paid at the corporate level. For a taxpayer in the 40 percent personal income tax bracket, the gross tax liability on the corporate income is $40 and the net tax liability (net of corporate tax payments) is $5. The shareholder has

$60 in after-tax income available for consumption or saving – the $65 dividend less the $5 personal tax liability. His corporate income has been subjected to a 40% tax.

Next, assume that the corporation retains the entire $65 in after-tax profits. Under the assumption that equity markets are efficient, the retention of $65 should increase share value by $65. Assuming efficient markets, the shareholder's income has gone up by $65 (the increase in value of the shares). As in the case of distributed profits, the shareholder pays a tax on the $100 of corporate income and receives a tax credit for the $35 in taxes paid at the corporate level. In addition, the cost basis for the stock is increased by the amount of retained earnings so that no tax liability will be incurred on the capital gains due to these retained earnings.

To see how this works, imagine the shareholder bought one share of stock in this corporation on Monday for $1,000. On Tuesday, the corporation earns $100 per share and pays taxes of $35 per share and retains $65. In an efficient market, the value of the stock will increase from $1,000 to $1,065. On Wednesday, the shareholder sells his share for $1,065. His selling price for purposes of calculating taxable capital gains is $1,065. His cost basis, however, is increased from $1,000 to $1,065 since $65 has been added to retained earnings. Thus, the taxable capital gain is $1,065 – 1,065 = $0. The shareholder has received $65 in capital gains upon sale and is subject to a net personal income tax liability of $5 (as in the dividend case above) and so has $60 in after-tax income. The corporate income again has been subjected to a tax of 40 percent[13].

[13] A simpler approach would be to simply eliminate the tax on capital gains at the personal level. There are a number of problems with this approach. For example, imagine that Bill Gates suddenly announces a special licensing arrangement with Apple Computer and, as a result, the value of Apple Computer stock increases by 15 percent. These capital gains are income that will not be subject to tax at the corporate or personal level if capital gains are no longer taxed at the personal level. Thus, the basis adjustment described in the text is a preferable method of handling retained earnings under the SAP.

Table 2 shows the marginal tax on a dollar of profits under the SAP. It shows that the various distortions discussed above are eliminated under the SAP.

Table 2. Tax Rates on Marginal Profits Under SAP		
	General Tax Rate	Current Tax Rate
Corporate Dividends	t_p	35.0%
Corporate Interest	t_p	35.0%
Corporate Retained Earnings	t_p	35.0%
Non-Corporate Payouts	t_p	35.0%

The shareholder allocation plan is considerably more complicated to administer than the dividend exclusion plan discussed below. Reporting and auditing burdens for corporations are likely to be significant. For example, the Treasury plan would not pass through corporate losses to shareholders but rather carry them forward at the corporate level. This is in keeping with general tax policy. In addition, change of stock ownership during a year complicates allocation of income and taxes to individuals. Since taxable income and tax liabilities are only measured once during the year, allocating income and share basis to shareholders must be done on a retrospective basis (and could in fact require taxpayers to file amended returns).

The 1992 Treasury study estimated that a fully phased in SAP would cost $36.8 billion annually at 1991 income levels. This estimate has three major components. First, corporate income is taxed at the top personal tax rate rather than the corporate tax rate. Before any other adjustments, this costs $33 billion in lost tax revenue. Second, the change in basis reduces taxes of capital gains due to retained earnings. I make a rough estimate $11.2 billion in lost tax revenue as a result of this change. Finally, tax integration is likely to lead to a shift from debt to equity finance as the tax disadvantage towards equity finance is reduced. An economic analysis in the 1992 Treasury report

estimates that corporate leverage falls somewhere between 1 and 7% when there is lump sum replacement of the lost tax revenues. The shift from debt to equity finance reduces interest deductions on the corporate income tax and so raises revenue to offset some of the loss on the personal tax side. I estimate this raises about $7.4 billion in taxes. Combining these three components yields the $36.8 billion 1991 revenue loss. Applying this methodology to 2003 data, I obtain a rough estimate of the annual revenue loss from adoption of the SAP of $36.7 billion at 2003 income levels.

The complexity of the SAP as well as the revenue loss entailed suggests that a more modest and simple integration approach might be more appropriate. Thus, I next consider the dividend exclusion approach.

2. Dividend Exclusion Prototype

The Dividend Exclusion Prototype (DEP) is a simpler form of corporate tax integration that achieves partial integration of the two income taxes. Specifically, it excludes dividend income from taxation at the personal level. Thus, corporate profits paid out in dividends are only subject to the corporate income tax. The major advantage of the DEP is its simplicity and ease of implementation. Its simplicity led the Department of the Treasury to prefer this approach to any form of dividend imputation credit scheme (U.S. Department of the Treasury (1992)).

Table 3 shows the marginal tax on a dollar of profits under the DEP. Given the convergence of the top corporate and personal income tax rates in 2003, the DEP comes close to full integration of the tax system.

Table 3. Tax Rates on Marginal Profits Under DEP		
	General Tax Rate	Current Tax Rate
Corporate Dividends	t_c	35.0%
Corporate Interest	t_p	35.0%
Corporate Retained Earnings	$t_c + (1-t_c)t_g$	37.6%
Non-Corporate Payouts	t_p	35.0%

Let us now turn to an estimate of the revenue loss under the DEP. As a rough guide to the revenue cost of excluding dividends from taxable income in the personal income tax, I can use an estimate of the average marginal income tax rate on dividend income constructed from the NBER's TAXSIM tax calculator (Feenberg (2000)). This average tax rate in 2003, the year in which I do my analysis, was 17.6 percent and an estimate of reported dividends in 2003 is $104.6 billion.[14]

Excluding dividends from taxable income would lead to a revenue loss of $18.4 billion for that year (.176x$104.6). A few adjustments to this calculation are required to obtain a more accurate measure. First, as noted above, tax integration is likely to lead to a shift from debt to equity finance as the tax disadvantage towards equity finance is reduced. Second, there are a number of smaller changes including a reallocation of physical capital from the household, non-corporate and state/local government sectors to the corporate sector, as well as changes in the equilibrium interest rate and dividend payout rates. Taking these considerations into account, I estimate that the revenue loss falls to $23.0 billion per year.

I will consider the following two DEP proposals:

1) exclusion of all dividends from personal income tax financed by a carbon tax. Based on the calculation above, this would require a carbon tax of $23 billion per year.

[14] Dividends reported on the personal income tax are not available for 2003. I grossed up reported dividends from 2002 by the growth in dividends in NIPA from 2002 to 2003.

It is worth pausing to consider which industries benefit the most from tax integration. There are no data available on distribution of corporate equity holdings by industry across equity owners. I will assume that households hold equities by industry in proportion to dividend payouts by industry. Table 4 below shows the top 10 industries in terms of net corporate dividend payments. These ten industries account for over half of dividend payments in 2003 and are likely to be the greatest beneficiaries of tax integration.

Table 4. Top 10 Corporate Dividend Paying Industries

Industry	$billions
Management of companies and enterprises	37.9
Retail trade	32.9
Construction	22.3
Chemical products	22.2
Wholesale trade	21.7
Miscellaneous professional, scientific, and technical services	17.2
Food and beverage and tobacco products	13.5
Broadcasting and telecommunications	13.0
Utilities	11.4
Ambulatory health care services	9.9

Source: NIPA Data for 2003

Conversely, I can identify those industries that are impacted most heavily by a carbon tax. Given the significant impact on these industries, I consider a second policy option:

2) exclusion of 100% of dividends from personal income tax from industries most heavily affected by a carbon tax combined with 50 percent exclusion for all other industries.

III. Modeling Approach and Analysis

A number of economists have studied the economic consequences arising from corporate tax integration. The most common approach is to utilize a computable general equilibrium (CGE) model. Such models have been used by Ballard et al. (1985a), Fullerton et al. (1981) and U.S. Department of the Treasury (1992) to analyze the impact

of corporate tax integration. CGE models are typically large, complex structural models of an economy derived from fundamental economic theory. Their strengths are their logical consistency as well as their usefulness for policy and counterfactual analysis. Their very complexity, however, makes them difficult to evaluate from the outside and often deeply embedded assumptions and modeling approaches play an important role in driving results in ways that are not obvious to the casual observer.

Rather than employ a CGE model, I undertake an analysis that utilizes behavioral response estimates from CGE modeling as well as other empirical analyses. I focus on three major changes: shifts in the allocation of capital, changes in the sources of funding for capital projects, and changes in uses of funds from capital projects.

The first critical behavioral response arising from corporate tax integration is a shift in the allocation of capital. Integrating the corporate and personal income tax will reduce the effective tax rate on corporate capital. This in turn leads to a shift in capital from the non-corporate to the corporate sector. In particular, capital flows from the household, government, and non-corporate sector to the corporate sector. This will lead to an increase in corporate taxes and a decrease in personal taxes as taxable profits shift from the non-corporate sector (as well as the nontaxable sectors) to the corporate sector.

The second critical behavioral response is a change in corporate leverage structure. Corporate tax integration removes (or reduces) the advantage to debt financing (relative to equity financing). Thus I expect less debt financing and more equity financing. I calculate the change based on empirical estimates of the impact of taxes on financing structure from Graham (1999). Shifts from debt to equity financing affect tax collections in three ways: 1) they reduce corporate interest deductions and so increase corporate tax collections, 2) they reduce interest income taxable at the personal level, and

3), they increase retained earnings (to the extent that equity related profits are retained rather than distributed. These retained earnings will be taxed at the personal level upon realization of the capital gains associated with the earnings.

The third critical behavioral response is a change in dividend payout behavior. Chetty and Saez (2004) document that corporations responded to the decrease in dividend taxation in 2003 by increasing dividend payouts both by existing firms and by firms that hitherto had not paid dividends. It will turn out changes in dividend payout behavior have little impact on the revenue estimates. After tax integration, payout behavior only affects tax collections to the extent that capital gains are taxed. As discussed below, on an accrual basis, capital gains are taxed quite lightly and so changes in their tax treatment have only a minimal impact on tax collections.

Shareholder Allocation Prototype

I begin with an analysis of the Shareholder Allocation Prototype (SAP). As noted above, the SAP treats corporate income in a similar fashion to partnership income. The corporate income tax continues to operate in its present fashion but it should now be properly viewed as a withholding tax. Corporate income and corporate tax payments are attributed to individual shareholders who report the income on the personal income tax and take credits for any taxes paid at the corporate level.

I first note the assumptions that I make about the three types of behavioral changes I expect after tax reform. First, there is the shift in capital from the non-corporate to the corporate sector. Based on the analysis in the Treasury study, I would predict a shift in capital (as a fraction to total capital) towards the corporate sector of 2.8 percentage points (see column 3 in table). As Table 5 below demonstrates, this implies an increase in corporate capital of 10.8 percent (column 4).

Table 5. Capital Stock Distribution				
Sector	Capital Stock 2003 levels (1)	Share (2)	Shift in Total Capital Stock (3)	Percentage Change in Capital Stock (4)
Corporate	9,032	26.0%	2.8%	10.8%
Non-corporate	4,217	12.2%	-0.3%	-2.5%
Government	6,493	18.7%	-0.1%	-0.5%
Household	14,951	43.1%	-2.4%	-5.6%
Total	34,693	100%		
Source: NIPA and Authors' calculations				

What impact this shift will have on taxable income in the corporate sector is unclear. One thought might be that taxable profits increase at the same rate as does the capital stock (assuming constant returns to scale in production and a scaling up of all other inputs in production at the same rate as capital). This overstates the growth in taxable profits for two reasons. First, a change in relative prices (decrease in cost of capital) will lead to an increase in the use of the favored factor greater than any increase in other factors. On this basis alone, the growth in output would be likely to be something on the order of 1/4 to 1/3 the growth in capital. Second, this view ignores the impact of the decline in the housing sector on production in the economy. Demand for durable goods, construction, and other industry outputs would fall as capital shifts out of residential housing. Because of these two considerations, I do the following. First, I report detailed industry impacts assuming no change in corporate and non-corporate output. Then, I show how the aggregate revenue estimates are affected by changes in corporate and non-corporate output. The distribution across sectors of price changes is not appreciably affected by changes in output and so our understanding of the relative industry impacts is not affected.

The second behavioral response is a change in the source of funds for corporate investment. To calculate this change, I use results from Graham (1999). Graham

regresses the debt to value ratio on a number of variables including the tax preference for debt variable, $P = (1-\tau_p) - (1-\tau_c)(1-\tau_e)$, where τ_p is the tax rate on interest income, τ_c is the corporate tax rate and τ_e is the tax rate on equity. The estimated change in the debt to value ratio will be $\beta(P_1-P_0)$ where β is the estimated coefficient on the debt tax preference variable in Graham's regression, and P_1-P_0 is the change in the value of this variable following tax integration.

The tax rate on equity is a weighted average of the tax rate on dividend income and the accrual equivalent tax rate on capital gains (weighted by the dividend payout ratio). Following Graham (1999), Gordon and Mackie-Mason (1990), and Feldstein et al. (1983), I reduce the statutory rate on capital gains by 75 percent to convert to an accrual equivalent. This is a conventional assumption based on half the taxes being foregone through deferral and half again from basis step-up at death. I assume an accrual equivalent tax rate on capital gains of 5 percent.[15] The pre-tax reform tax on equity equals (.62)(.176) + (.38)(.05) = .128 where the dividend payout ratio for 2003 was 62 percent and the average marginal tax on dividends is 17.6 percent. Thus the debt preference variable (P_0) equals 8.31 percent. The Shareholder Allocation Prototype drives the tax preference variable to zero ($P_1 = 0$). Based on Graham's preferred regression and coefficient estimate of 0.070, this reduces the leverage ratio by .58 percentage points.

Finally, I assume a 4.3 percent increase in the dividend payout ratio based on the 1992 Treasury study. It turns out that this parameter has little impact on the results. Since dividends are no longer taxed at the personal level and the accrual equivalent tax

[15] The top tax rate on capital gains in 2003 was 20 percent prior to May 6 and 15 percent after May 5. My results are insensitive to using 5 percent, 3.75 percent, or a weighted average of the two rates.

rate on capital gains is only 5 percent, the change in tax collections is minor relative to other changes.

I begin by reporting summary results on aggregate changes in taxation resulting from the SAP.

Table 6. SAP Revenue Losses ($billions)			
	Change in		
	Corporate Tax	Personal Tax	Total
Domestic	2.1	-33.2	-31.0
Rest of the World	0.0	-5.7	-5.7
Total	2.1	-38.9	-36.7
Source: Author's calculations			

The row labeled "Rest of the World" represents tax revenues on earnings from foreign corporations owned by domestic taxpayers. The SAP loses $5.7 billion in personal income taxes that do not benefit owners of domestic firms. See Appendix Table A1 for a detailed breakdown of the revenue losses.

I next turn to the analysis of carbon taxes and the overall impact of the tax reform on industry prices. To finance corporate tax integration, I impose a carbon tax designed to raise $36.7 billion in 2003. Carbon emissions that would be potentially subject to a carbon tax totaled 1,574.3 million metric tons of carbon in 2003 (Energy Information Administration (2004)). Assuming no change in emissions, a carbon tax of $23.31 per metric ton of carbon would be necessary to raise $36.7 billion. Carbon emissions break down as follows:

Table 7. Carbon Emissions in 2003			
Fuel Source	**Emissions (mmtc)**	**Fraction of Total**	**Revenue ($bill)**
Coal	571.3	36.3%	$13.3
Natural Gas	321.6	20.4%	$7.5
Petroleum	681.4	43.3%	$15.9
Total	1574.3	100.0%	$36.7

I now have all the information to determine the direct impact of the tax reform. All I need to do is offset the tax reductions in Appendix Table 1 with tax increases of $13.3 billion for the coal mining industry and $23.4 billion for the oil and gas extraction industries. This approach, however, ignores the indirect impacts of the taxes as prices change in the economy. I turn to that analysis now.

The conventional view of the incidence of carbon taxes is that they will be passed forward in the form of higher product prices to consumers. The input-output analysis makes that assumption and translates the intermediate goods taxes into higher industry prices as energy intensive inputs (now more expensive) are used in the production of downstream goods. Corporate tax integration, by reducing the double taxation of capital income should increase the income of owners of all capital (corporate and non-corporate). This result was first shown by Harberger (1962) and this incidence assumption is frequently used (see, for example, Pechman (1985)). It is possible that in the context of a package reform where corporate tax integration is combined with a carbon tax, the entire package of taxes is passed forward in changes in prices of industry products. This follows as the higher prices of goods (due to the carbon tax) put domestic goods at a competitive disadvantage relative to imported goods. This competitive force makes it difficult for owners of capital to appropriate the gains from corporate tax reductions.

If this argument is correct, then the price changes I report below can be viewed as a measure of the industry incidence impact of the tax reform. Alternatively, it may be that the conventional story continues to hold and that the carbon tax is passed forward into higher prices while the corporate tax integration tax reductions accrue to owners of capital (are passed backward). Rather than attempt to determine the ultimate incidence of

this complex reform, I take a different tack. I report a statistic that I call the Breakeven Incidence Share (BIS). The BIS represents what fraction of the carbon tax must be shifted back to shareholders to offset the gains from corporate tax integration. For example, if an industry experiences a price increase of 4 percent due to the carbon tax and the equivalent of a 0.4 percent decrease due to corporate tax integration, then the BIS is 10 percent. In other words, so long as no more than 10 percent of the carbon tax is shifted back to capital owners, the benefits of corporate tax integration exceed the costs of the carbon tax from the perspective of capital owners.

First I show the price impacts resulting from corporate tax integration. As noted above, these are the price impacts under the assumption that the tax reductions are passed forward to consumers. I are not arguing that this in fact will happen; this allows us to present the tax changes in a way that allows comparison with the carbon tax price changes.

Table 8. Price Changes Due to SAP	
Greatest Declines in Price Due to SAP	
Industry	Price Change
Management of companies and enterprises	-2.42%
Petroleum and coal products	-1.10%
Chemical products	-0.96%
Food and beverage and tobacco products	-0.86%
Apparel and leather and allied products	-0.73%
Smallest Declines in Price Due to SAP	
Industry	Price Change
Computer systems design and related services	-0.18%
Government	-0.18%
Warehousing and storage	-0.19%
Information and data processing services	-0.19%
Legal services	-0.20%

Not surprisingly, three of the five industries with the greatest price declines are included in the list of top corporate dividend paying industries (Table 4). Interestingly, the Petroleum and Coal Products industry, which I would expect to be heavily impacted by the carbon tax, benefits disproportionately from corporate tax integration. The dispersion of price changes is moderate and in all cases negative. The price changes arising from the SAP are of a comparable magnitude to the dispersion of price changes due to the carbon tax (except for three industries) as the next table shows:

Table 9. Price Changes Due to Carbon Tax	
Greatest Increases in Price Due to Carbon Tax	
Industry	Price Change
Petroleum and coal products	7.34%
Coal mining	6.81%
Utilities	5.08%
Mining, except coal, oil and gas	1.77%
Primary metals	1.46%
Smallest Increases in Price Due to Carbon Tax	
Industry	Price Change
Computer systems design and related services	0.06%
Legal services	0.06%
Performing arts, spectator sports, museums, and related activities	0.08%
Motion picture and sound recording industries	0.09%
Ambulatory health care services	0.09%

Petroleum refining, coal mining, and utilities suffer very large price increases relative to other industries (and relative to the price decreases from SAP). Combining the two price changes, I can see that the rankings are largely driven by the carbon tax increases:

Table 10. Total Changes in Prices Due to Tax Reform	
Greatest Increases in Price	
Industry	Price Change
Coal mining	6.40%
Petroleum and coal products	6.20%
Utilities	4.43%
Mining, except coal, oil and gas	1.18%
Primary metals	1.07%
Greatest Decreases in Price	
Industry	Price Change
Management of companies and enterprises	-2.30%
Retail trade	-0.55%
Apparel and leather and allied products	-0.52%
Food and beverage and tobacco products	-0.51%
Chemical products	-0.49%

Complete results for all sectors are presented in the appendix. Of the 58 sectors analyzed, only 14 have a positive net price change while 44 have a negative price change. Once I get past the top three industries, the price changes range from -2.30 to 1.18 percent, a relatively moderate range of net price changes.

Comparing these two price changes is only appropriate if the reduction in capital income taxation is passed forward to consumers in the form of lower prices (or if the carbon tax is passed back to capital owners in the form of lower returns). I next report my measure of the required amount of pass-back in the carbon tax possible before equity holders are adversely affected by this reform. I report it for the ten industries with the highest net price increase.

Table 11. Breakeven Incidence Shares				
Industry	**Carbon Tax**	**SAP**	**Sum**	**BIS**
Coal mining	6.81%	-0.38%	6.40%	6%
Petroleum and coal products	7.34%	-1.10%	6.20%	15%
Utilities	5.08%	-0.63%	4.43%	12%
Mining, except coal, oil and gas	1.77%	-0.59%	1.18%	33%
Primary metals	1.46%	-0.38%	1.07%	26%
Pipeline transportation	1.09%	-0.54%	0.54%	50%
Air transportation	0.83%	-0.35%	0.48%	42%
Waste management and remediation services	0.76%	-0.46%	0.29%	61%
Government	0.41%	-0.18%	0.23%	44%
Truck transportation	0.47%	-0.33%	0.14%	70%

So long as less than 6 percent of the carbon tax is passed back to equity holders in the coal mining industry, returns to shareholders will not fall following this green tax reform[16]. The column labeled "Sum" provides the consumer price increases under full forward passing of both taxes.

Another way to present the information in the BIS is to report which industries are harmed under various amounts of backward shifting of the carbon tax. The next table reports this.

[16] This abstracts from any redistribution of returns between corporate and non-corporate capital. The standard Harberger assumption is that the benefits of corporate tax reduction accrue to all owners of capital, not simply owners of corporate capital.

Table 12. Backward Shifting of Carbon Tax and Impacted Industries
10 percent shift
Coal mining
20 percent shift
Coal mining, Utilities, Petroleum refining and related products
30 percent shift
Coal mining, Utilities, Petroleum refining and related products, Primary Metal Industries
40 percent shift
Coal mining, Utilities, Petroleum refining and related products, Primary Metal Industries, Other Mining
50 percent shift
Coal mining, Utilities, Petroleum refining and related products, Primary Metal Industries, Other Mining, Air transportation, Government

Summing up, the SAP financed by a carbon tax blunts to a modest degree the price increases that arise from the latter tax. If the carbon tax is fully passed forward to consumers, then the tax reform benefits the owners of equity in nearly all industry sectors. This is worth emphasizing. The standard incidence view is that a carbon tax would be passed forward to consumers in the form of higher product prices while capital tax reductions would be passed back to owners of capital. If this view is correct, business (or, more precisely, the equity holders) would generally benefit from corporate tax integration financed by a modest carbon tax.

The SAP above is estimated to cost nearly $37 billion a year. That is based on no growth in corporate profits (and corporate taxes - other than changes resulting from changes in financial policy). If production were Cobb-Douglas with a capital output elasticity of .25, then a 10.8 percent increase in capital would bring about a 2.7 percent increase in output. The decrease in capital use in other sectors would have a spill-over effect on the corporate sector as described above. Rather than try to estimate the growth

in taxable corporate profits, I present some revenue estimates for different growth assumptions[17].

Table 13. SAP Revenue Estimates			
Growth Rate of Corporate Profits	**Change in Corporate Income Tax**	**Change in Personal Income Tax**	**Change in Total Taxes**
0.0%	2.1	-38.9	-36.7
1.0%	5.0	-39.1	-34.1
2.0%	7.9	-39.3	-31.4
3.0%	10.7	-39.5	-28.8

As the growth rate of corporate profits increases, so do corporate income tax collections. This is offset by a slight decrease in personal income tax collections as corporate income is now taxed at a lower average rate and non-corporate income falls. Income from the non-corporate sector also falls a bit as capital shifts from the non-corporate to the corporate sector.

The good news is that growth in corporate revenues arising from the shift in capital reduces the need for a substantial carbon tax, perhaps by as much as 20 to 25 percent based on the growth rates in Table 13. While a carbon tax raising only $30 to $35 billion a year would not bring about the reductions in carbon use called for in the Kyoto Protocol, a carbon tax of this magnitude would have considerably less of an impact on the economy and would allow for learning about the efficiency and distributional impacts of a carbon tax if it were decided in the future to increase reliance on this tax to effect a substantial reduction in carbon emissions.

Dividend Exclusion Prototype

The next analysis that I consider is the dividend exclusion prototype (DEP) discussed above. Put simply, dividends are no longer taxable at the personal level. My

[17] I assume a similar growth rate for non-corporate output based on the change in non-corporate capital.

assumptions about financial behavior are the same as in the previous section. Again, note that the pre-tax reform tax on equity equals (.62)(.176) + (.38)(.05) = .128 where the dividend payout ratio for 2003 was 62 percent and the average marginal tax on dividends is 17.6 percent. Excluding dividends from taxable income at the personal level reduces the tax on equity from 12.8 percent to 1.9 percent and the debt preference variable from 8.31 percent to 1.24 percent. Based on Graham's preferred regression, this reduces the leverage ratio by 0.49 percentage points.

Table 14 presents summary results on the changes in taxation resulting from the DEP.

Table 14. DEP Revenue Losses ($billions)

	Change in		
	Corporate Tax	Personal Tax	Total
Domestic	1.8	-17.9	-16.1
Rest of the World	0.0	-4.0	-4.0
Total	1.8	-21.9	-20.1

Source: Author's calculations

First I show the price impacts resulting from corporate tax integration. Table 15 lists the five industries with the lowest price declines and the five with the highest price declines (complete results are in Appendix Table A3). The price changes are relatively modest.

Table 15. Corporate Tax Integration: DEP	
Industry	**DEP**
Least Benefit from Corporate Tax Integration	
Computer and electronic products	-0.06%
Government	-0.07%
Warehousing and storage	-0.08%
Educational services	-0.08%
Other transportation and support activities	-0.09%
Greatest Benefit from Corporate Tax Integration	
Management of companies and enterprises	-0.66%
Electrical equipment, appliances, and components	-0.48%
Chemical products	-0.40%
Petroleum and coal products	-0.31%
Paper products	-0.28%

The benefits from corporate tax integration are fairly evenly distributed across industry groups. In contrast, the costs of the carbon tax are highly concentrated as the following table shows.

Table 16. Carbon Tax Price Increases	
Industry	**Carbon Tax**
Highest Price Increases	
Petroleum and coal products	4.02%
Coal mining	3.62%
Utilities	2.74%
Mining, except coal, oil and gas	0.95%
Primary metals	0.78%
Lowest Price Increases	
Legal services	0.03%
Computer systems design and related services	0.03%
Performing arts, spectator sports, museums, and related activities	0.04%
Broadcasting and telecommunications	0.05%
Wholesale trade	0.05%

Three industries face price increases of more than 2.7 percent while the remainder face price increases of one percent or less.

I next turn to the combined effects of the overall tax reform. Table 17 shows the five industries with the largest gains and losses from the tax reform expressed as a percentage change in price.

Table 17. Direct and Indirect Effects of Green Tax Reform

Industry	Carbon Tax	DEP	Sum
Highest Price Increases			
Petroleum and coal products	4.02%	-0.31%	3.70%
Coal mining	3.62%	-0.14%	3.47%
Utilities	2.74%	-0.22%	2.51%
Mining, except coal, oil and gas	0.95%	-0.27%	0.68%
Primary metals	0.78%	-0.15%	0.63%
Highest Price Decreases			
Management of companies and enterprises	0.06%	-0.66%	-0.60%
Electrical equipment, appliances, and components	0.16%	-0.48%	-0.32%
Retail trade	0.06%	-0.22%	-0.16%
Broadcasting and telecommunications	0.05%	-0.19%	-0.14%
Apparel and leather and allied products	0.11%	-0.25%	-0.14%

A list of price changes for all industries in included in the appendix. Of the 58 sectors analyzed, 20 pay more in carbon taxes than they receive in tax reductions, 1 is unaffected, and 37 benefit from the tax reform. What is striking, however, is that once I get past the top three industries, the price changes are quite modest, not exceeding 1 percent in absolute value.

I once again report the BIS statistic for the industries with the highest net price increase.

Table 18. Breakeven Incidence Shares				
Industry	**Carbon Tax**	**DEP**	**Sum**	**BIS**
Petroleum and coal products	4.02%	-0.31%	3.70%	8%
Coal mining	3.62%	-0.14%	3.47%	4%
Utilities	2.74%	-0.22%	2.51%	8%
Mining, except coal, oil and gas	0.95%	-0.27%	0.68%	28%
Primary metals	0.78%	-0.15%	0.63%	19%
Pipeline transportation	0.60%	-0.20%	0.40%	33%
Air transportation	0.45%	-0.10%	0.36%	22%
Nonmetallic mineral products	0.40%	-0.17%	0.23%	43%
Waste management and remediation services	0.41%	-0.24%	0.17%	59%
Government	0.22%	-0.07%	0.16%	32%

The BIS threshold for the top three industries is lower under the DEP than the SAP plan raising the likelihood that equity holders would be adversely affected by the DEP relative to the SAP.

I can reduce the impact on the top three carbon impacted industries somewhat by giving preferential dividend exclusion treatment to these industries relative to the remaining sectors. For example, the following table illustrates the price impacts from excluding all dividends from personal income taxation for the petroleum refining, coal mining, and utility industries while excluding 50 percent of dividends for remaining industries.

Table 19. Direct and Indirect Effects of Green Tax Reform: Preferential Treatment for Heavily Impacted Industries				
Industry	**Carbon Tax**	**DEP**	**Sum**	**BIS**
Highest Price Increases				
Petroleum and coal products	1.98%	-0.24%	1.74%	12%
Coal mining	1.76%	-0.10%	1.66%	6%
Utilities	1.34%	-0.19%	1.15%	14%
Mining, except coal, oil and gas	0.46%	-0.14%	0.32%	30%
Primary metals	0.38%	-0.08%	0.30%	21%
Highest Price Decreases				
Management of companies and enterprises	0.03%	-0.34%	-0.31%	*
Electrical equipment, appliances, and components	0.08%	-0.24%	-0.16%	*
Retail trade	0.03%	-0.11%	-0.08%	*
Apparel and leather and allied products	0.06%	-0.13%	-0.07%	*
Wood products	0.06%	-0.13%	-0.07%	*
In the BIS column, an asterix indicates that more than 100% backward shifting of the tax would be required for the reform to harm equity owners.				

While this preferential treatment reduces the price impact for these three industries (and raises the BIS), they still face sharply higher prices relative to other sectors. Moreover, the amount required to be raised by a carbon tax is reduced from $20.1 billion to $9.9 billion. The cost of reducing the interindustry impacts is a reduced need for carbon tax revenues and impetus for reductions in carbon use.

Finally, returning to the first DEP scenario (excluding all dividends from personal income taxation), I report alternative revenue estimates assuming different growth rates for corporate profits.

Table 20. DEP Revenue Estimates			
Growth Rate of Corporate Profits	**Change in Corporate Income Tax**	**Change in Personal Income Tax**	**Change in Total Taxes**
0.0%	1.8	-21.9	-20.1
1.0%	4.3	-22.1	-17.9
2.0%	6.7	-22.3	-15.6
3.0%	9.2	-22.5	-13.3

Tax revenues fall by one-third when corporate profits rise by 3 percent relative to the no growth scenario.

IV. Conclusion

The United States lags behind other developed countries in its use of environmental taxes as a revenue source. In this paper I consider how a carbon tax could be used to finance reductions in capital income taxation through corporate tax integration. I note that a carbon tax used to finance corporate tax integration could have beneficial efficiency effects. Moreover, the industry impacts are likely to be modest (in the sense of returns to shareholders). Put differently, there is little need to provide substantial additional relief to particular industry sectors in the economy to hold them harmless in the reform.

I close with three additional comments about a carbon tax linked to corporate tax integration. First, the revenue required of a carbon tax to offset revenue losses from tax integration is relatively modest and the carbon tax would certainly fall short of levels required to bring about significant reductions in carbon emissions. This proposal could be viewed as a first step towards a serious carbon policy whereby the U.S. gains experience with this new tax before committing to more substantial levels of carbon reduction.

Second, a carbon tax could lead to a shift away from domestic production of carbon intensive commodities towards foreign production and importation of those commodities. Any significant carbon tax would need to address this possibility by imposing some sort of levy on the embodied carbon in imported goods. One simple, albeit imperfect, way to do this would be to use domestic input-output tables to estimate

the carbon content embodied in commodities and apply these estimates to imported goods. Further research on this issue would be useful.

Third, my focus in this paper on industry level distribution of taxes is somewhat unusual and is of interest more from a political economy perspective than a traditional tax incidence perspective. My focus is dictated by my interest in linking a carbon tax with a tax which would increase economic efficiency. Reductions in capital income taxation are generally held to be more efficient than other types of tax reductions. Corporate tax integration has the added benefit of combining reductions in capital income taxation with an equalizing of tax treatment across various forms of capital. This focus on efficiency comes at the cost of a likely reduction in overall progressivity in the tax code under this proposed reform. Whether policy makers should emphasize progressivity or efficiency in crafting a green tax reform with a carbon tax is beyond the scope of this analysis. What I have argued in this paper, however, is that a carbon tax provides additional flexibility to policy makers as they strive to balance the various goals of efficiency, distribution, and simplicity in tax administration while addressing growing fiscal budgetary pressures and mounting environmental concerns.

Appendix A. Input-Output Analysis

The input-output accounts trace through the production of commodities by industries and the use of those commodities by other industries. Taken together, one can trace the use of inputs produced by one industry and used by all other industries. Various adding up identities along with assumptions about production and trade allow the accounts to be manipulated to trace through the impact of price changes in one industry on the products of all other industries in the economy. A brief description of the use of the input-output accounts follows[18].

Tracing price changes through the economy on the basis of input-output accounts dates back to work by Leontief (documented in Leontief (1986)). The model makes a number of important assumptions the most important of which are 1) goods are produced and sold in a perfectly competitive environment such that all factor price increases are passed forward to consumers, 2) domestic and foreign goods are sufficiently different that the price of domestic goods can adjust following changes in factor prices[19], and 3) input coefficients a_{ij} (the amount of industry i used in the production of industry j) are constant. Thus input substitution is not allowed as factor prices change. This last assumption means that price responses are only approximate as they don't allow for product mix changes as relative prices change. In effect, the input-output accounts can be used to trace first order price effects through the economy.

Two sets of equations define the basic input-output accounts. The first set relates the demand for goods from an industry to the value of output from that industry:

---

[18] This discussion is based on Metcalf (1999).

[19] Fullerton (1996) terms this the Armington assumption following work by Armington (1969).

$$
\begin{aligned}
x_{11}p_1 + x_{12}p_1 + ... + x_{1N}p_1 + d_1p_1 &= x_1p_1 \\
x_{21}p_2 + x_{22}p_2 + ... + x_{2N}p_2 + d_2p_2 &= x_2p_2 \\
&\vdots \\
x_{N1}p_N + x_{N2}p_N + ... + x_{NN}p_N + d_Np_N &= x_Np_N
\end{aligned}
\tag{B1}
$$

where x_{ij} is the quantity of the output from industry i used by industry j, p_i is the unit price of product i, d_i is the final demand for output i, and x_i is the total output of industry i. These N equations simply say that the value of output from each industry must equal the sum of the value of output used by other industries (intermediate inputs) plus final demand. Without loss of generality, I can choose units for each of the goods so that all prices equal 1. This will be convenient as the expenditure data in the input-output accounts can then be used to measure quantities prior to any taxes that I will impose.

The second set of equations relates the value of all inputs and value added to the value of output:

$$
\begin{aligned}
x_{11}p_1 + x_{21}p_2 + ... + x_{N1}p_N + v_1 &= x_1p_1 \\
x_{12}p_1 + x_{22}p_2 + ... + x_{N2}p_N + v_2 &= x_2p_2 \\
&\vdots \\
x_{1N}p_1 + x_{2N}p_2 + ... + x_{NN}p_N + v_N &= x_Np_N
\end{aligned}
\tag{B2}
$$

where v_i is value added in industry i. Define $a_{ij} = x_{ij}/x_j$, the input of product i as a fraction of the total output of industry j. The system (B2) can be rewritten as

$$
\begin{aligned}
(1-a_{11})p_1 - a_{21}p_2 - ... - a_{N1}p_N &= v_1/x_1 \\
-a_{12}p_1 + (1-a_{22})p_2 - ... - a_{N2}p_N &= v_2/x_2 \\
&\vdots \\
-a_{1N}p_1 - a_{2N}p_2 - ... + (1-a_{NN})p_N &= v_N/x_N
\end{aligned}
\tag{B3}
$$

These equations can be expressed in matrix notation as

$$(I - A')P_I = V \tag{B3'}$$

where I is an NxN identity matrix, A is an NxN matrix with elements a_{ij}, P_I is an Nx1 vector of industry prices, p_i, and V is the Nx1 vector whose i^{th} element is v_i/x_i. Assuming that (I-A') is non-singular, this system can be solved for the price vector:

(B4) $$P_I = (I-A')^{-1}V.$$

With the unit convention chosen above, P_I will be a vector of ones. However, I can add taxes to the system in which case the price vector will now differ from a vector of ones as intermediate goods taxes get transmitted through the system. Specifically, let t_{ij} be a unit tax on the use of product i by industry j. In this case, the value of goods used in production (grossed up by their tax) plus value added now equals the value of output:

(B5)
$$\begin{aligned}
x_{11}p_1(1+t_{11}) + x_{21}p_2(1+t_{21}) + \ldots + x_{N1}p_N(1+t_{N1}) + v_1 &= x_1p_1 \\
x_{12}p_1(1+t_{12}) + x_{22}p_2(1+t_{22}) + \ldots + x_{N2}p_N(1+t_{N2}) + v_2 &= x_2p_2 \\
&\;\;\vdots \\
x_{1N}p_1(1+t_{1N}) + x_{2N}p_2(1+t_{2N}) + \ldots + x_{NN}p_N(1+t_{NN}) + v_N &= x_Np_N
\end{aligned}$$

This set of equations can be manipulated in a similar fashion to the equations above to solve for the price vector:

(B6) $$P_I = (I - B')V$$

where B is an NxN matrix with elements $(1+t_{ij})a_{ij}$.

I regrouped industries in the input-output accounts into 50 industry groupings. Tax rates are computed as the ratio of required tax revenue from the industry divided by the value of output from that industry. Imagine that a carbon tax is designed to collect $20 billion on coal. The tax rate applied to the coal industry then equals

$$t_{4.} = \frac{20}{\sum_{j=1}^{N} x_{4j}}$$

where the tax is designed to collect $20 billion from the coal industry (industry 4). This tax is applied to all variables in the fourth equation of B5. Other industry level taxes are computed in a similar fashion. Some taxes only apply to the output of certain industries used by certain other industries. The treatment of industry 5, crude oil and natural gas, provides an example. The crude oil and natural gas industries are combined into one industry by the input-output accounts. Natural gas, however, is predominantly used by the utilities industries (industry 36) while crude oil goes to the petroleum refining industry (industry 17). Thus, I allocate the tax on natural gas to output from the crude oil and natural gas industry (industry 5) used by the utilities (industry 36) while the carbon tax on petroleum is allocated to the use of industry 5 by the petroleum refining industry (industry 17).

Table A1. SAP Tax Revenue Changes

Industry	Corporate Tax	Personal Income Tax	Total Taxes
Farms	0.008	-0.120	-0.112
Forestry, fishing, and related activities	0.006	-0.056	-0.049
Oil and gas extraction	0.003	-0.357	-0.354
Coal mining	0.001	-0.023	-0.022
Mining, except coal, oil and gas	0.002	-0.085	-0.083
Support activities for mining	0.002	-0.051	-0.049
Utilities	0.036	-1.488	-1.452
Construction	0.009	-1.920	-1.912
Food and beverage and tobacco products	0.012	-2.363	-2.352
Textile mills and textile product mills	0.002	-0.107	-0.105
Apparel and leather and allied products	0.002	-0.191	-0.190
Wood products	0.001	-0.187	-0.187
Paper products	0.005	-0.428	-0.423
Printing and related support activities	0.005	-0.306	-0.301
Petroleum and coal products	0.002	-1.486	-1.484
Chemical products	0.012	-2.188	-2.176
Plastics and rubber products	0.006	-0.326	-0.321
Nonmetallic mineral products	0.001	-0.296	-0.296
Primary metals	0.001	-0.085	-0.084
Fabricated metal products	0.002	-0.719	-0.717
Machinery	0.002	-0.511	-0.509
Computer and electronic products	0.003	0.334	0.337
Electrical equipment, appliances, and components	0.001	-0.329	-0.328
Motor vehicles, bodies and trailers, and parts	0.003	-0.189	-0.186
Other transportation equipment	0.001	-0.419	-0.418
Furniture and related products	0.001	-0.151	-0.150
Miscellaneous manufacturing	0.001	-0.380	-0.379
Wholesale trade	0.014	-2.950	-2.936
Retail trade	0.019	-4.566	-4.547
Air transportation	0.002	-0.110	-0.108
Rail transportation	0.001	-0.076	-0.075
Water transportation	0.000	-0.040	-0.040
Truck transportation	0.004	-0.144	-0.140
Transit and ground passenger transportation	0.001	-0.019	-0.018
Pipeline transportation	0.000	-0.053	-0.053
Other transportation and support activities	0.003	-0.285	-0.282
Warehousing and storage	0.001	-0.029	-0.028
Publishing industries (includes software)	0.014	-0.400	-0.386

Motion picture and sound recording industries	0.004	-0.039	-0.035
Broadcasting and telecommunications	0.020	-1.105	-1.085
Information and data processing services	0.006	-0.004	0.002
Finance, insurance, real estate, rental, and leasing	1.898	-13.907	-12.009
Legal services	0.001	-0.220	-0.220
Miscellaneous professional, scientific, and technical services	0.001	-1.101	-1.100
Computer systems design and related services	0.000	-0.145	-0.145
Management of companies and enterprises	-0.005	-6.819	-6.823
Administrative and support services	0.005	-0.459	-0.455
Waste management and remediation services	0.000	-0.113	-0.113
Educational services	0.001	-0.081	-0.080
Ambulatory health care services	0.003	-0.820	-0.817
Hospitals and nursing and residential care facilities	0.003	-0.350	-0.347
Social assistance	0.001	-0.154	-0.153
Performing arts, spectator sports, museums, and related activities	0.003	-0.098	-0.096
Amusements, gambling, and recreation industries	0.003	-0.097	-0.095
Accommodation	0.004	-0.175	-0.171
Food services and drinking places	0.011	-0.401	-0.389
Other services, except government	0.003	-0.301	-0.298
Source: Author's calculations.			

Table A2. Price Changes from Carbon Tax/SAP Reform				
Industry	**Carbon Tax**	**SAP**	**Total Taxes**	**BIS**
Farms	0.52%	-0.39%	0.13%	75%
Forestry, fishing, and related activities	0.16%	-0.26%	-0.10%	*
Oil and gas extraction	0.22%	-0.52%	-0.31%	*
Coal mining	6.81%	-0.38%	6.40%	6%
Mining, except coal, oil and gas	1.77%	-0.59%	1.18%	33%
Support activities for mining	0.44%	-0.63%	-0.20%	*
Utilities	5.08%	-0.63%	4.43%	12%
Construction	0.29%	-0.45%	-0.16%	*
Food and beverage and tobacco products	0.35%	-0.86%	-0.51%	*
Textile mills and textile product mills	0.43%	-0.65%	-0.22%	*
Apparel and leather and allied products	0.21%	-0.73%	-0.52%	*
Wood products	0.22%	-0.51%	-0.29%	*
Paper products	0.61%	-0.72%	-0.11%	*
Printing and related support activities	0.25%	-0.67%	-0.42%	*
Petroleum and coal products	7.34%	-1.10%	6.20%	15%
Chemical products	0.47%	-0.96%	-0.49%	*
Plastics and rubber products	0.37%	-0.64%	-0.28%	*
Nonmetallic mineral products	0.74%	-0.66%	0.08%	89%
Primary metals	1.46%	-0.38%	1.07%	26%
Fabricated metal products	0.40%	-0.61%	-0.21%	*
Machinery	0.30%	-0.58%	-0.28%	*
Computer and electronic products	0.16%	-0.23%	-0.07%	*
Electrical equipment, appliances, and components	0.29%	-0.65%	-0.36%	*
Motor vehicles, bodies and trailers, and parts	0.28%	-0.38%	-0.09%	*
Other transportation equipment	0.23%	-0.60%	-0.37%	*
Furniture and related products	0.23%	-0.57%	-0.34%	*
Miscellaneous manufacturing	0.23%	-0.63%	-0.40%	*
Wholesale trade	0.09%	-0.48%	-0.39%	*
Retail trade	0.12%	-0.66%	-0.55%	*
Air transportation	0.83%	-0.35%	0.48%	42%
Rail transportation	0.28%	-0.38%	-0.11%	*
Water transportation	0.39%	-0.49%	-0.10%	*
Truck transportation	0.47%	-0.33%	0.14%	70%
Transit and ground passenger transportation	0.38%	-0.29%	0.09%	76%
Pipeline transportation	1.09%	-0.54%	0.54%	50%
Other transportation and support activities	0.29%	-0.40%	-0.12%	*
Warehousing and storage	0.27%	-0.19%	0.08%	70%
Publishing industries (includes software)	0.12%	-0.42%	-0.30%	*
Motion picture and sound recording industries	0.09%	-0.22%	-0.13%	*
Broadcasting and telecommunications	0.10%	-0.40%	-0.30%	*

Information and data processing services	0.10%	-0.19%	-0.09%	*
Finance, insurance, real estate, rental, and leasing	0.12%	-0.51%	-0.40%	*
Legal services	0.06%	-0.20%	-0.15%	*
Miscellaneous professional, scientific, and technical services	0.11%	-0.32%	-0.21%	*
Computer systems design and related services	0.06%	-0.18%	-0.12%	*
Management of companies and enterprises	0.12%	-2.42%	-2.30%	*
Administrative and support services	0.15%	-0.30%	-0.15%	*
Waste management and remediation services	0.76%	-0.46%	0.29%	61%
Educational services	0.11%	-0.24%	-0.13%	*
Ambulatory health care services	0.09%	-0.30%	-0.21%	*
Hospitals and nursing and residential care facilities	0.16%	-0.30%	-0.14%	*
Social assistance	0.19%	-0.37%	-0.18%	*
Performing arts, spectator sports, museums, and related activities	0.08%	-0.27%	-0.20%	*
Amusements, gambling, and recreation industries	0.16%	-0.29%	-0.13%	*
Accommodation	0.16%	-0.36%	-0.21%	*
Food services and drinking places	0.24%	-0.38%	-0.14%	*
Other services, except government	0.16%	-0.27%	-0.11%	*
Government	0.41%	-0.18%	0.23%	44%

Source: Author's calculations. The Breakeven Incidence Share (BIS) reports the maximum fraction of carbon tax that can be passed back to equity owners before the returns to shareholders falls. An asterix means that more than 100% backward shifting of the tax would be required for the reform to harm equity owners.

Table A3. Price Changes from Carbon Tax/DEP Reform				
Industry	**Carbon Tax**	**DEP**	**Sum**	**BIS**
Farms	0.28%	-0.17%	0.12%	61%
Forestry, fishing, and related activities	0.09%	-0.17%	-0.08%	*
Oil and gas extraction	0.12%	-0.17%	-0.06%	*
Coal mining	3.62%	-0.14%	3.47%	4%
Mining, except coal, oil and gas	0.95%	-0.27%	0.68%	28%
Support activities for mining	0.24%	-0.21%	0.03%	88%
Utilities	2.74%	-0.22%	2.51%	8%
Construction	0.16%	-0.20%	-0.04%	*
Food and beverage and tobacco products	0.19%	-0.27%	-0.08%	*
Textile mills and textile product mills	0.23%	-0.23%	0.00%	100%
Apparel and leather and allied products	0.11%	-0.25%	-0.14%	*
Wood products	0.12%	-0.25%	-0.13%	*
Paper products	0.33%	-0.28%	0.05%	85%
Printing and related support activities	0.13%	-0.23%	-0.10%	*
Petroleum and coal products	4.02%	-0.31%	3.70%	8%
Chemical products	0.26%	-0.40%	-0.14%	*
Plastics and rubber products	0.20%	-0.24%	-0.04%	*
Nonmetallic mineral products	0.40%	-0.17%	0.23%	43%
Primary metals	0.78%	-0.15%	0.63%	19%
Fabricated metal products	0.21%	-0.23%	-0.01%	*
Machinery	0.16%	-0.18%	-0.02%	*
Computer and electronic products	0.09%	-0.06%	0.03%	67%
Electrical equipment, appliances, and components	0.16%	-0.48%	-0.32%	*
Motor vehicles, bodies and trailers, and parts	0.15%	-0.20%	-0.05%	*
Other transportation equipment	0.13%	-0.16%	-0.03%	*
Furniture and related products	0.13%	-0.19%	-0.06%	*
Miscellaneous manufacturing	0.12%	-0.26%	-0.14%	*
Wholesale trade	0.05%	-0.16%	-0.12%	*
Retail trade	0.06%	-0.22%	-0.16%	*
Air transportation	0.45%	-0.10%	0.36%	22%
Rail transportation	0.15%	-0.13%	0.02%	87%
Water transportation	0.21%	-0.15%	0.07%	71%
Truck transportation	0.26%	-0.11%	0.14%	42%
Transit and ground passenger transportation	0.21%	-0.12%	0.08%	57%
Pipeline transportation	0.60%	-0.20%	0.40%	33%
Other transportation and support activities	0.16%	-0.09%	0.06%	56%
Warehousing and storage	0.15%	-0.08%	0.07%	53%
Publishing industries (includes software)	0.07%	-0.12%	-0.06%	*
Motion picture and sound recording industries	0.05%	-0.09%	-0.04%	*

Broadcasting and telecommunications	0.05%	-0.19%	-0.14%	*
Information and data processing services	0.06%	-0.09%	-0.04%	*
Finance, insurance, real estate, rental, and leasing	0.06%	-0.12%	-0.05%	*
Legal services	0.03%	-0.11%	-0.08%	*
Miscellaneous professional, scientific, and technical services	0.06%	-0.17%	-0.11%	*
Computer systems design and related services	0.03%	-0.10%	-0.07%	*
Management of companies and enterprises	0.06%	-0.66%	-0.60%	*
Administrative and support services	0.08%	-0.12%	-0.04%	*
Waste management and remediation services	0.41%	-0.24%	0.17%	59%
Educational services	0.06%	-0.08%	-0.02%	*
Ambulatory health care services	0.05%	-0.14%	-0.09%	*
Hospitals and nursing and residential care facilities	0.09%	-0.10%	-0.01%	*
Social assistance	0.10%	-0.15%	-0.04%	*
Performing arts, spectator sports, museums, and related activities	0.04%	-0.17%	-0.13%	*
Amusements, gambling, and recreation industries	0.09%	-0.14%	-0.06%	*
Accommodation	0.08%	-0.15%	-0.07%	*
Food services and drinking places	0.13%	-0.14%	-0.01%	*
Other services, except government	0.09%	-0.11%	-0.02%	*
Government	0.22%	-0.07%	0.16%	32%

Source: Author's calculations. The Breakeven Incidence Share (BIS) reports the maximum fraction of carbon tax that can be passed back to equity owners before the returns to shareholders falls. An asterix indicates that more than 100% backward shifting of the tax would be required for the reform to harm equity owners.

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