A Carbon Dividend as an Efficient Transfer Writing Sample

Asher Dvir-Djerassi

Abstract

In the United States, the world's second largest emitter of greenhouse gas (GHG) pollutants, policies designed to reduce GHGs have met political resistance. Key to that resistance is fear of the potential regressive consequences of policies aimed at curbing GHGs. A cap-and-dividend or a tax-and-dividend program holds the promise of reducing GHGs without such regressive consequences. Such a program would either cap GHG emissions and sell permits to major emission sources or directly tax GHGs; the revenue collected would then be distributed in equal proportion to U.S. residents. Building from projections made by Boyce and Riddle (2007), this paper estimates the economic burden of a cap-and-dividend or a tax-and-dividend program across the income distribution. In addition to evaluating distributional consequences, this paper estimate the potential of such a program to serve as an efficient transfer program by simulating the labor supply effects of a carbon reduction program proposed by Boyce and Riddle (2007). By applying the 2008 CPS March Supplement to an adapted version of a labor supply model proposed by Saez (2002), net changes in employment, hours worked, and national income from the introduction of a cap/tax-and-dividend program are estimated. Through changes in labor supply, the introduction of a $96.9 billion carbon reduction program is projected to reduce economic output by no more than $320 million – a mere 0.0023 percent of 2007 U.S. GDP.

1 Introduction

Global climate change, spurred by anthropogenic greenhouse gas (GHG) emissions, threatens to impose prodigious costs and, potentially, existential consequences. Despite the Paris climate accord's recent international breakthrough to reduce global GHG emissions, comprehensive efforts to reduce GHGs have been stymied in the United States. While the reasons for the lack of political consensus are varied, fear that the cost of reducing carbon emissions will unduly burden Americans at the bottom of the income distribution perennially tears away support for legislation that limits GHGs.

Any policy able to significantly curb GHGs must reduce the consumption of carbon dioxide (CO_2) – the most impacting anthropogenic GHG, accounting for 82 percent of total GHG emissions in the U.S. (EPA, n.d.). Aside from directly sponsoring alternatives to clean energy, the main proposed policies to lessen CO_2 emissions rely on limiting its supply or the imposition of Pigovian taxes on its purchase. Both mechanisms raise the cost of goods and services associated with carbon emissions – a ubiquitous array of products from steel to quotidian groceries. Since low-income earners dedicate a higher share of their income towards consumption than high-income earners, raising the cost of carbon may be regressive.

Cap-and-trade and a revenue-neutral carbon tax, the most commonly considered policy proposals aimed at lowering CO_2 emissions, accept these regressive outcomes. To ameliorate the regressive consequences of raising the cost of carbon, certain economists and policy-makers have proposed amended versions of cap-and-trade and a carbon tax where revenue raised from the sale of carbon permits or a tax on carbon is recycled as an untaxed carbon rebate to all American residents in equal proportion. Such a cap-and-dividend program or tax-and-dividend program would address the regressive effects of placing a charge on carbon while internalizing the currently

externalized cost of carbon pollution and reducing CO_2 emissions.

Hansen (2009) and Van Hollen (2009) have proposed a cap-and-dividend program, where CO_2 emissions would be capped at the main entry points of carbon intensive resources and products into the economy, such as oil extraction, coal mining, and concrete manufacturing. Permits would be sold to firms responsible for carbon intensive goods and services. The revenue from these permits would be distributed to U.S. residents in equal proportion to deal with the relatively higher costs of carbon intensive goods. If revenue is sufficient, a carbon dividend may ameliorate the potentially regressive effects of such a program. Under Hansen's proposal, the cap would be adjusted such that CO_2 emissions would be reduced by 80 percent of their 2005 levels by 2050.

Progressive distributional impacts can equivalently come about through a carbon tax-and-dividend. Such a program uses the same mechanics as a cap-and-dividend, except it taxes CO_2 rather than caps CO_2. Like the cap-and-dividend programs, the tax-and-dividend distributes the revenue collected in equal proportion to U.S. residents. If the revenue raised and the relative cost of carbon intensive goods increase by the same amount under both programs, these two programs will have identical distributional consequences. Both a cap-and-dividend and a tax-and-dividend (further on referred to as a cap/tax-and-dividend) offer nearly equivalent mechanisms of internalizing the cost of CO_2, lowering emissions, and preventing regressive outcomes.

Beyond ameliorating the regressive impacts of reducing carbon emissions, a cap/tax-and-dividend holds the promise of serving as an efficient income transfer program – a facet of this program which has often been overlooked. With few exceptions, Americans who receive government benefits face implicit taxes on earnings in addition to explicit income and payroll taxes. For instance, under the Supplemental Nutrition Assistance Program (SNAP), formerly referred to as food stamps, for every additional

dollar in earnings, a SNAP recipient faces an effective loss of 25 cents in SNAP benefits (i.e. SNAP imposes a 25 percent effective implicit tax on earnings). [1] In contrast, a cap/tax-and-dividend would be void of implicit marginal taxes on earnings. Given that all American residents, regardless of income, would receive the same tax-free carbon dividend, an increase or decrease in earnings would have no effect on the size of one's dividend and their net taxes, implicit or explicit.

Primarily, high implicit taxes on earnings present two significant problems. First, many low and middle-income earners face considerable losses of transfer benefits when their incomes rise – imposing barriers on the economic mobility of low and middle-income earners. For instance, as a result of a raise, choosing to work additional hours, or through an increase in the minimum wage, the Urban Institute estimates that a single adult with two children making $20,000 annually would face a combined implicit and explicit tax rate of 75-percent on an additional dollar of income (Steuerle and Quakenbush, 2015). If that same person earned $30,000 annually they would face a 90-percent tax on an additional dollar of labor market income.[2]

Secondly, reducing the marginal benefit from employment via implicit taxes on employment unambiguously disincentivizes labor supply. The higher the marginal tax on a transfer recipients' earnings, the greater the incentive to substitute away from work. This is termed the substitution effect – i.e. the greater the tax, the greater the substitution away from that item or activity which is taxed. While the magnitude of this effect is debated in the labor supply literature, the literature clearly shows that marginal changes in tax rates, both implicit and explicit, impact labor supply (*see*

[1] *See* CBO (2012) for estimates of the effective implicit rates of taxation imposed by most government transfer programs.

[2] These estimated effective tax rates include explicit taxes – Federal income taxes, state income taxes, and payroll taxes – as well as implicit taxes from SNAP, Medicaid, the Children's Health Insurance Program (CHIP), and premium assistance subsidies. However, these simulated taxes exclude federal housing subsidies and Temporary Assistance for Needy Families (TANF). Urban's estimates are derived from the Urban-Brookings-Tax Policy Center's microsimulation model, which, it should be noted, overstates the effective taxes households face for a variety of reasons that are beyond the scope of this paper.

Chetty, Friedman, and Saez, 2008)

However, unlike most transfer programs, a cap/tax-and-dividend would be void of marginal taxes on earnings. A cap/tax-and-dividend program would only impact labor supply decisions through an income effect – i.e. ceteris paribus, a reduction of net income will encourage labor supply, while an increase in income will incentivize less work. Typically, the estimated magnitude of income effects are substantially smaller than substitution effects (*see* McClelland and Mok, 2012). Therefore, a cap/tax-and-dividend may function as a relatively efficient transfer and income maintenance program.

I test this hypothesis by estimating the aggregate labor supply effect of introducing a cap/tax-and-dividend program proposed by Boyce and Riddle (2007). In Boyce and Riddle's proposal, U.S. emissions would be capped at 93 percent of their 2007 levels in the program's first-year. Under assumptions made by Boyce and Riddle, reducing carbon to this level, either implicitly through a carbon cap or explicitly through a Pigovian tax, would generate $ 225 billion in revenue.[3] If this revenue were distributed in equal proportion to all American residents as a tax-free carbon dividend, each U.S. resident would receive a transfer payment of $ 763. Absent dynamic effects, Boyce and Riddle estimate the six bottom expenditure deciles would see an effective net subsidy resulting from this tax/cap-and-dividend program. Those at the top of the distribution, however, would face an effective net cost (*see* Table 2). Such distributional outcomes imply this program would be progressive, rather than regressive.

Building from the projections made by Boyce and Riddle, this paper estimates the cost burden of this program across the income distribution when accounting for potential changes in labor supply. Combining data from the 2008 CPS March Supplement on

[3] All estimates reported by Boyce and Riddle (2007) are in 2003 U.S. dollar. All dollar amounts reported in this paper have been inflation adjusted to 2007 U.S. dollars.

non-retired/non-disabled working-age U.S. residents with Boyce and Riddle's distributional estimates, this paper estimates aggregate net changes in labor supply using a model adapted from Saez (2002). This labor supply model estimates changes along both the intensive (hours worked) and extensive (employment participation) margins. By summing the marginal intensive and extensive labor supply effects of this program, net aggregate change in labor supply are derived and, consequently, changes in economic output from the introduction of a cap/tax-and-dividend program comparable to the one proposed by Boyce and Riddle.

2 The Political Barriers of a Regressive Program

In June of 2009, soon before the American Clean Energy and Security Act of 2009 (ACES) – a cap-and-trade program styled on the European Union Emission Trading Scheme (EUTS) – passed the House, but failed to see a vote in the Senate, three-quarters of Americans thought the federal government should regulate GHG, including a majority of Republicans and independents (Mufson and Agiesta, 2009.). However, a mere 52 percent of Americans supported a cap-and-trade scheme as the means to do this. Around the same time, a Washington Post-ABC News poll showed support for a cap-and-trade scheme was inversely related to fears about price increases. Fears that fuel, gasoline, and other carbon intensive essentials would rise beyond affordability was highest in households with annual incomes under $50,000. The Washington Post explains, "Nearly all of the drop-off in support for cap-and-trade... comes among people who live in such households. Those in higher-income households were relatively unfazed by the increased costs."

Given this political vulnerability central to the design of cap-and-trade legislation, it is unsurprising that commentators and factions opposed to the legislation, disingenuously or not, directed their chief arguments against the ACES at its regressive

impacts. In its editorial against the cap-and-trade legislation, The Wall Street Journal (2009) did not claim climate change was a farce; rather, The Wall Street Journal made a case against the bill for being regressive. The paper claimed the bill would disproportionately affect households lower on the income distribution.

The arguments heard from most lobbies opposed to the ACES generally followed the argument that prices will increase and low and middle-income earners will have to pay for them. Lobbyists for the American Petroleum Institute, the National Pork Producers Council, and Friends of the Earth maintained that price increases would hit essentials (Mufson, 2009). Citing the CBO, the American Petroleum Institute campaigned that cap-and-trade would raise gasoline prices by some 77 cents a gallon. While claims made by lobbyist were exaggerated, their spirit was not completely out of sync with reality. The CBO's analysis of the ACES, indeed, corroborated the potential for regressive impacts. American households, the CBO (2009) reported, would incur a net effective loss of purchasing power of $175 a year by 2020. The gross cost of the legislation in 2020 was projected to be 2.5 percent of after-tax income for households in lowest income quintile and 0.7 percent of after-tax income for households in the highest quintile. When utility rebates were taken into consideration, the magnitude of these regressive consequences were projected to diminish, but the legislation clearly imposed an uncompensated cost on most American households, particularly those below the midpoint of the income distribution.

Given that some of the strongest arguments against legislation designed to curb carbon emissions are based on the prediction that the effects of such legislation will be regressive, a cap/tax-and-dividend offers a strong political case. For reasons of economic fairness, a carbon dividend offers a way to secure durable public support for an effective policy to wean the economy away from dependence on fossil fuels.

3 Boyce and Riddle's Carbon Dividend

. The 2009 ACES bill, like the EU's cap-and-trade program (EUTS), suffered from a paucity of ways to address the regressive impacts of raising the cost of carbon. Central to the ACES's failure to appropriately redress vulnerable stakeholders is that legislation's inability to raise revenue. Unlike a carbon tax or a carbon cap program where carbon permits are auctioned, the ACES followed the typical route of cap-and-trade proposals by distributing carbon permits free of charge to historical GHG polluters and CO_2 emitters.[4] This entailed that the ACES, like other cap-and-trade legislation, raised revenue only from sources outside of the carbon cap. Boyce and Riddle argue against this central aspect of typical cap-and-trade programs given that it functions as an effective subsidy to the shareholders of GHG polluting firms. This is doubly the case when considering that carbon permits can be sold to other firms and polluters, thereby allowing historic polluters to profit from their pollution records.

The small pool of funds that would have been allocated by the ACES to ostensibly soften the burdens of raising the price of carbon would have been distributed unevenly across households. The CBO (2009) estimates that under the ACES roughly two-thirds of these funds would flow to households in the top quintile of the income distribution. This implies that in addition to the size of the fund dedicated to placating stakeholders, the way in which these funds are distributed is also vitally important. From the literature on the incidence of cap-and-trade and carbon tax policies as well as from Boyce and Riddle's work, such results are not surprising.[5] The takeaway from this literature is simple: the tax or cost incidence of a carbon program is regressive in the absence of a sufficient income maintenance transfer for

[4] Nat Keohane (2007) of the Environmental Defense Fund notes that while grandfathering permits have historically been the modus operandi of cap-and-trade proposals, there is no mechanical reason requiring carbon permits be allocated free of charge, rather than auctioned. For instance, Keohane notes, the Regional Greenhouse Gas Initiative – the regional cap-and-trade system for utilities instituted in several northeastern states – began to transition to auctioning carbon permits in 2007.

[5] See, for example, Parry 2004; Metcalf 2009; Burtraw et al. 2009; and Shammin and Bullard 2009

Table 1: Distributional Impact of Cap-and-Dividend, Absent Labor Supply Effects

Expenditure Deciles	Per Capita Incidence			As Percentage of Expenditures		
	Added Cost	Dividend	Net Benefit	Added Cost	Dividend	Net Benefit
1	242	763	521	11.2	35.2	24
2	381	763	384	9.6	19.3	9.7
3	477	763	286	9.0	14.3	5.4
4	579	763	185	8.6	11.3	2.7
5	649	763	115	7.8	9.2	1.4
6	731	763	34	7.3	7.7	0.3
7	824	763	-60	6.8	6.3	-0.5
8	942	763	-178	6.3	5.1	-1.2
9	1153	763	-390	6.0	3.9	-2.0
10	1661	763	-897	4.9	2.3	-2.7

Source: Adapted from Table 7 in Boyce and Riddle (2007)
Notes: Based on a $225 tax on each ton of carbon and 100 recycling of revenue.

those at the bottom of the income distribution.

The program proposed by Boyce and Riddle contrasts heavily with the ACES. Boyce and Riddle's program raises revenue from all primary entry points of carbon into the U.S. economy, including mines, oil refineries, major manufacturers, and the import of hydrocarbons. Based on estimates from the CBO, Boyce and Riddle claim there would be some 2000 points of entry that would be required to purchase carbon permits. As new CO_2 emitters and new points of entry develop, the EPA would designate they purchase carbon permits equal to their emissions. Over time, the number of permits auctioned would decrease to further limit CO_2 emissions. All revenue from the sale of these permits would be recycled directly to adult permanent residents in the form of a tax-free unconditional transfer.[6]

Building from the Intergovernmental Panel on Climate Change (IPCC) estimates and others in the literature, Boyce and Riddle assume a midrange estimate of $225 per ton of carbon for what the market price of carbon would be if emissions were limited to 93 percent of their 2007 levels. Boyce and Riddle assume that the heightened price

[6] Boyce and Riddle make the case that dividends should be allocated according to the number of children in a household as well as the number of adults. However, for the sake of simplifying the estimates made here, it is treated as if adults are the only recipients of the carbon dividend.

of carbon will be passed onto the consumer. As the price of carbon-intensive products and production processes increase, consumers would substitute away from expensive carbon-intensive products towards now relatively cheaper, less carbon-intensive goods and services. By applying a range of price elasticities of demand from the literature to data on consumer spending habits, Boyce and Riddle project how consumer behavior will change due to the heightened price of carbon.

Table 1 shows Boyce and Riddle's estimates of the cost incidence of this program by income decile. From a $225 per ton fee on each ton of carbon, it is estimated this will draw an annual $763 dividend. Summing the estimated per capita incidence and the carbon dividend solves for, what is termed in Table 1, 'Net Benefit'. The size of one's net benefit is inversely related to expenditure decile, meaning that this carbon program is progressively distributed.

4 Data and Methods

To simulate the aggregate labor supply response from the introduction of the cap/tax-and-dividend program proposed by Boyce and Riddle (2007), this paper applies a structural labor supply model proposed by Saez (2002) to the 2008 CPS March Supplement. This model estimates labor supply decisions along two fronts: the intensive and extensive margin. Intensive marginal income effects (i.e. how an increase or decrease in income changes the number of hours one chooses to work) are estimated first. Using the estimated change in hours and, consequently, labor market income, extensive marginal labor supply effects are estimated (i.e. how an increase or decrease in the net benefit from working increases or decreases the likelihood of choosing to be employed).

As is typical for structural labor supply models, the labor demand curve is treated

as perfectly elastic; all that determines employment is labor supply decisions. This assumption is clearly not realistic. However, for the purposes of this paper, this assumption will not be fatal. All changes in labor supply will be exaggerated. Given that the direction of movements in labor supply does not require an accurate labor demand curve, we can treat all results produced here as high-end estimates. This model will exaggerate the decrease in labor supply among those in the bottom 60 percent of the income distribution, who would see a net increase in their income and therefore income effects that push down labor supply. For the top 40 percent of the income distribution, a cohort that would see a net increase in labor supply, these increases will too be exaggerated. Despite these biases, the conclusion of this paper will not be impacted by their presence. Given that true changes in labor supply will be closer to zero, these biases imply that such a carbon reduction program will impose fewer distortions than are estimated here.

As with any structural labor supply model, Saez's modeling approach requires that the cost or benefit of any labor supply decision is made explicit to the model. For example, if the minimum wage increases, the new tax rate that a minimum wage earner would face must be made explicit in order to predict whether a minimum wage earner would seek to work additional hours or fewer hours. Rather than using outside information to simulate such benefits and costs, I apply the CPS March Supplement to a regression framework to impute unseen potential transfers and after-tax earnings one would receive if they had a different employment status. For instance, by using relevant labor market characteristics, the potential net income of someone not employed in 2007 is imputed using comparable observations who were employed. The approach used here deviates from traditional microsimulation models, like the Tax Policy Center's and the Tax Foundation's. Under traditional microsimulation approaches, a wide array of complex program rules are applied to individual observations in a data-set in order to project the taxes observations face and the transfers

they are eligible for. Rather, this approach simulates the net benefit or cost of any labor supply decision by identifying how nearly identical observations in the CPS March Supplement fare under a certain change in labor supply.

4.1 Data

The empirical building blocks to the projections made here are consumer data used by Boyce and Riddle and the 2008 CPS March Supplement. The CPS March Supplement is an annual survey of a representative sample of American households conducted by the U.S. Census (IPUMS-CPS). While collected on the household level, this data can provide information on the person level. This paper uses such person-level information and ignores potential intra-household transfers so as to be able to estimate individual labor supply decisions. The CPS March Supplement provides a rich array of information on employment and income. The survey asks respondents to provide information on earned income, transfer income by program source, and income from any other sources. This information is essential when estimating the impact of a policy change on labor supply. Given that this paper concerns the labor supply response to the introduction of a cap/tax-and-dividend, the sample used here is restricted to observations of typical working age (i.e. observations between the ages of 18 and 65 who are not Social Security retirement insurance beneficiaries).

4.2 Labor Supply Model

This paper adapts an innovative labor supply model proposed by Saez (2002). In contrast to the main currents in the structural labor supply literature prior to Saez's 2002 paper, this model does not treat workers as selecting from a continuum of labor supply choices. Rather, Saez's model treats workers as facing fixed-costs, institutional barriers, and an array of other forces that make it so there is a discrete labor supply

choice between being employed and not employed.

For those who are employed, it is assumed they can select from an array of labor supply choices along an intensive margin (i.e. hours worked margin). Those who are not employed only make the choice of whether to become employed or maintain their status; this choice is made along the extensive margin (i.e. the participation margin). In addition to movements along the intensive margin, the employed may also choose to change their employment status (i.e. a movement along the extensive margin). In the event of a policy change, such as the introduction of the cap/tax-and-dividend program in question, this model considers movements along the intensive margin first and then incorporates such movements in evaluating the labor supply changes along the extensive margin.

Two forces determine the direction of labor supply changes along the intensive margin: 1) Substitution effects, which are relevant when the marginal benefit of an additional hour of work increases or decreases and 2) Income effects, which concern the choice to increase or decrease the number hours worked when total effective income increases or decreases. In the context of a cap/tax-and-dividend program, movements along the intensive margin will only be determined by income effects. Given that the unconditional universal carbon dividend is distributed to all residents regardless of employment status, hours worked, or earned income, substitution effects have no relevance here.

After estimating the income effects of those employed before the policy change (i.e. how people will increase or decrease the number of hours in which they work), each observation's estimated change in working time is multiplied by their wage rate. This allows for an estimate to be made of the effective increase or decrease in earned income that would result from the labor supply decisions associated with the carbon policy. Using the estimated movements along the intensive margin, movements along

Table 2: Assumed Income and Employment Elasticities by Earned Income Quintiles

		Quintiles				
		Lowest fifth	Second fifth	Middle fifth	Fourth fifth	Highest fifth
Income Elasticity	Men & Single Women	-0.10	-0.10	-0.05	-0.01	-0.01
	Married Women	-0.10	-0.10	-0.05	-0.01	-0.01
Employment Elasticity	Men & Single Women	0.10	0.10	0.05	0.01	0.01
	Married Women	0.30	0.30	0.25	0.20	0.20

Sources: Mok and McClelland (2012).

the extensive margin are found. Such movements are a function of the benefit from working (net earnings plus transfer income when employed) minus the monetary benefit from not working, namely earnings from transfer income.

If an observation is estimated to choose to work more hours, then the estimated benefit of working for that observation will also rise because of greater earned income. Analogously, if an observation is estimated to see a negative movement along the intensive margin, then the net benefit from working will decrease. If the benefit from working increases relative to the benefit from not working, the probability of choosing to become employed increases for the non-employed. If the policy has the opposite impact, the probability of choosing to become employed decreases and the probability of the employed choosing to become non-employed also increases. Using these estimated probabilities, a total effective change in employment is estimated.

4.2.1 Intensive Marginal Effects

Like Boyce and Riddle (2007), this paper treats one's placement in the income distribution, and therefore one's spending habits, as the chief determinant of whether this cap/tax-and-dividend program imposes an effective positive lump-sum transfer or a negative lump-sum tax. The former would occur when increased expenditure on consumer goods are less than the carbon dividend, while the latter would occur when price increases cause expenditures to rise above the carbon dividend.

As outlined above, given that this carbon policy operates as an effective lump-sum transfer or tax, as it does not vary with income or employment status, the labor supply effects of this program are only sourced in income effects along the intensive margin (i.e. the hours worked margin). To estimate the income effects, the following equation is solved for each employed observation, i,

$$\frac{\delta l_i}{l_i} = \frac{\delta Y_i}{Y_i} \times \rho_i \tag{1}$$

where annual hours worked for those employed in 2007, l_i, is derived from the 2008 CPS March Supplement;[7] total income, Y_i, is derived from information reported to the CPS March Supplement;[8] and assumed elasticities of labor supply with respect to total income, ρ_i, are based on the baseline elasticities the CBO typically assumes (*see* Table 2), whose value varies by earned income quintile.

Changes in total income due to the introduction of the cap/tax-and-dividend program are based on the estimates made by Boyce and Riddle (2007). Depending on an observation's place in the income distribution as derived from the weighted 2008 CPS March Supplement, an observation is assigned a net change in income as large as $521 and as low as a decrease of $897. The changes in annual hours worked for those employed as a consequence of the cap/tax-and-dividend program's income effects are estimated by multiplying each observation's change in hours worked by that individual's wage-rate (*see* Table 3).[9]

[7] While the CPS March Supplement reports average weekly working hours, it is reported as a categorical variable broken up into large intervals (e.g. 1 to 4 hours a week, 5 to 10 hours, etc.). Unfortunately, the modeling approach taken here requires a continuous variable. For the purposes here, an 'average weekly hours worked' variable is constructed by dividing 'annual hours worked' by 'weeks worked' in 2007.

[8] This term includes labor market earnings, transfer income, and all other sources of reported income.

[9] The CPS March Supplement 2008 does not provide a wage rate variable. Therefore, the wage rate used is constructed by dividing each observation's total earned income by their reported annual hours worked. For an eighth of observations with reported positive earnings, the wage rate variable constructed was less than the 2007 federal minimum wage. For these observations,

4.2.2 Extensive Marginal Effects

To simulate employment effects, I assign each observation to a group based on characteristics relevant to employment (e.g. education, family size, etc.). Using these groups, net income when employed, C_j, is found for each group before and after the policy intervention. Additionally, net income when not employed, C_j, is found for each group before and after the policy intervention as well. Because of non-linearities and discontinuities in the implicit and explicit tax schedule, each group potentially faces different distortions along the extensive and intensive margins for the same wage rate.

Since some members of each group may not be employed, to find the net income when employed, C_j, the average earnings of those who are employed are used. To impute what the non-employed would earn if they were working, an estimate of expected income is made. Two models are estimated of the following form for those employed in 2007, one model contains information from prior to the policy change and the other contains information from after the policy change:

$$\textit{Net Income When Employed}_j = \beta_{kj} X_{kij} + u_{ij} (2)$$

where β_{kj} is a vector of variables related to employment used to construct each group, j. The fitted values of this regression are treated as the group members' net income if they were employed.

Similarly, I estimate the expected net income that the average group member receives when not employed. By summing all sources of income received by those not employed, an analogous model to the one above is run, except the dependent variable now estimated is 'net income when not employed,' C_0, and the observations are

it is assumed that they face a wage rate equal to the federal minimum wage of \$5.85. effective from July 24, 2007, to July 23, 2008 (Department of Labor).

restricted to those not employed. As previously done, a model is estimated for the dependent variable before the policy intervention and after the policy intervention (i.e. excluding and including the respective changes along the intensive margin).

$$\textit{Net Income When Not Employed}_j = \beta_{kj} X_{kij} + u_{ij} \tag{3}$$

As done previously, the fitted values of this regression are treated as the group members' net income if they were not employed.

Lastly, I run a linear probability model of the same form as the previous two equations to estimate the employment rate of each group, $Emply_j$.

$$Emply_j = \beta_{kj} X_{kij} + u_{ij} \tag{4}$$

Using the estimates from the models above, the elasticity of employment with respect to a change in the net benefit of working is evaluated for each group, j,

$$\eta \times \frac{Emply_j}{C_j - C_0} = \frac{\delta Emply_j}{\delta(C_j - C_0)} \tag{5}$$

where η is the assumed elasticity of employment with respect to the net benefit from employment (*see* Table 2); $Emply_j$ is the predicted probability that an individual in each group is employed; $C_j - C_0$ is equal to the net benefit from employment prior to the policy intervention, and $\frac{\delta Emply_j}{\delta(C_j - C_0)}$ is the change in employment with respect to the change in the net benefit from employment.

Lastly, the elasticity of employment with respect to a change in the net benefit of working $\frac{\delta Emply_j}{\delta(C_j - C_0)}$ is used to solve for the aggregate change in labor supply. By multiplying the predicted change in the net benefit from working for each group, the

percentage point change in employment for each group is estimated:

$$\Delta Emply_j = \frac{\delta Emply_j}{\delta(C_j - C_0)} \times \Big[(C_j - C_0)_{post-policy} - (C_j - C_0)_{pre-policy}\Big]$$

5 Discussion: The Efficiency of a Carbon Dividend

With and without dynamic effects, under this program roughly the bottom 60 percent of Americans would see their net incomes rise. Currently in the United States, there is no government income-maintenance or antipoverty transfer program that has the same reach and widespread positive net impacts that this program would be projected to have. According to the Census Bureau (2015), 52.2 million Americans (21.3 percent of the population) participated in one or more government transfer program in 2014. In contrast, this carbon dividend would touch all Americans. The combined effect of the carbon cap/tax and the dividend would directly raise the incomes of three times the number of people currently touched by the transfer system.

This model estimates that Boyce and Riddle's proposed carbon program would transfer $96.9 billion to the 127 million Americans employed in 2007 – nearly $30 billion greater than the $67.5 billion in combined cash and food stamp payments received in 2007 (IPUMS-CPS). Under the labor supply elasticities assumed and the assumption that the labor demand curve is flat, this program is estimated to decrease annual hours worked for those employed by an average of 1.2 hours annually (*see* Table 3) and decrease full-time equivalent employment by an estimated 28,769 working years – a 0.022 percentage point decrease in total employment (*see* Table 4). This reduction in hours worked and employment translates into a loss of annual output of $75.8 million (*see* Table 3) and $244 million(*see* Table 4), respectively. In sum, the estimated labor supply costs of this programs are equal to 0.4 percent of the total annual cost of the dividend.

Table 3: Estimated Changes in Annual Hours and Associated Change in Income for Those Employed

Deciles	Mean Earnings	Mean Change in Earnings	Total Change in Earnings	Net Change in Total Income	Pre-Policy Mean Annual Hours Worked	Post-Policy Mean Annual Hours Worked
1	$2,728	-$50	-$1,190,199	$471	976	0
2	$3,468	-$36	-$341,000,000	$348	684	674
3	$9,266	-$25	-$274,000,000	$261	1323	1320
4	$15,782	-$17	-$262,000,000	$168	1736	1734
5	$22,125	-$5	-$74,300,000	$110	1920	1920
6	$28,714	-$2	-$24,700,000	$32	2021	2021
7	$36,752	$1	$8,969,548	-$59	2112	2112
8	$46,799	$2	$26,000,000	-$176	2167	2167
9	$62,252	$4	$56,900,000	-$386	2235	2236
10	$125,899	$8	$127,000,000	-$889	2375	2376
Total	$35,378	-$12	-$75,832,065	-$12	1914	1912.8

Source: Author's Analysis of the 2008 CPS March Supplement

As addressed in the methods section, because the labor demand curve is assumed to be flat, the magnitude of all estimated changes in labor supply are upwardly biased; this applies both to positive and negative shifts along the intensive and extensive margins. Therefore, the results here can be treated as an extremum – the estimates of the highest reasonable absolute value given the labor supply elasticities assumed. Taking this into account, the sum projected change in national income of -$319.8 million can be treated as suggestive of the consequences of this program. The projected decline in economic output from a change in labor supply is extremely small. It is mere 0.00841 percent of the $3.8 trillion Federal budget, 0.0023 percent of 2007 U.S. GDP, and it is equivalent to less than a reduction in one dollar in GDP for each American.

How do the projected costs of this transfer program compare to existing transfer programs? Unfortunately, this is a difficult question to answer. It is rare in the literature to conduct analyses of the aggregate labor supply impact of a transfer program. However, David Autor and Mark Duggan's 2003 work on the Social Security Disability Insurance income (DI) can provide some perspective. These authors estimate that between 1984 and 2001, the share of nonelderly adults receiving DI rose by 60 percent. Concurrently, health outcomes dramatically improved, suggesting this growth can partially be explained by "reduced screening stringency, declining demand for less

Table 4: Change in Full-Time Equivalent Employment & Earnings

	Employment		Earnings	
Deciles	Percentage Point Change	Total Change	Mean Change	Total Change
1	-0.00051	-9,067	$0.00	-$7,504
2	-0.00041	-6,904	-$1.46	-$24,800,000
3	-0.00031	-5,377	-$2.41	-$41,200,000
4	-0.00022	-4,203	-$4.25	-$79,800,000
5	-0.00009	-1,394	-$2.04	-$31,500,000
6	-0.00008	-1,347	-$2.46	-$41,500,000
7	-0.00001	-223	-$0.48	-$8,217,694
8	0.00002	302	$0.97	$16,100,000
9	-0.00001	-149	-$0.50	-$8,301,941
10	-0.00002	-409	-$1.47	-$24,500,000
Total	-0.00017	-28,769	-$1.43	-$244,000,000

Source: Author's Analysis of the 2008 CPS March Supplement

skilled workers, and an unforeseen increase in the earnings replacement rate." For these reasons, many recipients of this program can be treated as an income transfer or anti-poverty transfer program recipients facing large effective marginal taxes on income and employment.

Because DI recipients face a limit of earning $1000 a month before their benefits are terminated, the structure of the DI program imposes prodigious cost on working. Autor and Duggan estimate that in 2001 the effective participation taxes imposed by DI reduced the national employment rate by one-half a percentage point – an estimate which is corroborated by Maestas and Song (2011). In 2001, DI cost $61 billion (roughly $2/3^{rds}$ the size of the carbon dividend) and reached 6.7 million recipients. Yet the carbon dividend program, which reaches all Americans, including all 127 American residents employed in 2007, is estimated to reduce employment by less than $1/20^{th}$ the amount of the DI program in 2001 (0.022 percentage points for the

Cap/Tax-and-Dividend versus 0.5 percentage points for the DI program).

Relative to the size of the American economic pie and given the extent of this program's reach and its economic cost relative to existing transfers programs, such as the DI, a carbon dividend can clearly be treated as an efficient income transfer program. The estimates here strongly suggest that a cap/tax-and-dividend can reduce inequality, curb carbon without regressive distributional impacts, and increases incomes among the bottom 60 percent of the income distribution with very little economic cost.

6 Conclusion

This paper provides evidence that a cap-and-dividend and a tax-and-dividend program pose the potential to overcome some of the main political fissures inhibiting the passage of a comprehensive carbon reduction program. This paper shows that a cap/tax-and-dividend program can substantially reduce carbon while bringing forth progressive distributional outcomes. As addressed in this paper's discussion of the 2009 ACES, the outcomes of a cap/tax-and-dividend program contrast with the regressive distributional outcomes of most cap-and-trade programs. Furthermore, the labor supply analysis undertaken here estimates that the economic costs due to the introduction of a carbon dividend are minimal, despite how extensive the impacts of this program are. These findings clearly suggest that a carbon-dividend can serve as an efficient transfer.

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