BROOKINGS

THE CLIMATE AND ENERGY ECONOMICS PROJECT

CLIMATE AND ENERGY ECONOMICS DISCUSSION PAPER | DECEMBER 14, 2012

DISTRIBUTIONAL EFFECTS OF A CARBON TAX IN BROADER U.S. FISCAL REFORM

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DISTRIBUTIONAL EFFECTS OF A CARBON ~~TAX~~ BURNING FEE** IN BROADER U.S. FISCAL REFORM*

http://www.aei.org/files/2012/12/18/-mathur-distributional-effects-of-a-carbon-tax-in-broader-us-fiscal-reform_17161031273.pdf

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* We gratefully acknowledge assistance from the Alex C. Walker Foundation and the Center for Climate and Energy Solutions. We thank Danny Cohen and Daniel Hanson for their excellent research assistance. The views expressed in the paper are those of the authors and should not be interpreted as reflecting the views of any of the above organizations or of the institutions with which the authors are affiliated.

** We are replacing the "Carbon Tax" terminology with the "Carbon Burning Fee" concept. Republicans hate the word tax and when they hear this word, they can no longer think straight (or at all). So let's call it what it is – taking responsibility for our behavior – acting as adults – it is a "Replacement & Repair Fee" for our action of burning hydrocarbons and for dumping CO_2 into the atmosphere. Rather than expect future generations to clean up our mess, the Carbon Burning Fee pays for the immediate replacement of the hydrocarbon resource we consumed (replaced by harvesting an energy equivalent amount of current sunlight) and repairing the damages we incur by dumping our combustion waste into the common air, water, soil. It's time for homo sapiens to grow up, take responsibility for the needless waste they generate and learn to live sustainably like the other 1.9 million species on the planet.[1] We can use carbon in a number of sustainable ways but burning the sequestered carbon (hydrocarbon) is not one. Combustion consumes the material forever AND releases once sequestered carbon back into the atmosphere causing a change in the heat balance between the Earth and the Sun. This in turn contributes to climate change, weather extremes, sea level rise, acidification of the ocean, etc. – nothing good for the forms of life that have evolved on our planet up to this point.

Of course if we humans are hell bent on causing our own extinction and that of millions of other living species so we can see what can re-evolve on the planet at higher temperatures, with more extreme weather, etc., then our current human behavior is right on. Drill Baby Drill!

UNSTATED OBSERVATIONS / FACTS OF THE REAL WORLD

The current American economic system we use to influence our choices is broken.

This human-created economic system is advising us Americans to make choices that are unsustainable in the Real World – choices that are, to be blunt, suicidal / insane for a conscious species.

[1] (biologists estimate there are an additional 8 million species in the interdependent web of life yet to be documented – guess they are by definition illegal species.)

We humans created this economic system so we can also update it to reflect the Real World we know about today – the one that is quite different from the world Adam Smith perceived in the 18th century.

The Real World we know about today is a finite planet that has finite resources that in turn demand global population management and no further growth. Yet today's obsolete economic system assumes a "real world" where the planet and its resources are infinite; refuses to place any inherent value on these resources in situ and demands perpetual economic growth.

The Real World we know about today is one where Earth's natural resources are available to and required for all living species. Non-human life has evolved to Borrow these resources and Return (Recycle) every atom of these resources so they are available for future generations. Yet today's human-created economic system influences us to buy a product and throw it in a landfill rather than recycle it 100% - because that's the "cheapest" approach.

The Real World today is one where the behavior of 7 billion homo sapiens results in dumping copious (7 trillion metric tonnes per year by Americans alone) quantities of CO_2 (plus other waste products) into our common finite atmosphere contributing to changes such as extreme weather /climate change / global warming due to changes in the heat balance between Earth and Sun, sea level rise due to polar ice melting from warmer average temperatures, acidification of the oceans due to increasing levels of CO_2 in the atmosphere, etc. Yet today's economic system, design to influence our choices advises us to burn coal, oil, natural gas, tars sands oil, shale oil, etc. because it is "cheaper" than deriving our energy from renewable sources such as solar and wind.

We could go on and on, but these examples illustrate a few of the fatal flaws in the current American economic system.

Using an economic system that advises us to live this way is both insane and suicidal – yet that is the economic system we are using.

We can and must change our human-created American economic system to reflect our current day knowledge of the Real World. This is not a political issue; this is not a religious issue. This is an issue involving human behavior that is attempting to defy unwavering principles of the Universe. This is an issue involving human choices and the economic system that influences these choices.

Despite the misinformation piped into our brains by the oil, gas and coal industries, we do not have to buy and burn their ancient hydrocarbon products so THEY can continue to make extraordinary profit while the rest of the planet suffers loses – including loss of life – and worse, the extinction of thousands of living species - that's the loss of birth.

When we update our current economic system to reflect the Real World, we will see there are viable sustainable alternatives to burning hydrocarbons available now. These alternatives require intellectual and physical effort (i.e. they create JOBS); can create a profit for the producer AND can be of mutual benefit for all life on the planet.

Despite the reluctance of Wall Street to disrupt the status quo (note: they too are part of the 1% doing quite well financially thank you very much), it is possible (and quite frankly it is mandatory) to update our current American economic system to reflect today's Real World.

Mathur and Morris explore one such possible change in our economic system they call a "carbon tax." We simply attempt to reframe it to reflect the Universe Story[2] that describes the Real World as we

[2] The Universe Story is simply a term used to represent the collective knowledge and wisdom available to us today – it is the ever growing result of collective learning – a marvelous capability of homo sapiens. With each generation, new chapters are written to this Universe Story as we continue to extend human consciousness.

know it today.

UNSTATED GOALS

Modify the current "economic system" to influence choices so that homo sapiens no longer burn ANY form of ancient hydrocarbon (petroleum, coal, natural gas, tar sands oil, shale oil). We have sustainable sources of energy available to us today, despite the oil, gas and coal industries propaganda to the contrary.

Modify the current "economic system" to influence choices so that homo sapiens minimize burning ANY biofuel (wood, animal dung, animal derived oils/fats, plant derived oils/fats/biofuels, etc.)

> It is of utmost importance to STOP burning ancient reserves of one-time-only hydrocarbon – often viewed as a fuel to be burned – with the combustion waste products dumped into the common atmosphere. Ancient hydrocarbons are far too valuable to be burned / consumed forever.
>
> This human behavior is so unsustainable it is actually immoral with respect to future generations (our grandchildren and beyond):
> a) they will no longer have this valuable hydrocarbon available for future sustainable applications (plastics, light weight materials, coke for making steel, etc.),
> b) they will have to live in a different world of weather extremes, rising sea levels, dying species on land (including humans) and in the seas because of acidification of the oceans, etc.,
> c) they will know that even though we knew better, we continued to burn/consume this non-renewable resource with no intention of every paying it back for them to use, and
> d) they will look back and know that we had viable/sustainable alternatives to burning hydrocarbons but consciously choose not to change our behavior. And wonder why?
>
> Our human-created (yet sacrosanct) American economic system does show a profit for the 1% who hoard (we euphemistically say accumulate) wealth[3] so they are then able to wield unfair economic power over the 99%. Yet we choose not to change/update this economic system that is the root cause of our unsustainable behavior – the root cause of the unsustainable choices we are making today.

One possible change we could make to our "economic system" would be to stop externalizing the costs of burning hydrocarbon materials[4].

Another change would be to update the economic system to replace all Consumption with Borrowing/ Returning. It is perfectly acceptable to Borrow resources from planet Earth as long as those resources are Returned when we are no longer using them.

> Atoms don't wear out, but they can become misplaced (thrown into a land fill, dump, ocean, burned and scattered to the wind, etc.).

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[3] Hoarding: A human behavior that historically was considered a mental illness but seems to be "admired" by the "developed western world" in the 20th and beginning of the 21st century CE.

[4] There are numerous updates to be made to our economic system that could be derived from a new eco-morality: the ethics of sustainable living and evolving consciousness – including: 1) All Consumption is replaced by Borrowing / Returning; 2) Every adult is responsible for sustainably harvesting the energy required for their (and their family's) life style; 3) Hoarding (money, power, property, resources, etc.) is a mental illness that must be healed before a person can participate fully as part of interdependent web of life; 4) Human behavior / choices must respect all Life – we are all one family; 5) "Growth" of Individual Consumption is replace by Growth of Collective Consciousness / Awareness / Cooperation. The planet and its resources are finite. Human population must be managed at a sustainable level – probably not more than 7 billion people (TBD)

Every atom extracted from Earth must be available for future generations – this is sustainable living – a way of living that mimics all other forms of life on the planet (See Biomimicry).

But you can't borrow ancient hydrocarbons, burn them and expect to return them – the process of burning literally reduces the hydrocarbon to water vapor, CO_2 and other combustion/waste products of little use for future generations – this is true consumption.

We are reframing the original paper indicated in Black Text for several reasons. 1) Linguistic studies (see Lakoff, "The Little Blue Book," indicate that "framing" is everything, 2) the Real World indicates the extreme urgency in finding and implementing an updated economic system that puts Americans back on the track to sustainable living. We can kiss off being the world leaders in this area – there are about 190 countries around the world already out ahead in making these changes. (See the proceedings of RIO+20). But at least we Americans can change from being obstinate obstructionists to being reluctant followers and thereby become a part of solution rather than just the primary contributor to the problem.[5]

EXECUTIVE SUMMARY

This paper analyzes the distributional implications of an illustrative $15[6] carbon burning fee (aka carbon tax) imposed in 2010 on carbon in ~~fossil~~ hydrocarbon[7] fuels. We analyze its incidence across income classes and regions, both in isolation and when combined with measures that apply the carbon burning fee ~~tax~~ revenue to lowering other distortionary taxes[8] in the economy. "Distortionary taxes" include any other Fees used to repair the damage/destruction cause by this unsustainable human behavior of burning hydrocarbons. The analysis first uses an input-output table approach to estimate

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[5] The U.S. makes up about 5% of the world's population but is responsible for 25% of the CO_2 that is dumped into the atmosphere each year.

[6] Although $15/ metric tonne might be a starting point, an analysis at MIT for three different types of hydrocarbon burning plants indicates that "…mitigation costs of $121 per tonne of CO2 avoided for a capture IGCC plant, $168 per tonne of CO2 avoided for a capture PC plant and $49 per tonne of CO2 avoided for a capture NGCC plant" are values closer to the actual externalized (ignored) cost in the Real World. Nomenclature: IGCC (integrated coal gasification combined cycles), PC (pulverized coal-fired simple cycles), and NGCC (natural gas-fired combined cycles) Ref: **THE COST OF CARBON CAPTURE, Jeremy David and Howard Herzog,** Massachusetts Institute of Technology (MIT), Cambridge, MA, USA http://sequestration.mit.edu/pdf/David_and_Herzog.pdf

[7] Further discussion may conclude that the Carbon Burning Fee could be different for biofuels as opposed to a much higher Fee on burning ancient one-time-only-reserves that are intended to be burned(consumed forever)

[8] Any tax measure will "distort" the economy from the path that would have prevailed in its absence. For example if one observes that a specific type of economic system is on a path that creates an undesirable (and unsustainable) separation of wealth where the rich get richer and the poor get poorer and the middle class disappears, a "progressive" tax can be applied that changes this trajectory and prevents this separation of wealth. Today 1% of the population of the U.S. have 42% of the wealth. This was not the case in the mid 1950s. During the Eisenhower administration, the U.S. used a "progressive" income tax, where the upper marginal tax rate was 92%. With this "progressive" distortionary tax structure, there was a vibrant middle class and a healthy economy.

Another example of a purposeful "distortionary tax" is a Pigovian tax that deliberately creates a distortion in the economy (deliberately changes how the economy influences peoples' choices) to correct for externalities (a known cost that is deliberately ignored to fool the market into making a choice to buy a specific product or service so that producer can make a profit). A carbon burning fee is such a "correction" to the current economic system – it is designed to account for externalities that are present in the Real World in the Universe Story, but not in the "real world" of the human-created 'economic' world.

Getting the correct value for the carbon burning fee is problematic – because we know burning hydrocarbons is unsustainable in the Real World with a finite planet with finite resources and a finite supply of this one-time-only ancient hydrocarbon. Any fee that causes humans to stop pretending that because coal, petroleum, natural gas, etc are calculated to be the "cheapest" choice, that they must be the "correct" choice is a sufficient fee. The proposed $15 / metric ton of CO_2 may or may not be a sufficient fee to cover all the ignored costs of burning hydrocarbons. As a minimum we would expect the carbon burning fee to reflect the replacement cost of an equivalent amount of energy from a renewable source and the cost to repair the damage burning hydrocarbons is having on the planet (e.g. sequestering CO_2 is one repair suggestion). But then how does one assign a fee that attempts to compensate for human behavior that is causing the inundation of the Maldives island nation and the extinction of the polar bear species and….?

the effect of the carbon burning fee ~~tax~~ on consumer prices, assuming that the fee ~~tax~~ is passed through fully to retail prices.[9] Then, using Consumer Expenditure Survey data on consumption patterns, we estimate the burdens across households, **assuming no behavioral response**[10] to the new prices.

Consistent with earlier findings, we too find that a carbon burning fee ~~tax~~ is regressive. Taking into account both direct and indirect energy costs, the carbon burning fee ~~tax~~ burden would ~~comprise~~ consume 3.5 percent of the income of the poorest decile of households and only 0.6 percent of the income of the highest decile. In the consumption approach, the carbon burning fee ~~tax~~ is substantially less regressive, with the ratio of average fees ~~taxes~~ paid by the bottom and top deciles equal to about 1.7.

Although "Tax Swaps" are a method of artificially manipulating a broken free market system it is not preferred over a valid free market system – so we will not comment on these aspects of the paper.

> In the fee-tax swap simulations, we subtract the burden of other taxes that the carbon burning fee ~~tax~~ revenue could displace[11], such as the corporate and personal income taxes, and compute the net effect on households. We analyze revenue-neutral tax shifts under three assumptions about how those other taxes lower households' capital and labor income: all borne by labor, all borne by capital, and a 50/50 split. Although all of the tax swaps lower the overall burden of the carbon tax (as a share of household income) on the poorest two deciles, tax swaps also exacerbate the regressivity of the carbon tax on the high end. This means that the benefit to the highest income households of the reduction in other taxes is greater than their share of the burden of the carbon tax.
>
> Results suggest that if policymakers direct about 11 percent of the tax revenue towards the poorest two deciles, for example through greater spending on social safety net programs than would otherwise occur, then on average those households would be no worse off after the carbon burning fee ~~tax~~ than they were before.

The degree of variation in the carbon burning fee ~~tax~~ incidence across regions (with no offsetting tax decreases) is modest; the maximum difference in the average rate across regions is 0.45 percentage points of income.

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[9] Where the "Carbon Burning Fee" is collected deserves much more evaluation. All hydrocarbons are "produced" by extraction from the Earth – the current economic model assumes there is no inherent value to this resource in situ. We, of course, know that this is the first fatal flaw of our economic model, because these hydrocarbons do have an inherent value – even buried deep within the Earth. This inherent value is apparent when we recognize these materials represent the arrangement of carbon and hydrogen in a chemical matrix that includes chemical bonds that in turn store energy that originated 300-360 million years ago (during the carboniferous period of the Paleozoic era) as sunlight. Hence these materials are often referred to as ancient sunlight because they were probably being formed over a 60 million year time frame. In addition to having value because they are a stable, convenient, safe method of storing energy, these material have a value because they sequester carbon preventing it from appearing in our atmosphere in its lowest Gibbs Free Energy state as CO_2 – a green house gas at normal / standard temperature and pressure. How do we assign an intrinsic value to the in situ hydrocarbon? Probably by defining how much it would cost to synthesize it ourselves using CO2 in the air, water, and sunlight – of course plants do this naturally, so one way of assigning a value to the oil, coal, etc. would be to "grow" biomass energy equivalent to the ancient sunlight version or to harvest an equivalent amount of sunlight as electrical energy using human-made solar PV modules. The cost of wind and solar electrical energy generating equipment is well known and will be discussed later..

[10] No behavioral response! – in actuality, we want the carbon fee to change human behavior – to influence choices so that the "free market" chooses to use viable sustainable alternatives to burning carbon – be it for household energy needs, transportation, commercial or business applications. If the fee DOESN'T result in a behavioral change it is not sufficient.

[11] This too requires further detailed discussion. If we are attempting to account for ALL externalities associated with the burning of ancient hydrocarbons, then we would have to include health issues to human and non-human life, and even issues such as the separation of wealth if these extraction corporations are a root cause of the rich getting richer and the poor getting poorer – otherwise framed as "excess profit" for the1% at the detriment of the 99%. There is much here to discuss and consider that is currently absent from the economic model.

Of the tax swaps, the labor tax swap results in the least variation in net burdens across regions, with a maximum difference across regions of 0.5 percentage points of income. In contrast, the capital tax swap produces a maximum difference across regions of 1.66 percentage points. This suggests that capital incomes are more unevenly distributed across regions than labor incomes.

1. INTRODUCTION

Burning ancient one-time-only hydrocarbons for a fuel (i.e. to produce heat) is unsustainable human behavior.

Today's economic system, a social construct created by humans to influence choices (supposedly for the mutual benefit of the planet) is actually encouraging unsustainable human behavior and benefiting only a few people (i.e. the 1%).

Conclusion: The current American economic system is broken. It is contributing to the decline of the American society, to the de-evolution of the human species, and to the extinction of millions of living species on the Planet. Otherwise there's no problem with our current economic system – it is influencing choices and working exactly as it is designed to operate.

> **Simple Example:** Americans have the personal freedom to make a choice between:
>
> > 1) installing solar Photovoltaic (P V) panels on their roof tops to generate 100% of their electrical power needs and not burn coal, oil, gas **or**
> >
> > 2) purchasing their power from a "for profit" utility company that burns coal, oil, gas to generate this electrical power.
>
> Americans "run the numbers" using the current economic system before making their choice and conclude that it's "cheaper" (hence preferred) to buy power generated by burning coal or 'clean' (joke/lie) natural gas. They reach this conclusion after seeing that the numbers generated by the economic system indicate that it will take 8-10 years to recoup their investment in solar PV technology. After that point, their electrical power is free for the next 10-15 years (design life of today's solar panels is about 20-25 years). Who wants to wait 8-10 years for a payback? So Americans choose to continue to burn ancient hydrocarbons – the oil, gas and coal industry as well as the for-profit utility companies applaud this choice of the free market and smile all the way to the bank.
>
> This example represents the "real world" created by humans. Everyone is behaving as they should within the influences suggested by the American economic system – a system that we humans created. Unfortunately this human behavior is self-destructive – but the economic system we designed and promote religiously in America could care less (or GARA).

Greenhouse gas emissions are primarily a result of combustion of fossil fuels and biofuels containing carbon. Economists have long argued that a pigovian tax[12] (e.g. carbon tax) is an efficient and obvious policy tool to effect long-term reductions in carbon emissions. A carbon burning fee ~~tax~~ imposes a cost on carbon emissions, and is therefore a market-based instrument that forces polluters (humans who choose to behave irresponsibly) to internalize the cost of the externality (and in effect take responsibility for the actions). A carbon burning fee ~~tax~~ that reflects the marginal social damages from the pollution can improve social welfare, if the revenue is used directly to repair any damage done and hopefully level the playing field for sustainable alternatives so human choices are influenced to affect change in this unsustainable behavior.

However, economic challenges to the use of carbon burning fee ~~taxes~~ arise. Policymakers should care about the long-term health of the planet but instead they seem to care about the distribution of policy

[12] Intended to "fix" a broken economic system by adding in an ignore cost – an externality. Pigou was the economist who coined the term externality. A correct comprehensive economic system does not need these tax bandages to fix the system because all costs andbenefits are already considered in the system. The American economic system desperately needs to be updated to reflect the Real World of today.

financial effects across different household groups, in particular across different income classes and those in different geographic regions – after all we cannot alienate the voting public OR the major campaign funding sources. If an economic policy financially burdens lower-income households relatively more than higher-income households as a share of household income, then economists call the policy financially regressive. If an economic policy (e.g. a carbon burning fee designed to reduce the emissions of coal fired power plants) benefits the long-term health of lower-income households (for example the Moapa Paiutes who live in the immediate vicinity of the Reid Gardner power plant north of Las Vegas) relatively more than higher-income households (who live 60 miles away in Las Vegas), the economic system has no response and economists are silent. In general, lower income households spend a higher percentage of their income on energy and other goods whose relative prices will go up under a carbon burning fee ~~tax~~. That suggests a carbon price will be financially regressive (for the Moapa Paiutes), although the exact measure of its financial regressivity depends on how one ranks households by socioeconomic status and how one analyzes the financial burden of the carbon burning fee ~~tax~~. The American economic system does not provide any suggestions on how the carbon price affects the Paiute children living nearby on their reservation - children who are now suffering from asthma and other respiratory diseases after breathing the coal ash from the power plant since they were born.

Some also fear that areas of the U.S. that are heavily dependent on coal for electricity, for example, will be hit much worse (financially) than other regions.[13] However, prior analysis of the distribution of financial burdens across the country shows that households in different regions will likely bear similar financial burdens as a share of income. Of course the financial impacts due to extreme weather events are now showing up on the radar screen of the large insurance corporations that pay out large sums after each of these frequently occurring “100 year” major weather events. That is because people in different regions use different mixes of fuels to heat and cool homes, and they also vary in their gasoline consumption. Hassett et al (2009) show that these differences tend to even out the impact of the price on carbon. In other words, areas where electricity prices may go **up** most may be areas where expenditures on transport fuels are relatively **low**(or not - areas where electricity prices may go **up** most may also be areas where expenditures on transport fuels are relatively **high)**. In addition, households in most regions consume similar baskets of non-energy goods, resulting in similar patterns of indirect energy consumption. However, the study estimates that a carbon burning fee ~~pollution tax~~ could fall a little harder than average on households in Eastern central states because of their higher overall fuel consumption as a share of income.

The final economic incidence of a carbon burning fee ~~tax~~ depends heavily on what happens to the revenue.

As a firm believer that fees should be tied to their reason for existing in this first place, we might examine a few simple example of fees and how this “revenue” is used.

Example 1: We are all familiar with the “library fee” assessed when you fail to return a publically owned book that you checked out but failed to return because you “lost it.” This library fee is used to

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[13] “hit much worse than other regions” was not intended to be ironic, but after hurricane Sandy of 2012, we can interpret this phrase several ways. By continuing to use an obsolete economic system that externalizes major costs associated with burning hydrocarbons and dumping the waste combustion products into the common atmosphere at a such a rate that natural processes cannot clean up our human scat fast enough, we are altering the heat balance between Earth and the Sun and contributing to weather extremes that are indeed hitting some regions “much worse than other regions. “ Only when we stop externalizing / ignoring inconvenient costs and update our obsolete economic system will we be able to live sustainably. Until then we will continue to live unsustainably in this human-created dream world.

replace that which was lost and did not return to the system as expected. We would question the library system if they chose to use this fee to pay the head librarian a year-end bonus instead of replacing the lost book. We would even question the library system if they chose to use this fee to help pay off the national debt instead of replacing the lost book.

Example 2: Another simple example is the "garbage collection/disposal fee" assessed to pick up one's waste/ garbage and dispose of it. Hopefully the fee pays for the effort to recycle all non-renewable materials you have "discarded." We would question the collection service if they just dumped our garbage in the ocean because it was cheaper than recycling it and used the revenue from our fee to send their CEO to a South Pacific Island for three weeks.

To even consider using the revenue from a Pigovian fee intended to correct an externality for something other than correcting that ignored cost is a common practice of economists. They appear to be more interested in manipulating their human created "real world" than remembering the underlying reason for this fee was to right an injustice in the Real World.

The carbon burning fee is such a case. Diverting the revenue to fund anything but the transition away from burning hydrocarbons is unconscionable. The revenue should be used to "replace" the carbon burned and "repair/right any injustice" that may have occurred. In this specific example the Pigovian fee would be used to:

1) Harvest an equivalent amount of energy from a renewable source (using solar, wind, hydro, geothermal, tidal,…technology OR natural autotrophic living species) that was extracted plus the energy used to extract it (mine, drill, etc.) and store (re-store) that harvested energy for future generations,
2) Re-sequester that burned carbon, by operating a CO_2 extraction facility that pulls an equivalent amount of CO_2 from the atmosphere and stores it safety so it does not contribute to altering the heat balance between the Earth and the Sun,
3) Pay for the medical care resulting from the other waste products that were dumped into the common atmosphere, oceans, soil – including coal ash, mercury, sulfur, methane, fracking chemicals that were placed in above ground holding ponds so that these toxic volatile chemicals could evaporate and be "dumped" into the atmosphere and hurt downwinders, etc.

> As discussed in Dinan (2012), a number of studies have examined of the distributional effects of a carbon burning fee ~~tax~~ under varying assumptions about how the revenues are used.
>
> This paper provides new estimates for the net burden on households by income class and region when the revenue is used to reduce other taxes. This approach is of particular appeal because it offers the potential to both cost effectively improve the environment and also provide an efficiency-enhancing tax reform. The most efficient form of revenue recycling would offset the most distortionary taxes, meaning the ones that have the highest marginal deadweight loss.
>
> A number of scholars have examined such "tax swaps."[14] Although the studies use different tools and arrive at different conclusions about how much of the macroeconomic cost of a carbon burning fee ~~tax~~ can be mitigated, it is clear that reducing existing tax distortions can be an important way to lower its overall burdens.

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[14] A review of this literature appears in Parry and Williams (2011). Also see Goulder et al. (1999), Parry et al. (1999), Parry and Oates (2000), Parry and Bento (2000), and CBO(2007).

Analyzing a 15 percent cut in emissions through a cap-and-trade system, the Congressional Budget Office estimated that the downward hit to GDP from a cap-and-trade system (which can be economically similar to a carbon tax) could be reduced by more than half if the government sold allowances and used the revenues to lower corporate income taxes rather than to provide lump-sum rebates to households or to give the allowances away.[15] Metcalf (2007) also suggests that linking a carbon tax to a capital income tax reduction could be efficiency-enhancing. Parry and Bento (2000) find that efficiency gains are particularly large when revenue recycling lowers taxes that favor some kinds of consumption (such as housing or health insurance) over others. Feldstein (2006) argues that the distortions from the tax system are greater than most people realize, resulting in costs of about $0.76 for every dollar the federal government raises. Some recent modeling evidence suggests that carbon tax swaps could improve welfare and/or economic growth, irrespective of the environmental benefits.[16]

However, one complication of pursuing the most efficient revenue recycling could be the distributional results. Some of the most distortionary taxes fall on high personal incomes and corporate income, so lowering those marginal tax rates is regressive, even while it provides the greatest efficiency gains and minimizes the cost of the program. Put another way, the most economically efficient recycling benefits poor households (who pay very little in taxes) proportionately less than rich households (who pay much more in taxes). Thus, there is an intrinsic tradeoff between optimizing the macroeconomic effects of the tax reform and making it distributionally neutral or progressive.[17]

In this paper, we consider the effect of an illustrative carbon tax of $15 per metric ton[18] of carbon dioxide in the year 2010. We analyze how the carbon tax affects households of different income differently and what happens if the carbon tax is accompanied by reductions in taxes that fall on labor and/or capital income. This study, along with Dinan (2012), presents new evidence on the net distributional effects of a carbon tax used to offset other taxes. In the next section, we discuss our methodology and data. Section 3 presents distributional burdens by income class for a carbon burning fee ~~tax~~. Section 4 presents incidence results when we swap a corporate or personal income tax with a carbon burning fee ~~tax~~. Section 5 presents regional distributions, and Section 6 concludes.

15 Elmendorf (2009)

16 See for example Rausch and Reilly (2012) and McKibbin, Morris, and Wilcoxen (2012).

17 See Dinan and Rogers (2002).

18 We've discussed this $15 assessment elsewhere in the reframing. It should be large enough to change behavior – to make it logical that renewable energy sources are the cheapest approach. It actuality, the fee should be at least ten (10) times higher ~$150 / ton just to re-sequester the carbon dumped into the atmosphere plus an additional fee (TBD) to replace the energy extracted from the Earth.

2. METHODOLOGY

Energy related emissions of CO_2 were 6,821.8 million metric tons in 2010. Given the $15 per metric ton tax rate and ignoring initial reductions in emissions, the carbon burning fee ~~tax~~ would be expected to raise $102.3 billion in 2010.[19]

The incidence calculations divide up the $102.3 billion in burning fees ~~tax~~ paid across households and regions.

We assume the burning fee ~~tax~~ is levied on coal at the mine mouth, natural gas at the well head, and on petroleum products at the refinery[20]. Imported fossil fuels are also subject to the burning fee ~~tax~~.

As noted above we assume in all cases that the tax is passed forward to consumers in the form of higher fossil energy prices and higher prices of goods and services that had energy as an input somewhere in their supply chain.

> Metcalf (2007) estimates that a tax of $15 per metric ton of CO_2 applied to average fuel prices in 2005 would nearly double the price of coal, assuming the tax is fully passed forward. Petroleum products would increase in price by nearly 13 percent and natural gas by just under seven percent.

The tax is also passed on indirectly to other industries that use these energy sources as inputs.

> The procedure for evaluating the effect of a carbon tax as it is passed through the economy is discussed in detail in Fullerton (1995) and Metcalf (1999), and a summary appears in the Appendix of this paper.

In short, we start with Input-Output matrices from U.S. Bureau of Economic Analysis (BEA) called the Summary Make and Use matrices from 2010. The Make matrix shows how much each industry makes of each commodity, and the Use matrix shows how much each industry uses of each commodity. Using

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[19] An analysis by the Energy Information Administration suggests that a $15 tax on CO_2 would reduce emissions by about five (5) percent in the short-run. This change of course is totally inadequate and quite frankly laughable. A reduction of 100% is required. See Energy Information Administration (2006).

[20] This deserves a bit more discussion. There are some uses of these ancient hydrocarbons that do not require burning – reducing them to their lowest Gibbs Free Energy level. For example, some hydrocarbons can be used as the feedstock for plastic materials that in theory and in future practice can be recycled over and over. Some hydrocarbons can be used as additives to iron to produce steel. Some of the hydrocarbon material can be the feedstock for producing carbon fibers/filaments used to make light weight materials (e.g. blades for wind turbines – electrical power generation; light weight transportation vehicles (cars, trains, planes, boats, bikes,…). The "burning fee" would not apply to such uses of the hydrocarbon – uses where the resources is not consumed but rather fashioned into a different form with assurances that it will be 100% recycled / returned for use by future generations at the same or higher energy state. If the mine operation sells his product for use in a certified sustainable process flow, then the burning fee is waived (not applicable), otherwise the worse is assumed – that the coal, oil gas, etc. is going to be burned/consumed. In that case the extractor is assessed the burning fee at the source. The actual burning fee is directly related to 1) the cost to replace the amount of energy extracted, assuming that the revenue will go directly to a for-profit corporation that harvests sunlight and produces a storable form of hydrocarbon equivalent to amount extracted. The free market will determine this replacement cost. If just a few corporations get involved there can be a great deal of profit to be made harvesting sunlight to make a hydrocarbon replacement product. 2) the "burning fee" will also cover the cost to repair/clean up the waste produced by non-discriminate burning and dumping the combustion products into the common air, water, soil. Again the free market / for-profit enterprise system will set this cost. The worst case burning fee assessment will be assumed unless there is certification of less costly burning – the worst case is how what we do today. Consume oxygen in the common atmosphere, combust the hydrocarbon to extract the chemical energy and transform it into heat (about 60% of the energy is wasted – (called waste heat in the Carnot cycle). The combustion products are gases, vapors, and some solids (ashes in the case of coal). The gases are dumped into the atmosphere. The burning fee will include the cost of extracting the CO2, sulfur dioxide, NOx released and sequestering these products so they can do no harm to any human or non-human life on the planet. 3) the burning fee will also include a 5% administrative charge to fund the government agency that collects the certifications of non-burning use, accounts for the replacement credits and the repair credits. Conclusion: The **burning fee** does not go to the "government" (except the 5% admin fee), but instead goes back into the economy as jobs – into the free enterprise system to replace (energy extracted) and repair (the damage from burning ancient hydrocarbons.)

these two matrices, we derive an industry-by-industry transactions matrix that traces the use of inputs by one of 66 industries to all the other industries. Using various adding-up identities and making assumptions about production and trade, we can trace the impact of price changes from the carbon tax in one industry to the products of all other industries in the economy. We translate those price increases into corresponding price increases for these consumer items using the PCE Bridge tables, also from BEA. Then, we use data from the U.S. Bureau of Labor Statistics' Consumer Expenditure Survey (CEX) for 2010 to compute the carbon taxes paid (via those higher prices) by each household in the survey across 33 categories of personal consumption items. These price increases are shown in Appendix Table 1.

Tax incidence measures the ultimate impact of a tax on the welfare of members of society. The economic incidence of a tax may differ markedly from the statutory incidence because participants in the supply chain shift the burden forward and backward as much as supply and demand conditions in their markets allow. The economic incidence of a carbon tax in particular is likely to differ markedly from the statutory incidence. For example, while the statutory incidence of an upstream tax on gasoline may be on the refinery owner, the economic incidence is likely to be on final consumers as fuel refiners and marketers shift the tax forward to consumers in the form of higher prices.

Estimating the incidence of a tax necessarily requires numerous assumptions and methodological choices. First, we must determine a unit of observation, such as an individual or a household. For this study, we use the household as a unit. Second, we must choose the time frame over which to characterize households' incomes. The early tax incidence literature used current income as the basis of burden measures; it compared the tax liability over a short period (such as a year) to income earned over that same period. Following Friedman (1957) and the permanent income hypothesis, a realization emerged that households make consumption decisions a longer time horizon. Hence, in this view analysts should measure income as the present discounted value of lifetime earnings and inheritances. Failing to do so creates substantial measurement problems, particularly at the low end of the income distribution. For example, elderly people drawing down their savings in retirement will look poor from an annual income perspective when in fact, they may be comfortably well off. In other words, many low-income people are not necessarily poor. Caspersen and Metcalf (1995) report cross tabulations on income and consumption that show that a large fraction of households are in consumption deciles substantially above their income deciles. Poterba (1989) follows the approach of using current consumption as a proxy for permanent income, since if consumer behavior is consistent with the permanent income hypothesis, then consumers would set current consumption proportional to permanent income. Therefore, we also use current consumption as a proxy for lifetime income.

The final assumption in an incidence analysis is the allocation of the tax burden between consumers and producers. Taxes on energy can be passed forward into higher consumer prices or backward in the form of lower returns to factors of supply (capital, labor, and resource owners). Our approach assumes that consumers bear the full burden of the tax. Considerable theoretical work on the incidence of energy taxes in general, and of carbon taxes, in particular supports this approach. A number of large-scale general equilibrium models (CGE models) suggest that in the short to medium run, the burden of a carbon tax will be mostly passed forward into higher consumer prices.[21]

Our analytic approach assumes no consumer behavioral response to the after-tax prices, and we do not account for how price-indexed social safety net programs could buffer the effect on the poor. Consumer

[21] See, for example, Bovenberg and Goulder (2001) and Metcalf et al. (2008).

substitution away from more carbon-intensive products will indeed contribute to an erosion of the carbon tax base. But given the inelastic demand for energy in the short run, consumers' behavioral response to higher energy prices will reduce the tax burden by less than it reduces tax collections. Firms incur costs to shift away from carbon-intensive inputs, costs that will be passed forward to consumers. Consumers also will engage in welfare-reducing activities as they shift their consumption activities to avoid paying the full carbon tax. Although the burden impacts reported here do not take account of the range of economic responses to the tax, our estimates are a reasonable first approximation of the short run welfare impacts of a carbon tax.

3. DISTRIBUTION OF BURDEN OF THE CARBON TAX BURNING FEE BY INCOME AND CONSUMPTION

Table 1 presents our results for incidence using annual income as our measure of socioeconomic status. Figure 1 shows the results graphically. We have sorted households by income into ten equally sized groups, or deciles, from the ten percent of households with the lowest income to the ten percent with the highest income. The entries in the tables show the average carbon tax as a fraction of income for households in each income decile. Confirming earlier findings, the carbon tax is quite regressive when measured relative to current income. The burden in the lowest income decile in 2010 is over five times the burden in the top decile when measured as a fraction of annual income.[22]

Table 1. Distribution of Burden by Annual Household Income

Decile	Direct	Indirect	Total
Bottom	2.38	1.16	3.54
Second	1.83	0.90	2.74
Third	1.27	0.75	2.02
Fourth	1.06	0.61	1.67
Fifth	0.94	0.55	1.49
Sixth	0.78	0.48	1.26
Seventh	0.68	0.44	1.12
Eighth	0.54	0.41	0.95
Ninth	0.48	0.37	0.85
Top	0.31	0.31	0.63

Source: Authors' calculations. The table reports the within-decile average ratio of carbon tax burdens to income.

[22] The actual burden on each decile in dollars appears below

Figure 1.

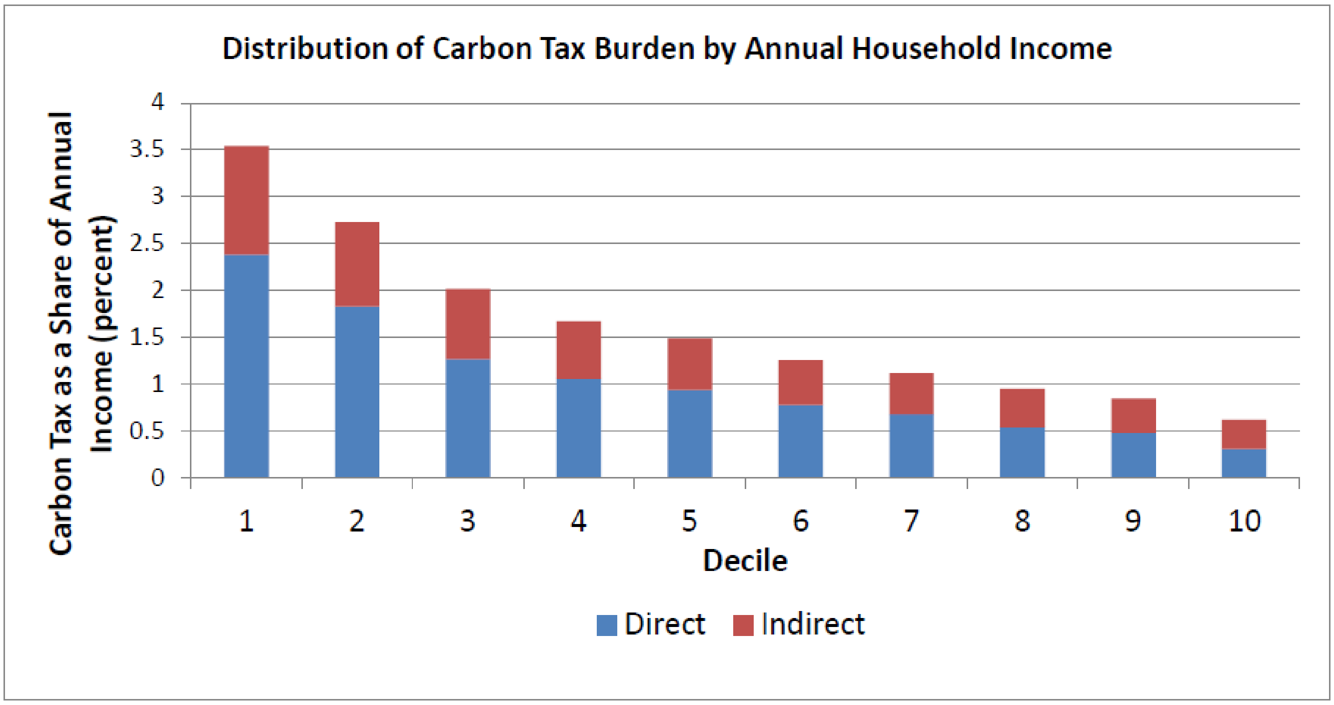


Table 1 and Figure 1 also show the burden of the direct and indirect components of the tax. The direct component of the tax is highly regressive – the average tax burden in the bottom decile is 7.6 times the average tax rate in the highest decile in 2010. The regressivity of the indirect portion of the tax is nearly half of the direct component. The indirect tax burden is 3.7 times higher for the bottom decile relative to the top. The result that the indirect component of the tax is regressive but to a lesser extent than the direct component is consistent with the observation of Herendeen, Ford, and Hannon (1981) that indirect and direct energy consumption profiles differ in shape. In summary, had a carbon tax been in effect in 2010, the tax would have looked quite regressive using annual income as a measure of household well being.

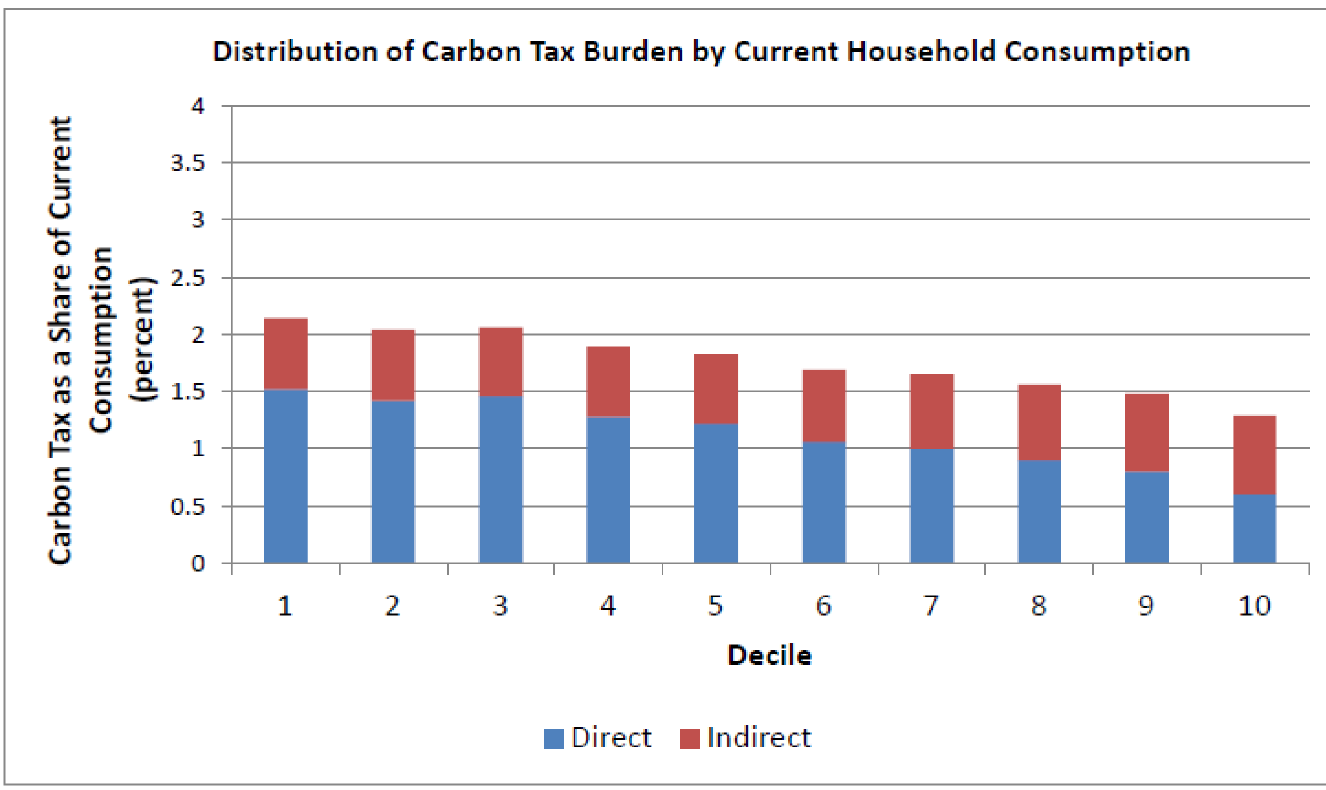
Another way of measuring regressivity uses the tax burden as a share of consumption, not income. Economists use consumption as a proxy for income averaged over an individual's lifetime, rather than annual income. Economists use this measure because income can vary greatly over the course of individuals' lifetimes. For example income tends to be smaller than average both in early and late life. Standards of living, i.e. consumption, fluctuate much less. The results change dramatically. Table 2 shows the distribution of the carbon tax in the three years when households are sorted by current consumption. Figure 2 show the results graphically on the same scale as Figure 1. For these results, the carbon tax burden is expressed as a fraction of overall consumption, rather than income.

Table 2. Distribution of Burden by Current Household Consumption

Decile	Direct	Indirect	Total
Bottom	1.52	0.62	2.14
Second	1.42	0.62	2.03
Third	1.46	0.60	2.06
Fourth	1.28	0.61	1.89
Fifth	1.22	0.61	1.82
Sixth	1.06	0.63	1.70
Seventh	1.00	0.65	1.66
Eighth	0.90	0.66	1.56
Ninth	0.80	0.68	1.48
Top	0.60	0.69	1.29

Source: Authors' calculations. The table reports the within-decile average ratio of carbon tax burdens to current consumption.

Figure 2.



In this measurement approach, the carbon tax is substantially less regressive, with the ratio of average taxes paid by the bottom and the top at about 1.7. The primary force driving this difference is the tendency for consumption to be more evenly distributed than income, especially in the lower brackets.[23]8 We also see that for the lowest deciles, the tax is a smaller
8. The reason for this is that the distribution of consumption is a lot more even than the distribution of

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[23] This relationship is well known in the literature. Krueger and Perri (2002) for example, document this fact. share of total consumption than income, whereas for higher income deciles the tax is a larger share of consumption than income

income. Consumption expenditures at the bottom are approximately 11 percent of those at the top. However, incomes at the bottom are only 4.5 percent of those at the top. Further, households in the bottom decile show average consumption expenditures that are higher than their average incomes. In other words, they tend to reduce saving and consume more than the income data would suggest. Therefore, carbon taxes are a smaller fraction of consumption than income for this decile. The opposite is true for higher income households. Average consumption expenditures are lower than average incomes, since these households tend to save out of income. As a result, carbon taxes are a larger fraction of consumption than income.

The direct and indirect burdens shown in Table 2 and Figure 2 demonstrate that nearly all of this regressivity can be accounted for by the direct component of the tax, since the indirect component is roughly proportional between the top and bottom deciles. Even the direct component is less regressive than when we used current income to construct average tax rates.

This result was similarly reported in Bull, Hassett, and Metcalf (1994) who found that the lifetime calculation changed the results because the proportion of energy in total consumption (or ratio of energy consumption to income) varied significantly over a person's life, with the elderly low income individuals in particular having relatively large current energy consumption. The ratio of direct taxes paid by the bottom is about 3 times that in the top deciles. This is less than half the ratio when we used current income as the welfare measure. The indirect burden is in fact, slightly progressive in 2010. Clearly, direct consumption has the characteristics usually associated with necessary consumption, while indirect consumption has a more varied distribution.

4. DISTRIBUTION OF BURDEN WITH TAX BURNING FEE SWAPS

We now turn to the question of the regressivity of a carbon tax if the revenue is used to reduce other tax burdens. In the results in Tables 1 and 2, we implicitly assumed the carbon tax revenue leaves the economy; essentially nobody gets it. More realistic would be an assumption that the money goes somewhere; the government could spend it, rebate it, reduce the budget deficit, or reduce other taxes. As noted above, economists widely favor using the carbon revenue for pro-growth tax reforms or deficit reduction. Here we don't capture any effects of the potential macroeconomic benefits of such revenue recycling. Rather, we estimate what would happen distributionally in the short run if other tax burdens fall.

What share of other taxes could a carbon tax replace? In 2010, the U.S. corporate income tax raised $191.4 billion, while the personal income tax brought in $898.5 billion.[24] Therefore, our carbon tax of $15 per metric ton generating revenues of $102.3 billion would replace slightly more than half of the corporate income tax or 11.4 percent of personal income tax revenues. In practice, those shares would evolve over time as carbon tax revenue and other revenues evolve at different rates.

To model the change in overall tax burden that would come with a carbon tax swap, we start with the carbon tax burdens we computed above. We now subtract the burden of other taxes that revenue could displace, such as the corporate and personal income taxes, and compute the net effect on households of the revenue-neutral shift in tax instruments. To do this, we need to make an

[24] White House Office of Management and Budget Historical Tables, Table 2.1, Receipts by Source 1934-2017. Downloaded from http://www.whitehouse.gov/omb/budget/Historicals.

assumption about how those other taxes lower households' capital and labor income. This is not as straightforward as it sounds because the statutory incidence is not the same as the economic incidence. For example, the employer's share of a worker's payroll tax could result in either lower profits for the employer or lower wages for the worker. It depends on how the labor market works.

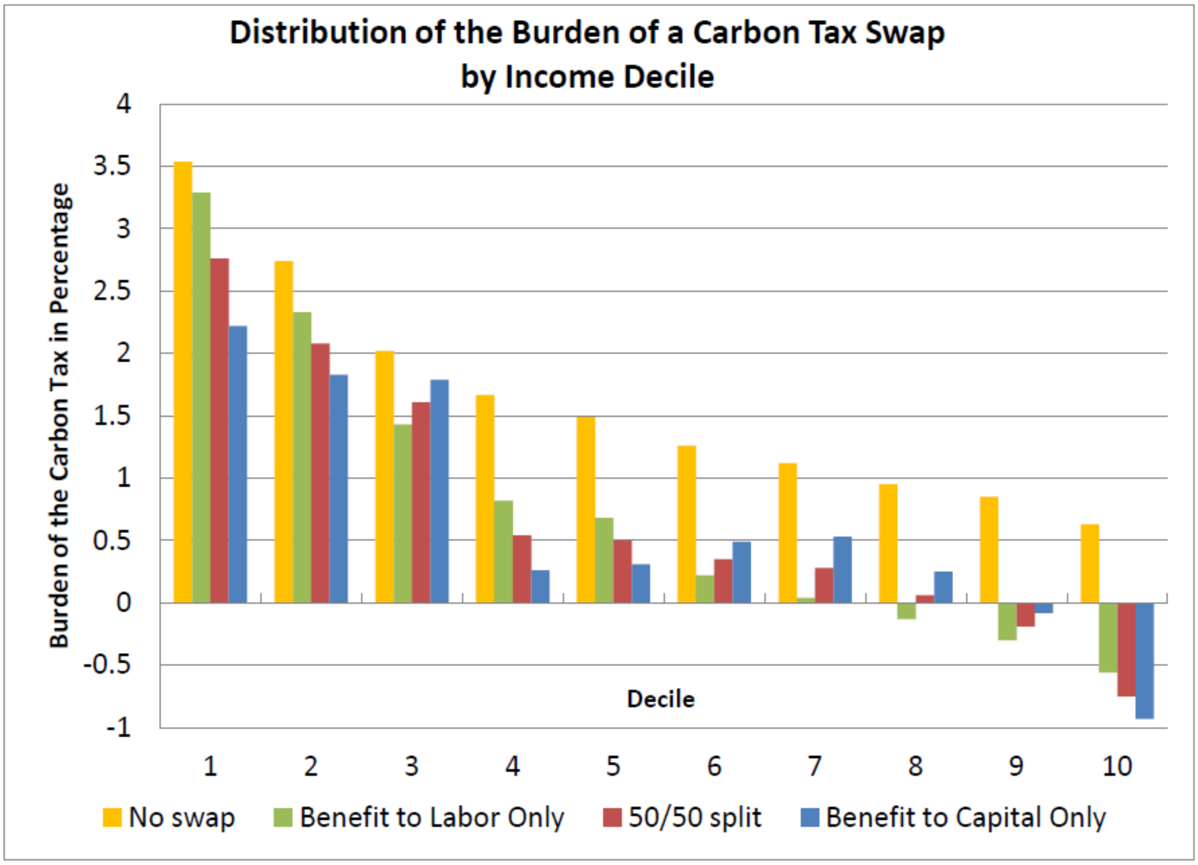
Therefore, we have to assume how the tax reduction will benefit workers in the form of higher wages, shareholders in the form of higher returns to capital, or a combination of both. To span the possible outcomes of a carbon tax swap, we compute the burden shift in three ways. First, we assume all of the taxes the carbon tax revenue offsets fall on households in proportion to their share of labor income. Then we assume the burden of the offset taxes are split 50-50 across labor and capital income, and third we assume all of the burden falls on households in proportion to their share of capital income. The burden of the tax swap is the ratio of higher consumer goods prices minus the benefits of higher returns to wage and salary income divided by household annual income.

In the CEX data, we use wage and salary income to define the returns to labor, and we use rents, dividends and interest to define the returns to capital. For the share of the swap that benefits labor, we assume that households receive higher wages based on their respective shares of labor income in the total population. Similarly, for the share of the swap that benefits capital, households receive higher capital income based on their respective shares of capital income in the population.

These scenarios are idealized, but they broadly correspond to what could happen in an actual tax reform situation. Economists generally find that that lowering payroll taxes and labor income taxes (the share of the personal income tax that falls on wages and other compensation) would benefit workers in the form of higher after-tax wage income. On the other hand, lowering taxes on corporate income, dividends, and capital gains is far more likely to increase after-tax income for shareholders.

Figure 3 graphs the results for the scenario with no tax swap (i.e. the carbon tax alone as shown in Figure 1), along with the three tax swap scenarios. Tables 3, 4, and 5 report the numerical results for the tax swap scenarios. Figure 3 shows that although all of the tax swaps lower the overall burden of the carbon tax (as a share of household income) on the poorest two deciles, tax swaps also exacerbate the regressivity of the carbon tax on the high end. This means that the benefit to the highest income households of the reduction in other taxes is greater than their share of the burden of the carbon tax. Of course, all households are better off than in the scenario in Table 1, in which we assume the carbon tax revenue leaves the economy entirely.

Figure 3.



One might wonder why the colored bars in Figure 3 do not appear to sum to zero in the tax swap scenarios since the same amount of money is being taken away with the carbon tax and being returned through lowering other taxes. Each decile represents 10 percent of households, not 10 percent of all income, and therefore the bars would not sum to zero. For example, the blue bar showing the positive net benefits to the highest income households from a capital tax swap represents a lot more money than the blue bar showing about a 2.2 percent net burden as a share of income to the lowest decile.

Table 3 shows that the burden of the tax swap is marginally lower for bottom income deciles and significantly lower for top income deciles under Scenario 1, relative to Table 1. Note that for the tables involving tax swaps, the direct and indirect burden do not sum up to the total burden since we have subtracted the benefits derived from the tax swap from both the direct burden as well as the indirect burden. In practice, the benefit will apply only once to the total.

The average tax burden on the bottom decile is 3.3 percent of income, and for the top decile, the burden is negative since the price increases are less than the returns to wage income from the reduction in the personal or corporate income tax. The ratio of the bottom to the top is (negative) 5.9. Much of this is driven by the direct tax burden which is significantly higher for the bottom deciles relative to the top. The indirect burden is also relatively unequally distributed. Thus, while this tax swap leads to lower absolute burdens in all deciles of the population, it seems to worsen the relative ratios since it helps the higher income groups much more than the lower income deciles.

Table 4 shows the results for the 50 percent labor/50 percent capital split. This reduces the average tax rate for all households relative to the 100 percent labor scenario, since not only are they getting higher "returns" on their wage income but also on their capital income. The bottom decile household

Table 4. Distribution of Burden: Tax Swap, Labor/Capital Split

Decile	Direct	Indirect	Total
Bottom	1.60	0.37	2.76
Second	1.18	0.25	2.08
Third	0.86	0.34	1.61
Fourth	-0.08	-0.52	0.54
Fifth	-0.06	-0.44	0.50
Sixth	-0.13	-0.43	0.35
Seventh	-0.15	-0.40	0.28
Eighth	-0.36	-0.48	0.06
Ninth	-0.56	-0.68	-0.19
Top	-1.06	-1.06	-0.75

Source: Author's Calculations. The table reports the within-decile average ratio of carbon tax burdens to income when the benefit of the reduced corporate tax is passed on equally to labor wages and capital.

now pays only 2.76 percent of the carbon tax on their income. The top decile again experiences a negative tax rate of -0.75 percent of income.

Finally, Table 5 shows a situation where 100 percent of the benefits are transferred to capital owners, and none to labor. This has the effect of further lowering average tax rates on the bottom and top deciles. Note that the distribution in this scenario looks relatively more even than in the earlier two cases since capital incomes in the CEX are not well measured at the top. Therefore, capital incomes are

Table 3. Distribution of Burden: Tax Swap, Full Benefit to Labor

Decile	Direct	Indirect	Total
Bottom	2.13	0.91	3.29
Second	1.43	0.50	2.33
Third	0.68	0.16	1.43
Fourth	0.20	-0.24	0.82
Fifth	0.13	-0.26	0.68
Sixth	-0.27	-0.56	0.22
Seventh	-0.40	-0.64	0.04
Eighth	-0.54	-0.67	-0.13
Ninth	-0.67	-0.79	-0.30
Top	-0.87	-0.87	-0.56

Source: Author's Calculations. The table reports the within-decile average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on labor wages.

more evenly distributed and tax burdens go down by less at the top than at the bottom income deciles. Note that we may be overstating the tax rates in this table since capital incomes are poorly measured in the CEX, particularly for the higher income households.

Share of Revenue Needed to Hold Poor Households Harmless

Table 5. Distribution of Burden: Tax Swap, Full Benefit to Capital

Decile	Direct	Indirect	Total
Bottom	1.06	-0.16	2.22
Second	0.92	0.00	1.83
Third	1.04	0.53	1.79
Fourth	-0.36	-0.80	0.26
Fifth	-0.25	-0.63	0.31
Sixth	0.00	-0.29	0.49
Seventh	0.09	-0.15	0.53
Eighth	-0.17	-0.29	0.25
Ninth	-0.45	-0.56	-0.08
Top	-1.25	-1.25	-0.93

Source: Author's Calculations. The table reports the within-decile average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on capital income.

Figure 3 shows that even if all the tax revenue is returned to households through lower taxes, the poorest households are still worse off under a carbon tax. Since hose households make little money, they pay a small share of federal taxes on labor and capital, and consequently a tax cut simply does not help them much.

This section examines how much of the revenue policymakers would have target to those households so that they are no worse off, leaving the remainder for a tax swap. Table 6 shows how much of the $102.3 billion in carbon tax revenue is paid by each group of households. It shows that the poorest 20 percent of households pay about 11 percent of the tax, and the richest twenty percent of households pay about 34 percent of the tax. The table suggests that if policymakers direct about 11 percent of the tax towards the poorest two deciles, for example through greater spending on social safety net programs than would otherwise occur, then those households would on average be no worse off after the carbon tax than they were before. Of course, individual households within those groups might be better or worse off depending on their individual energy consumption patterns and participation in federal spending programs.

Table 6. Share of the Burden by Income Decile

Decile	Burden ($ billions)	Cumulative burden ($ billions)	Percent of total burden (%)	Cumulative % of burden
Bottom	5.0	5.0	5	5
Second	6.5	11.5	6	11
Third	7.0	18.5	7	18
Fourth	8.2	26.7	8	26
Fifth	9.3	36.0	9	35
Sixth	10.0	46.0	10	45
Seventh	11.2	57.2	11	56
Eighth	12.1	69.3	12	68
Ninth	13.9	83.2	14	81
Top	19.1	102.3	19	100

Source: Authors' Calculations. The table reports the total carbon tax burdens to each household income decile, before any tax swaps or other redistribution of proceeds.

5. DISTRIBUTION OF BURDEN BY U.S. REGION

We next turn to a regional analysis of the incidence of the tax. Policymakers may be concerned that a carbon tax might burden some regions or parts of the country more than others. For example, regions that are more dependent on coal-fired electricity will likely see higher burdens than areas that derive electricity predominantly from renewables or nuclear power. Coal-dependent regions may start with electricity prices that are low relative to other areas, but a carbon tax would impose a relatively higher burden those regions at the same time it evens out electricity prices across the country.

To measure the geographic burden of the tax (had it been imposed in 2010), we group households by region and measure their average tax rate using weighted averages of the tax burdens.[25] First, we assume, as we did in the earlier section, that the revenue simply leaves the U.S. economy. Results appear in Table 7.[26] The tax burden as a share of household income varies around 1.5 percent, and the degree of variation across regions is modest. The maximum difference in the average rate across regions is just 0.45 percentage points. This is remarkable considering the variation in weather conditions, driving patterns, and other factors across the regions.

Table 7. Regional Distribution of Burden: Annual Income

Region	Direct	Indirect	Total
New England	0.90	0.59	1.49
Mid Atlantic	0.96	0.53	1.49
South Atlantic	0.83	0.54	1.37
East South Central	0.99	0.55	1.53
East North Central	1.15	0.58	1.73
West North Central	1.06	0.52	1.58
West South Central	0.85	0.56	1.41
Mountain	0.94	0.66	1.60
Pacific	0.69	0.58	1.27

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income.

The bulk of the variation across regions in carbon tax payments arises from the direct portion of the tax. The underlying data reveals that the relatively high regional burden for the East South and East North Central region is due to the higher consumption of gasoline per household in that region relative to others. By itself, this would have lead to much larger burdens of the carbon tax on consumers in this region. However, consumption of other direct energy goods such as natural gas, electricity and home heating oil are relatively low in that region. Such differences substantially even out the burden across regions. For instance, gas consumption is highest in the East North Central region, electricity is highest in the West South Central region, and home heating oil is highest in New England. There is little

[25] As with the distributional tables across income, we drop the bottom five percent of the income distribution from the analysis before carrying out the regional analysis.

[26] The states in each region are as follows: **New England**: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island; **Mid Atlantic:** New Jersey, New York, Pennsylvania; **South Atlantic:** West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, District of Columbia, Maryland, Delaware; **East South Central:** Kentucky, Tennessee, Missouri, Alabama, Mississippi; **East North Central**: Wisconsin, Illinois, Michigan, Indiana, Ohio; **West North Central**: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa; **West South Central**: Texas, Oklahoma, Arkansas, Louisiana; **Mountain:** Montana, Idaho, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico; **Pacific:** California, Oregon, Washington, Alaska, Hawaii.

variation in the indirect burden across regions. This suggests that consumers in different regions of the country buy similar mixes of non-energy commodities.

Figure 4 graphs both the results in Table 7 and the regional results for the three different tax swap incidence scenarios that appear in Tables 8, 9, and 10. The results suggest that a tax swap is likely to increase the variation in burden across regions. The incidence of a tax swap can vary significantly across regions, and the regional incidence depends importantly on whether the swap reduces labor or capital taxes. Of the tax swaps, the labor tax approach results in the least variation in net burdens across regions. In the case when full benefits are passed to labor, the maximum difference across regions is 0.5 percentage points, whereas in the capital tax swap the maximum difference across regions is 1.66 percentage points. This suggests that capital incomes are more unevenly distributed across regions than labor incomes. Figure 4 indicates where that capital income may be going; New England, the South Atlantic, and the Pacific region fare best with a tax swap favoring capital income, but the other regions fare best with lower labor income taxes.

Figure 4

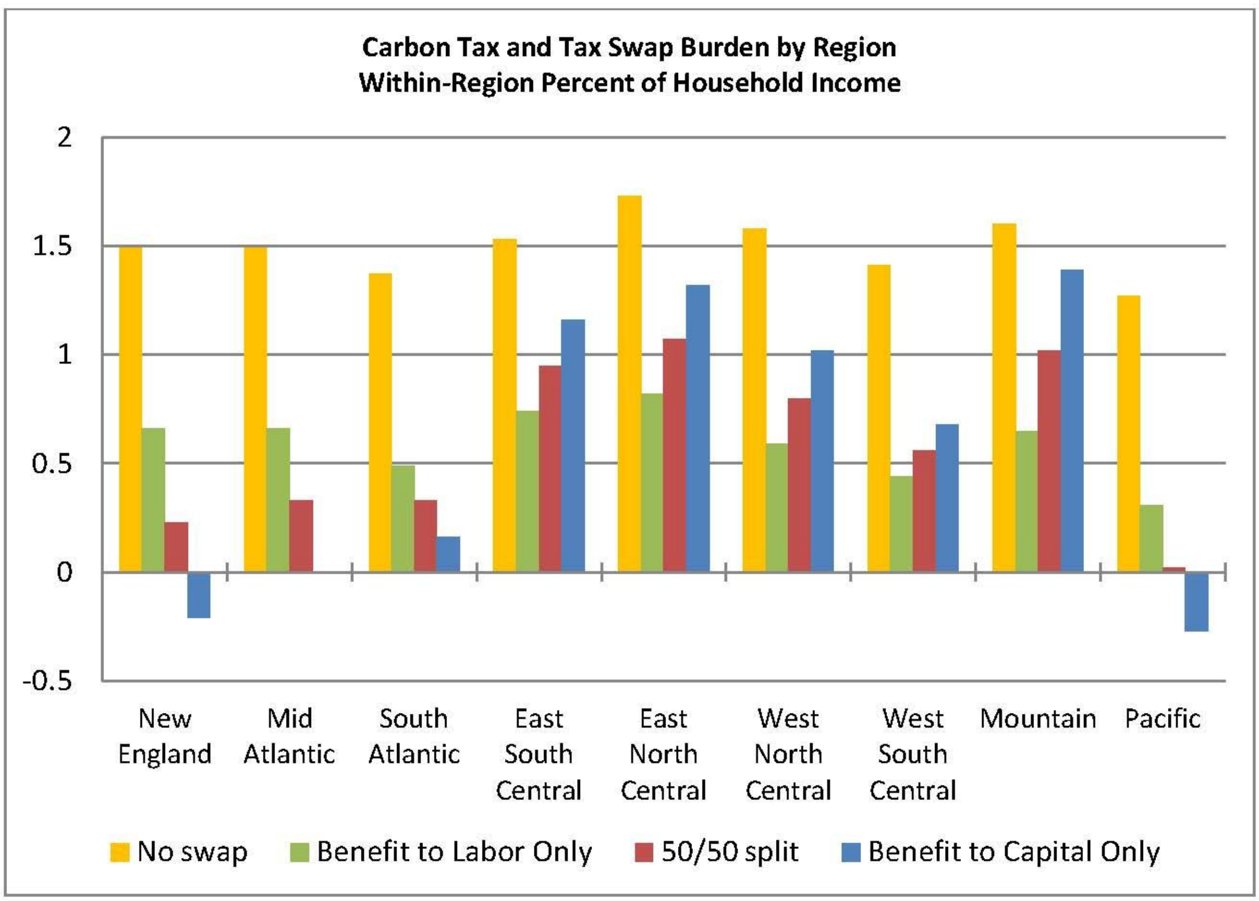


Table 8. Regional Distribution of Burden: Tax Swap, Full Benefit to Labor

Region	Direct	Indirect	Total
New England	0.08	-0.24	0.66
Mid Atlantic	0.13	-0.30	0.66
South Atlantic	-0.05	-0.34	0.49
East South Central	0.20	-0.25	0.74
East North Central	0.24	-0.32	0.82
West North Central	0.07	-0.47	0.59
West South Central	-0.12	-0.41	0.44
Mountain	-0.01	-0.29	0.65
Pacific	-0.27	-0.38	0.31

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on labor income. Regions are defined elsewhere.

Table 9. Regional Distribution of Burden: Labor/Capital Split Burden

Region	Direct	Indirect	Total
New England	-0.36	-0.67	0.23
Mid Atlantic	-0.20	-0.63	0.33
South Atlantic	-0.21	-0.50	0.33
East South Central	0.40	-0.04	0.95
East North Central	0.49	-0.08	1.07
West North Central	0.29	-0.26	0.80
West South Central	0.01	-0.29	0.56
Mountain	0.36	0.08	1.02
Pacific	-0.56	-0.67	0.02

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income when the benefit of the reduced corporate tax is passed equally to labor and capital income. Regions are defined elsewhere.

Table 10. Regional Distribution of Burden: Full Benefit to Capital

Region	Direct	Indirect	Total
New England	-0.80	-1.11	-0.21
Mid Atlantic	-0.53	-0.96	0.00
South Atlantic	-0.38	-0.67	0.16
East South Central	0.61	0.17	1.16
East North Central	0.73	0.17	1.32
West North Central	0.50	-0.05	1.02
West South Central	0.13	-0.17	0.68
Mountain	0.73	0.45	1.39
Pacific	-0.85	-0.97	-0.27

Source: Author's Calculations. The table reports the within region average ratio of carbon tax burdens to income when the full benefit of the reduced corporate tax is on capital income. Regions are defined elsewhere.

6. CONCLUSION

This paper measures the incidence of carbon burning fees ~~taxes~~ using both annual income and consumption as a basis for the household burden of the carbon burning fee ~~tax~~. We analyze a $15 per metric ton burning fee ~~tax~~ on CO_2 in the year 2010. We first use economy-wide Input-Output tables from the Bureau of Economic Analysis to assess how the $15 burning fee ~~tax~~ would affect the industrial sector generally and particularly the prices of energy goods and other industrial goods in which these energy goods serve as inputs. We then use this information to calculate the increase in prices of consumer goods as a result of the burning fee ~~tax~~. Once we obtain the price increases in 33 categories of consumer goods, we calculate the burden of the tax on households using consumption data from the Consumer Expenditure Survey.

Our results suggest that a carbon burning fee ~~tax~~ is regressive when using annual incomes as the base for the incidence measure, but less regressive when using consumption. Our analysis suggests that if policymakers direct about 11 percent of the burning fee revenue back ~~tax~~ towards the poorest two deciles, for example through greater funding of ~~spending on~~ social safety net[27] programs than would otherwise occur, then those households would on average be no worse off after the carbon burning fee ~~tax~~ than they were before. Of course, individual households within those groups might be better or worse off depending on their individual energy consumption patterns and participation in federal ~~spending~~ funded programs.

In the revenue ~~tax~~ swap simulations, we subtract the burden of other taxes that the carbon burning fee ~~tax~~ revenue could displace, such as the corporate and personal income taxes, and compute the net effect on households. We analyze revenue-neutral tax shifts under three assumptions about how those other taxes lower households' capital and labor income: all borne by labor, all borne by capital, and a 50/50 split. Although all of the revenue ~~tax~~ swaps lower the overall burden of the carbon tax (as a share of household income) on the poorest two deciles, revenue ~~tax~~ swaps also exacerbate the regressivity of the carbon burning fee ~~tax~~ on the high end. This means that the benefit to the highest income households of the reduction in other taxes is greater than their share of the burden of the carbon burning fee ~~tax~~.

The degree of variation in the carbon burning fee ~~tax~~ incidence across regions (with no offsetting tax decreases) is modest; the maximum difference in the average rate across regions is 0.45 percentage points of income. However, a revenue ~~tax~~ swap is likely to increase the variation in burden across regions. The incidence of a revenue ~~tax~~ swap can vary significantly across regions, and the regional incidence depends importantly on whether the swap reduces labor or capital taxes. This is driven primarily by the uneven distribution of capital incomes across regions.

Of the revenue ~~tax~~ swaps, the labor tax swap results in the least variation in net burdens across regions, with a maximum difference across regions of 0.5 percentage points of income. In contrast, the capital tax swap produces a maximum difference across regions of 1.66 percentage points. This suggests that capital incomes are more unevenly distributed across regions than labor incomes.

We stress that these results reflect short run distributional outcomes, and do not account for dynamic effects such as reductions in emissions, increases over time in the carbon burning fee ~~tax~~ rate, macroeconomic feedbacks, and efficiency gains from revenue recycling. Taxes of all kinds can produce important macroeconomic effects through the incentives or disincentives they create and the knock-on effects of how they change prices, wages, and other economic outcomes. We do not account for those effects here.

Nonetheless, these results illustrate the likely initial impacts of a modest carbon burning fee ~~tax~~ on

---

[27] Discuss externalized costs here. Discuss separation of wealth

households across the income spectrum and across different regions of the country. We present the burdens of the carbon burning fee ~~tax~~ in isolation, and how those burdens would change once the carbon burning fee ~~tax~~ revenue is recycled by lowering other tax burdens.

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APPENDIX

1. Using the BEA Input-Output Accounts[28]

The Input-Output accounts trace through the production of commodities by industries and the use of those commodities by industries. The Bureau of Economic Analysis provides two kinds of matrices that help us to track such transactions through the economy. The Make-matrix, M_{IxC}, shows how much each industry makes of each commodity, and the Use-matrix, U_{CxI}, shows how much of each commodity is used by each industry. Combining these two, we can derive the industry-by-industry transactions matrix by dividing each entry of M_{IxC} by its column sum and multiplying the resulting matrix by the use matrix, U_{CxI}. Using the resulting matrix, it is possible to trace the use of inputs by one industry by all other industries. Further, it is also possible to trace through the impact of price changes in one industry on the products of all other industries in the economy. Below we detail some of the steps involved.

Tracing price changes through the economy on the basis of Input-Output accounts dates back to work by 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 so that the price of domestic goods can adjust following changes in factor prices per Armington (1969) and (3) input coefficients (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:

[1]

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, we 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 we impose.

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

[28]This section is based on based on Fullerton (1995), and Metcalf (1999).

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

$$
\begin{aligned}
x_{11}p_1 + x_{21}p_2 + \ldots\ldots + x_{N1}p_N + v_1 &= x_1 p_1 \\
x_{12}p_1 + x_{22}p_2 + \ldots\ldots + x_{N2}p_N + v_2 &= x_2 p_2 \\
&. \\
&. \\
&. \\
x_{1N}p_1 + x_{2N}p_2 + \ldots\ldots + x_{NN}p_N + v_N &= x_N p_N
\end{aligned}
\qquad [2]
$$

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 [2] can be written as

$$
\begin{aligned}
(1-a_{11})p_1 - a_{21}p_2 - \ldots\ldots - a_{N1}p_N &= v_1/x_1 \\
-a_{12}p_1 + (1-a_{22})p_2 - \ldots\ldots - a_{N2}p_N &= v_2/x_2 \\
&. \\
&. \\
&. \\
-a_{1N}p_1 - a_{2N}p_2 - \ldots\ldots - a_{NN}p_N &= v_N/x_N
\end{aligned}
\qquad [3]
$$

These equations can be expressed in matrix notation as

$$(I - A')P_1 = V \qquad [3A]$$

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 ith element is v_i/x_i. Assuming that $(I - A')$ is nonsingular, this system can be solved for the price vector:

$$P_I = (I - A')^{-1}V \qquad [4]$$

With the unit convention chosen above, P_I, will be a vector of ones. However, we 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:

[5]

$$x_{11}p_1(1+t_{11})+x_{21}p_2(1+t_{21})+.....+x_{N1}p_N(1+t_{N1})+v_1 = x_1p_1$$
$$x_{12}p_1(1+t_{12})+x_{22}p_2(1+t_{22})+....+x_{N2}p_N(1+t_{N2})+v_2 = x_2p_2$$
$$.$$
$$.$$
$$.$$
$$x_{1N}p_1(1+t_{1N})+x_{2N}p_2(1+t_{2N})+....+x_{NN}p_N(1+t_{NN})+v_N = x_Np_N$$

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

$$P_I = (I-B')^{-1}V \quad [6]$$

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

We regrouped industries in the Input-Output Accounts into 66 industry groupings. Three separate industries for coal mining, metal ores mining and nonmetallic mineral ores mining and quarrying were created out of the industry group mining. This was done using the split in the 2002 benchmark Input-Output accounts. Tax rates are computed as the ratio of the required tax revenue from the industry divided by the value of output from that industry. For the carbon tax, the tax rate on coal equals

$$t_{4.} = \frac{\alpha_C R}{\sum_{j=1}^{N} x_{4j}} \quad [7]$$

where R is the total revenue from the carbon tax and α_C the share of the tax collected from the coal industry (industry 4). Based on carbon emissions in 2003, the share of the tax falling on the coal industry is 0.361. The taxes for oil and natural gas are computed in a similar manner.

Equation [6] indicates how price changes in response to the industry level taxes. We next have to allocate the price responses to consumer goods. The Input-Output accounts provide this information by means of the Personal Consumption Expenditures (PCE) Bridge tables for each year that show how much of each consumer item is produced in each industry. Let Z be an NxM matrix, where z_{ij} represents the proportion of consumer good j $(j=1,..,M)$ derived from industry i $(i=1,....,N)$. The columns of Z sum to 1.. If P_c is a vector of consumer goods prices (an $Mx1$ vector), then

$$P_c = Z'P_{1.}$$

The consumer prices derived using this methodology are then applied to consumption data in the CEX; they appear in Appendix Table 1 for all three years.

2. Consumer Expenditure Survey Data

The Consumer Expenditure Survey (CEX) data is collected by the Bureau of Labor Statistics. The CEX provides a continuous and comprehensive flow of data on the buying habits of American consumers. The data are based on two components, the Diary Survey and the Interview Survey. The Diary Survey interviews households for two consecutive weeks and is designed to obtain detailed expenditures data on small and frequently purchased items, such as food items. The Interview sample follows survey households for a maximum of five quarters. The database covers about 95 percent of all expenditures. In addition, the CEX collects information on a variety of socio-demographic variables and income. For this paper, we have used the Interview Survey data collected over the year 2010. As mentioned, the Interview Survey collects household level data where each household is followed for a period of four quarters. It is a rotating sample in which some households drop out of the survey at the end of the four quarters, and are then replaced by a new sample of households. Overall, the 2010 sample has five quarters of data.

For purposes of this study, it is important to note that we made the following changes to the sample. First, for all households, we have only included expenditures that occurred in 2010. The sample contains information for the last quarter of 2009 for the households that were interviewed in January and February of 2010. It also contains information for January and February of 2011 for households interviewed in March of 2011. However, these expenditures are excluded from the analysis since they are not relevant for the year of study. Moreover, we have only included those households for whom we have information on all four quarters, that is those who were present in the sample throughout 2010. Further, we have only included households with income data. Using these criteria, our sample size is only about 2320 households. Since the sample size drops a lot, it is important to reweight the sample so that the remaining households are representative of the population. For reweighting the data, we simply scaled up the weights for the attritioned sample so that they would add up to the original weights.

All of these adjustments resulted in aggregate household consumption that is about 70 percent of the actual consumption expenditures in the National Income and Product Accounts. This fits in fairly well with the average ratio of CEX expenditures to NIPA expenditures.[29]

[29] http://www.bls.gov/cex/cecomparison.htm.

Appendix Table 1: Price Increases for Consumer Goods

	CEX Categories	2010
1	Food At Home	0.83%
2	Food at Restaurants	0.47%
3	Food at Work	1.05%
4	Tobacco	0.64%
5	Alcohol	0.72%
6	Clothes	0.34%
7	Clothing Services/Tailors	0.22%
8	Toiletry/Miscellaneous	0.39%
9	Health and Beauty	0.55%
10	Tenant-Occupied Non-Farm Dwellings	0.17%
11	Other Dwelling Rentals	0.19%
12	Furnishings	0.74%
13	Household Supplies	0.83%
14	Electricity	5.21%
15	Natural Gas	18.92%
16	Water	0.46%
17	Home Heating Oil	6.10%
18	Telephone	0.27%
19	Health	0.32%
20	Business Services	0.24%
21	Life Insurance	0.06%
22	Automobile and Parts Purchases	1.04%
23	Other Car services	0.25%
24	Gasoline	4.72%
25	Automobile Insurance	0.06%
26	Mass Transit	0.75%
27	Other Transit	1.54%
28	Air Transportation	2.01%
29	Books/Magazines	0.35%
30	Recreation and Sports Equipment	0.63%
31	Other Recreation Services	0.31%
32	Education	0.44%
33	Charity	0.25%

Note: These price increases are calculated using a tax of $15 per metric ton of carbon dioxide.

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EXTRAS

Home Sweet Home: *Mid pleasures and palaces though we may roam, Be it ever so humble, there's no place like home;*

APPENDIX A

Environment

- Does EIA report water vapor emissions data? No
- How do I convert between short tons and metric tons?

Convert short tons to metric tons by multiplying the number of short tons by 0.907184
For example: 12,300 short tons X 0.907184 = 11,158 metric tons.
Convert metric tons to short tons by multiplying the number of metric tons by 1.10231
For example: 11,158 metric tons X 1.10231= 12,300 short tons.

- How does the hole in the ozone layer affect global warming?
- How much carbon dioxide (CO_2) is produced per kilowatt-hour when **generating** electricity with fossil fuels?

You can calculate the amount of CO_2 produced per kWh for specific fuels and specific types of generators by multiplying the CO_2 emissions factor for the fuel (in pounds of CO_2 per million Btu) by the heat rate of a generator (in millions of Btu per kWh generated).

For example, here are the number of pounds of CO_2 produced by a steam-electric generator for different fuels using that formula and the average heat rates for steam-electric generators in 2010:

Fuel	**Lbs of CO_2/Million Btu**	**Heat Rate (10^6 Btu/kWh)**	**Lbs CO_2/kWh**
Coal			
Bituminous	205.573	0.010142	2.02
Sub-bituminous	212.700	0.010142	2.10
Lignite	215.400	0.010142	2.12
Natural gas	117.080	0.010416	1.12
Distillate Oil (No. 2)	161.386	0.010249	1.57
Residual Oil (No. 6)	173.906	0.010249	1.70

Last updated: February 22, 2012

- How much carbon dioxide (CO_2) is produced when different fuels are burned?

Different fuels emit different amounts of carbon dioxide in relation to the energy they produce. To compare emissions across fuels you must compare the amount of CO_2 emitted per unit of energy output or heat content.

Pounds of CO_2 emitted per million Btu of energy for various fuels:

	Pounds of CO_2 emitted per million Btu
Coal (anthracite)	227

Coal (bituminous)	205
Coal (lignite)	215
Coal (subbituminous)	213
Diesel fuel & heating oil	161
Gasoline	156
Propane	139
Natural gas	117

The amount of CO_2 produced when a fuel is burned is a function of the carbon content of the fuel. The heat content or amount of energy produced when a fuel is burned is a function of primarily the carbon (C) and hydrogen (H) content of the fuel. Heat is produced when C and H combine with oxygen (O) during combustion. Because natural gas is primarily methane, or CH_4, it has a relatively high energy content relative to other fuels, and thus a relatively low CO_2 to energy content. Water and various elements such as sulfur and non-combustible elements in some fuels reduce their heating values and increase their CO_2 to heat contents.

- How much carbon dioxide is produced by burning gasoline and diesel fuel?

How much carbon dioxide is produced by burning gasoline and diesel fuel?

About 19.64 pounds of carbon dioxide (CO_2) are produced from burning a gallon of gasoline that does not contain ethanol. Most of the retail gasoline now sold in the U.S. contains about 10% ethanol by volume. Under international agreement, CO_2 from ethanol and other biofuels are not counted at the tailpipe, so burning a gallon of gasoline with 10% ethanol produces about 17.68 pounds of CO_2.

About 22.38 pounds of CO_2 are produced by burning a gallon of diesel fuel. It is possible to buy biodiesel fuel in some states. Burning a gallon of "B10" (diesel fuel containing 10% biodiesel by volume) results in emission of about 20 pounds of CO_2.

EIA estimates[1] that U.S. gasoline and diesel fuel consumption for transportation in 2011 resulted in the emission of about 1,089 and 430 million metric tons of CO_2 respectively, for a total of 1,519 million metric tons of CO_2. This total was equivalent to 82% of total CO_2 emissions by the U.S. transportation sector and 28% of total U.S. energy-related CO_2 emissions.

[1] As of March 28, 2012.

- How much of U.S. carbon dioxide emissions are associated with electricity generation?
- What are greenhouse gases and how do they affect the climate?
- What are the energy-related carbon dioxide (CO2) emissions by source and sector for the United States?

Energy-related CO_2 emissions by source and sector for the United States, 2011[1]

Sources	(Million Metric Tons)					
	Sectors					
	Residential	Commercial	Industrial	Transportation	Electric Power	**Source Total**
Coal	1	5	151	0	1,718	1,874
Natural Gas	256	171	419	39	411	1,296
Petroleum	78	49	345	1,802	25	2,299

Other[2]					11	11
Electricity[3]	827	767	567	4		
Sector Total	**1,162**	**992**	**1,482**	**1,845**	**2,166**	**5,481**

Total energy-related CO_2 emissions equal 5,481 million metric tons.

[1]Preliminary data for 2011.
[2]Miscellaneous wastes and from geothermal power generation.
[3]Electricity-related CO_2 emissions based on electricity use for each sector and associated electric power plant emissions.

- What are the sources of energy-related carbon dioxide emissions by type of fuel for the U.S. and the world?

  The energy-related carbon dioxide emissions by type of fossil fuel and the amount in million metric tons, and by percent share in 2010:

	United States		World	
	Amount	Share of Total	Amount	Share of Total
Total from Fossil Fuels	5,610		31,780	
Coal	1,985	36%	14,231	42%
Natural Gas[1]	1,274	22%	6,374	22%
Petroleum	2,351	42%	11,175	37%

[1]Includes combustion and flaring of natural gas.

- Where can I find emission factors for greenhouse gases and air pollutants?

  EIA publishes emission factors (or coefficients) for three major greenhouse gases: Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N20), and for the criteria air pollutants; Sulfur Dioxide (SO_2) and Nitrogen Oxides (NO_x), which are released when fuels are burned and when electricity is generated and used as follows:

  For combustion of fossil fuels:
  CO_2 for common fuels
  CO_2 for fuels used for electricity generation (PDF) (XLS)
  For electricity — as generated:
  CO_2, SO_2, and NO_x for electricity generated in each state for a specific year, in pounds per megawatthour, in Table 1 of State Electricity Profiles and averages for the United States.
  CO_2, CH_4, and N_20 for electricity generated in each state and U.S. Census Region.
  For electricity — as consumed:
  CO_2 , CH_4, and N_20 for electricity consumed in U.S. electricity market regions and in other countries.
  These factors were used by participants in EIA's Voluntary Reporting of Greenhouse Gas Emissions program.

  A source of emission factors for other substances and fuels is the U.S. Environmental Protection Agency.
  Last updated: May 16, 2012

- Why do carbon dioxide emissions weigh more than the original fuel?

During complete combustion, each carbon atom in the fuel combines with two oxygen atoms in the air to make carbon dioxide. The addition of two oxygen atoms to each carbon atom forms carbon dioxide, which has an atomic weight of 44 — roughly 3.6667 times the atomic weight of the carbon (12).

For example, subbituminous coal is on average 51% carbon, so the carbon in a short ton (2,000 pounds) weighs 1,020 pounds. The carbon dioxide emissions from burning a short ton of subbituminous coal are approximately 3,740 pounds, or about 3.67 times the weight of the carbon in a short ton of coal, and 1.87 times the weight of a short ton of coal.
The periodic table of elements shows the atomic weights of all elements.
How much carbon dioxide (CO_2) is produced when different fuels are burned?
Last reviewed: June 19, 2012