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How Effective are US Renewable Energy Subsidies in Cutting Greenhouse Gases?†

By Brian C. Murray, Maureen L. Cropper, Francisco C. de la Chesnaye, and John M. Reilly*

The threat of climate change has inspired efforts to increase the share of energy produced from renewable sources such as wind, solar, and biomass. When fossil fuel is replaced by renewable energy, it can reduce the emissions of greenhouse gases (GHGs) that contribute to climate change (NRC 2010). When fossil fuels are burned, carbon in the fuel combines with oxygen to produce carbon dioxide (CO_2), the most prevalent anthropogenic GHG. Extraction and distribution of fossil fuels can also lead to methane (CH_4) emissions, another powerful GHG. In contrast, renewables like wind and solar power do not use combustion to create energy. While CO_2 is emitted in the combustion of biomass, if there is a cycle of plant growth, combustion and regrowth, then biomass energy can be "carbon neutral."

In 2009, the United States Congress called on the National Research Council (NRC) of the National Academy of Sciences (NAS) to examine the effect of the federal tax code on the country's emissions of GHGs (NRC 2013). The US federal tax code includes a variety of provisions that affect energy use and production. Some provisions provide favorable treatment for the extraction and use of fossil fuels and, thus, might be thought to increase GHGs; other provisions subsidize renewable energy and, thus, might be expected to lower GHGs. As contributors to the NRC study, we focus this paper on the components of the study that address the largest subsidies for renewable energy: (i) production and investment tax credits for renewable electricity, and (ii) tax credits for the production and use of biofuels. We provide an overview of the provisions analyzed, briefly review previous research on the GHG impacts of the provisions, describe the models used to examine the effects of each provision on GHG emissions, and present key findings. We conclude with a discussion of the somewhat surprising study results and some insights on how tax policy can be used more effectively to achieve GHG reductions.

I. The US Federal Tax Code and Targeted Energy Subsidies

The renewable energy tax provisions operate within a complicated environment created by the interaction of the federal tax code, federal and state energy regulations, and globally interconnected commodity markets. The NRC study analyzed the tax code provisions that were in effect in 2011 when the study began. The analysis assumed that these provisions would remain in effect through 2035 and compared this situation to a world without the provisions.[1] Table 1 defines the terms of the renewable energy tax provisions analyzed in the study. The production tax credit (PTC) and investment tax credit (ITC) lower the cost of electricity generated from renewable resources, encouraging their substitution for fossil fuels. Producers may use the PTC or ITC, but not both. In 2011 the Internal Revenue Code (IRC) provided tax credits for bio-based fuels used as motor fuel. These credits lowered the cost of using biofuels, leading to

* Murray: Duke University, 2117 Campus Dr. Box 90335, Durham, NC 27708 (e-mail: bcmurray@duke.edu); Cropper: University of Maryland and Resources for the Future, 3114 Tydings Hall, College Park, MD 20742 (e-mail: mcropper@econ.umd.edu); de la Chesnaye: Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304 (e-mail: fdelachesnaye@epri.com); Reilly: Massachusetts Institute of Technology, 50 Memorial Drive, Cambridge, MA 02142 (e-mail: jreilly@mit.edu).

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[1] Some of the provisions analyzed in the study are no longer in force. See Table 1.

TABLE 1—TAX PROVISIONS ANALYZED

Provisions	Terms
Renewable electricity[a]	
Production Tax Credit (PTC) for first ten years of production[b]	2.3 cents per KWh for onshore wind and geothermal; 1.1 cents/KWh for landfill gas and hydroelectric power
Investment Tax Credit (ITC)	30 percent of initial investment for offshore wind, solar, small wind turbines, and biomass
Biofuels	
Volumetric Ethanol Excise Tax Credit (VEETC)[b]	$0.45 per gallon of fuel ethanol, typically blended with gasoline
Cellulosic ethanol producer tax credit[c]	$1.01 per gallon for ethanol made from lignocellulosic or hemi-cellulosic feedstock
Biodiesel blender credit[b]	$1.00 per gallon of biodiesel blended
Small producer credit	$0.10 per gallon of ethanol or biodiesel made
Ethanol import tariff[b]	$0.54 per gallon paid on ethanol imports

Notes:
[a]Producers can take either the PTC or the ITC, but not both.
[b]Provision has since expired.
[c]Back out VEETC if applicable, so producer gets net of $0.56/gallon.

their substitution for fossil-based gasoline and diesel fuels. Suppliers could take these credits as a rebate against their motor fuels excise tax liability or as a nonrefundable credit against their income tax liability for a given year. In practice, nearly all taxpayers preferred to claim the excise credit. These tax credits are not trivial relative to the price of the goods they affect. The PTC of 2.3 cents per kWh is about 20 percent of the average retail price of electricity in the United States; the biofuel credits of roughly $0.50–1.00 are about 15–30 percent of the relevant motor fuel prices.

In addition to tax credits, a $0.54 per gallon ethanol tariff on imported ethanol historically benefitted the US ethanol industry by reducing the competitiveness of imported ethanol. The tariff was originally intended to prevent imported ethanol from benefitting from the US tax credit.

A. *Key Regulatory Interactions*

Although not part of the IRC provisions, several preexisting regulations have important interactions with those provisions that must be factored into the analysis. 29 states have renewable portfolio standards (RPS) mandating that a certain percentage of electricity be generated from renewable sources. Likewise, the federal government has instituted a renewable fuels standard (RFS) mandate requiring that transportation motor fuels sold in the United States contain a minimum absolute volume of renewable fuels. In both cases, the mandates create redundancies that might be expected to alter the effect that the tax provisions have on the use of renewable energy and biofuels, interactions that we examine in the modeling analysis described below.

II. Existing Evidence on the Emissions Effects of the Provisions

We reviewed studies of the GHG emissions consequences of the renewable energy tax provisions. We found a few papers that econometrically estimated the effects of the production tax credit on wind capacity in the United States (Metcalf 2010 and Hitaj 2013) but found nothing that connected changes in renewable capacity to emissions through power and fuel market-clearing mechanisms.

Most studies analyzing the impacts of biofuels do not directly consider the GHG effects of specific tax code provisions. There are, however, several studies that consider important interactions between the tax code, renewable fuels mandates, and crop price supports (Gardner 2007; and Schmitz, Moss, and Schmitz 2007). Those studies find that the Renewable Fuel Standard (RFS) mandates are more effective than the tax incentives, and that the RFS effectively limited the impact of the tax incentives on renewable fuels production and consumption (de Gorter and Just 2008). One study also found that the crop price supports for ethanol feedstocks, such as corn, combined with quantity mandates for ethanol, may lead to an increase in petroleum consumption, similar to the results of our modeling efforts reported below (de Gorter and Just 2010).

Beyond these studies, much of the literature focuses on whether ethanol production and consumption lead to a net increase or decrease in GHGs per Btu of fuel (Yacobucci and Bracmort 2010; Gelfand et al. 2011). While not directly linked to the impacts of specific tax provisions, such literature is nonetheless informative in determining whether these impacts are likely to be on net positive or negative (Mosnier et al. 2013).

III. Methods and Key Findings

The primary focus of the NRC study was to estimate the emissions consequences of changes in the federal tax provisions, although the committee was also asked to examine effects on federal revenues and other variables, such as energy prices and resource utilization. We accomplished this by employing energy-economic models with sufficient detail on the relevant technologies, markets, and policies to capture the direct and indirect effects of modifying the tax provisions described in the previous section.

A. *National Energy Modeling System—NEMS-NAS*

We analyzed the renewable electricity tax provisions using the National Energy Modeling System (NEMS).[2] The US Energy Information Administration (EIA), which develops and maintains NEMS,[3] uses the model to produce its *Annual Energy Outlook*, an analysis and projection of energy market trends, typically over a 25-year period. Because of these efforts, NEMS's capabilities and shortcomings are well understood within the energy-modeling and energy-economics communities. There are many important assumptions that drive the NEMS-NAS model, the two most important being assumptions about US economic growth and world oil prices. Other key assumptions are those relating to macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. The energy sector details give the NEMS-NAS model an advantage in analyzing the energy-focused provisions we sought to study.

B. *Food and Agricultural Policy Research Institute—U. of Missouri (FAPRI–MU) Model*

Modeling biofuel policy is challenging because of (i) the complex interactions with agriculture, agricultural policy, and land use; (ii) the complex policy requirements of the Renewable Fuel Standard (RFS); (iii) the implications of land-use change for GHG emissions; (iv) tax credits that differentially treat different biofuel production pathways and feedstocks; and (v) international linkages in agriculture and energy markets. The FAPRI-MU model has the proper combination of agriculture and crop market detail, linkage to international markets, and inclusion of regulatory constraints relevant to the analysis of biofuel provisions. It also has a full representation of the intricacies of renewable fuel credits. The model captures multiple fuel production pathways representing both conventional (e.g., corn ethanol) and second-generation (cellulosic) processes, with links to global markets for crude petroleum and refined fuels.

The FAPRI-MU model does not explicitly consider land use or the carbon implications of land-use change but, instead, applies a fixed GHG coefficient per unit of fuel for each biofuel production pathway. These coefficients can include a factor that captures the implications of land-use change for emissions. FAPRI-MU uses estimates from the US Environmental Protection Agency (2010) of the CO_2, N_2O, and CH_4 implications of land-use change.

C. *Analysis*

Both models were used to develop reference case scenarios tied to common assumptions about rates of GDP growth, energy demand, and

[2] This model was run by OnLocation, Inc. of Vienna, Virginia; Frances Wood, team lead. Use for the NRC/NAS study necessitates adding "NAS" to the model title.

[3] EIA provides documentation on the NEMS model on its website: http://www.eia.gov/analysis/model-documentation.cfm.

Table 2—Effects of Removing Renewable Electricity Provisions on GHG Emissions

Policy scenario	Effect on annual emissions (MMT CO2e)	Percent difference from reference case US emissions[b]
No ITC/PTC—with state RPS	15	0.30
Range[a]	[−5.4, +16]	[−0.1, +0.3]
No ITC/PTC—without state RPS	32	0.50

Notes:

[a]Low end of range is tied to a NEMS reference case with low natural gas prices; the high end is tied to a reference scenario assuming higher economic growth.

[b]There are different reference cases for the scenarios with and without state RPS.

world oil prices. The reference case scenarios also assumed that each of the provisions of interest would continue to operate over the modeling time horizon, e.g., 2012–2035 for NEMS. Policy scenarios then removed the tax provisions individually or in combination, and outcomes were compared to the reference case to estimate the effects of the provision(s). Sensitivity analyses were conducted that varied critical assumptions. For example, the effect of the ITC and PTC were analyzed removing state RPSs, and the impact of biofuels provisions were analyzed assuming no federal RFS. Alternate assumptions were made about the annual rate of GDP growth and world energy prices.

Results: Renewable Electricity Provisions.—The emissions results for the renewable electricity provisions are presented in Table 2.

The analysis indicates that these provisions lower CO_2 emissions under the core reference case, but the impact is small, about 0.3 percent of US annual CO_2 emissions over the projected time horizon (2012–2035). Although the renewable electricity tax credits lead to an appreciable increase in renewable power generation, the total contribution of these sources is still small relative to the entire fleet of electricity generating units. The emissions effects therefore turn out to be small. If the revenue lost as a result of the PTC/ITC is divided by the reduction in CO_2 emissions, just under $250 in revenues are lost per ton of CO_2 reduced (see NRC 2013).

The state RPS mandates play an important role. When these mandates are removed from the baseline, the effects of the federal tax provisions roughly double, although they are still small relative to the economy's emissions (0.5 percent). Another finding is that the RPS mandates have almost the same impact on mitigating CO_2 emissions as the renewable electricity provisions, when each are examined separately.

Results: Biofuels Provisions.—The biofuels findings (Table 3) indicate that removing the VEETC would result in a *decrease* of 4.8 million metric tons (MMT CO2e) of emissions globally; removing all tax code provisions and the import tariff would decrease emissions by 5.4 MMT per year. The impact is less than 0.02 percent of global emissions and 0.1 percent of US emissions. These results are, at first glance, counterintuitive: the EPA GHG coefficients show biofuels to have lower GHG emissions than gasoline on a per unit energy basis. Thus, while subsidizing biofuels should presumably reduce CO_2 emissions, these results suggest the opposite. One factor that diminishes the emissions benefit of biofuel substitution is the increased emissions from land use change induced by raising bio-feedstock production. Moreover, the biofuels tax credits encourage the consumption of motor fuels because they lower the price of the blended fuels, and this rebound effect appears to offset the reduction in the GHG intensity of motor fuels.

The counterintuitive result can also be traced, in part, to the fact that the removal of the ethanol tariff increases the Brazilian sugarcane share of ethanol consumed in the United States. Brazilian ethanol has lower emissions per unit of energy than US ethanol, so increasing its share lowers emissions, all else equal.

The results are complicated by the mandates for renewable fuels. If the mandates are removed along with the subsidies, estimated emissions are lower; however, the marginal impact of the tax provisions is larger (7 million tons versus 5.4). This essentially means that the existence

TABLE 3—EFFECT OF REMOVING BIOFUEL SUBSIDY PROVISIONS ON GHG EMISSIONS

Policy scenario	Effect on annual emissions (MMT CO2e)	Effect on annual tax expenditures (billions of 2010$)
No VEETC—with RFS	−4.8	−$7.6
No provisions—with RFS	−5.4	−$12.6
Range[a]	[−14.9, +6.7]	[not calculated]
No provisions—without RFS	−7.0	−$10.1

Note:
[a]Low [high] end of range based on the use of a lower [higher] biofuel emissions factor.

of the RFS mitigates the effects of the tax provisions through redundancy.

The biofuels provisions are the most expensive directed renewable energy subsidies. Removing them would reduce tax expenditures by $10–12 billion per year. This includes losses of tax revenue through the credits themselves, but that is partly countered by the loss in revenues when the ethanol import tariff is removed. What Table 3 implies is that taxpayers are spending up to $2,300 in forgone tax revenues to increase CO_2 emissions by one ton (i.e., $12.6 billion/5.4 MMT). By any measure, this is an imprudent policy unless the social benefits from biofuels compensate for both the loss in tax revenue and the increase in CO_2 emissions.

IV. Conclusions

Policies at different levels of government have aimed to provide economic incentives to reduce GHG emissions. Many economists would favor placing a price on GHGs, either through a carbon tax or cap-and-trade program. However, political forces have limited the use of these approaches, favoring instead tax incentives for zero or low-GHG-emitting energy.

Unfortunately, there has been a dearth of studies that have examined the effectiveness of various tax provisions on emissions. To understand their effect requires understanding how the incentive affects market choices, given complex existing regulatory measures unrelated to the specific tax incentive, the reaction of multiple markets to the change, and, ultimately, the effect on emissions.

The analysis presented here was motivated by a Congressional request to examine the issue. Our key finding is that, despite tax revenue losses of $10 billion per year in 2010, these provisions have a very small impact on GHG emissions and, in some cases, may actually *increase* emissions. The results are troubling if GHG reduction is a significant goal of these policies. There are several reasons why these incentives have failed to significantly reduce GHG emissions. The renewable electricity tax credits do increase renewable power generation, but the effect is small relative to the entire generating fleet. The impact of the ITC and the PTC is also reduced by the existence of renewable power mandates in more than half the states. On the biofuel side, the subsidies do indeed increase the production and use of the subsidized products; however, this does little to lower the carbon intensity of fuel use because of the life cycle emissions from the cultivation of the feedstock, and transportation and production of the fuel. Moreover, the subsidy lowers the price of gasoline, leading to a classic rebound effect that increases emissions from higher gasoline use.

The findings also point to the importance of representing the complex institutional and market interactions inherent in these policies. Economists have been able to reduce many complex market relationships to simple elasticity estimates. A significant result of this study is that such reduced-form relationships can leave out structural aspects of the market and regulatory environment and lead one astray.

Perhaps it is not surprising that the tax code provisions studied are not particularly effective. Emissions reduction is only one of the policy's objectives; energy security, spurring "green" technology growth, and rural economic development are others, and the provisions are narrowly targeted at only a few emitting activities. Given the lack of political consensus to introduce a more effective GHG tax or cap-and-trade program, maybe the most we can hope for are tax incentives or other narrowly directed measures. However, based on this study, these do not appear likely to take us very far in reducing GHG emissions.

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