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The Distributional Effects of US Clean Energy Tax Credits

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Executive Summary

Since 2006, US households have received more than $18 billion in federal income tax credits for weatherizing their homes, installing solar panels, buying hybrid and electric vehicles, and other "clean energy" investments. We use tax return data to examine the socioeconomic characteristics of program recipients. We find that these tax expenditures have gone predominantly to higher-income Americans. The bottom three income quintiles have received about 10% of all credits, while the top quintile has received about 60%. The most extreme is the program aimed at electric vehicles, where we find that the top income quintile has received about 90% of all credits. By comparing to previous work on the distributional consequences of pricing greenhouse gas emissions, we conclude that tax credits are likely to be much less attractive on distributional grounds than market mechanisms to reduce greenhouse gases (GHGs).

I. Introduction

Worldwide, humans emit 49 gigatons of CO_2-equivalent greenhouse gas emissions each year, with 65% of these emissions coming from electricity generation, transportation, and other fossil-fuel related sources.[1] There is wide agreement among economists that the best policy to reduce greenhouse gas emissions and other negative externalities from energy use would be to use a tax or cap-and-trade program. Although there has been some movement in this direction, the vast majority of energy-related externalities worldwide remain unpriced. Instead, the

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approach that is receiving increased attention, mostly in richer countries, is to *subsidize* lower-greenhouse gas alternatives to traditional fossil-fuel based technologies. It can often be easier politically to introduce subsidies than taxes, but the two are not equivalent. Probably the single biggest limitation of technology-based subsidies is that they don't achieve the efficient level of *usage*, but economists have pointed out other limitations as well. For example, Holland et al. (2015) show that the external benefits from electric cars vary widely (and can even be negative), depending on how electricity is generated.

A growing literature examines the efficiency and overall cost-effectiveness of clean energy technology subsidies, but the distributional effects have received much less attention.[2] In this paper, we use tax return data to examine the socioeconomic characteristics of taxpayers who receive US federal income tax credits. We focus on four major tax credits for individuals aimed at encouraging households to weatherize their homes, install solar panels, and to buy hybrid and electric vehicles. Since 2006, tax expenditures for these "clean energy" tax credits have exceeded $18 billion.

We find that these tax expenditures have gone predominantly to higher-income Americans. All of these credits are nonrefundable, making it much less likely that lower-income filers can benefit from them, an issue that we examine more closely in a later section. Overall, the bottom three income quintiles have received about 10% of all credits, while the top quintile has received about 60%. The most extreme disparity is in the program aimed at electric vehicles, where we find that the top income quintile has received about 90% of all credits. We show that the distributional pattern is similar across years and reflects that higher-income taxpayers are much more likely to claim credits and for significantly larger credit amounts.

Whereas tax credits are received disproportionately by high-income households, a carbon tax would be *paid* disproportionately by high-income households. Hassett, Mathur, and Metcalf (2009), for example, find that with a carbon tax the top income quintile would pay about four times as much as the bottom quintile.[3] It would seem difficult, therefore, to prefer tax credits over a carbon tax on distributional grounds. There may well be political considerations that continue to favor tax credits, but this approach comes at real cost, both in terms of efficiency and equity.[4]

We also examine data on shipments of energy-efficient durable goods, installations of solar photovoltaic systems, and purchases of hybrid and electric vehicles. If these tax credits are successful in inducing changes in behavior, then we should expect to see increased purchases during years in which the subsidies are particularly generous. Conversely, if credits do not induce additional sales, then the primary effect is just to transfer rents to participants in transactions that would have taken place anyway (Boomhower and Davis 2014). We compare results across the different tax credits and technologies and, where possible, describe relevant related studies from the economic literature.

We do not in this paper attempt to estimate how much the subsidies to buyers caused prices to adjust upward, allowing sellers to absorb some of the subsidies. We cannot address this question of subsidy incidence because we have no data on prices paid for the energy efficiency and clean energy investments that are subsidized. Even if one could diagnose the impact of subsidies on transaction-specific prices, it would be difficult to know the degree to which sellers offered nonprice incentives or made quality and attribute changes that imply a different share of rents going to buyers than an analysis of price alone would suggest. Thus, our results should be interpreted only as demonstrating the level of subsidy going to transactions undertaken by taxpayers in different income brackets.

We see this work as filling an important gap in both the policy and academic literatures. Previous studies have examined the distributional effects of gasoline taxes (Poterba 1989, 1991; West 2004; Bento et al. 2009) and carbon taxes (e.g., Hassett, Mathur, and Metcalf 2009; Burtraw, Sweeney, and Walls 2009; Rausch, Metcalf, and Reilly 2011; Williams et al. 2015), but clean energy tax credits have received far less attention. Our work builds on two recent studies (Crandall-Hollick and Sherlock 2014; Neveu and Sherlock, 2016) that review the complete legislative history and report distributional statistics for two out of the four credits in selected years. Our paper extends these analyses to include the entire period since 2006 and reviews all four credits, including those aimed at hybrid and electric vehicles.

II. Overview of US Clean Energy Tax Credits

In this section, we review the income tax credits that have been available to US taxpayers since 2006 for clean energy investments. For each tax credit, we describe the different technologies that are covered, eligibility requirements, and important changes over time.

A. Nonbusiness Energy Property Credit

The largest of the tax credits available to US households is the Nonbusiness Energy Property Credit, or NEPC. This credit is for homeowners who weatherize their homes or make other types of residential energy-efficiency improvements. Neither renters nor landlords are eligible.[5] The main categories of qualified expenditures are insulation, energy-efficient windows, energy-efficient furnaces, and energy-efficient air conditioning systems.

The NEPC was established by the Energy Policy Act of 2005 and first available in 2006. During 2006 and 2007, the credit was 10%. The credit was not available in 2008 but then reintroduced and expanded in 2009 under the American Recovery and Reinvestment Act.[6] During 2009 and 2010, taxpayers were allowed a 30% tax credit, and the credit limit was temporarily increased to $1,500 up from the prior limit of $500. In 2011, the credit was decreased back to 10%, and the maximum credit limit was returned to $500. The NEPC expired at the end of 2013 but then was extended for one year through 2014 and may be extended again (retroactively) through 2015. For the complete legislative history, see Crandall-Hollick and Sherlock (2014), Sherlock (2015), and Neveu and Sherlock (2016).

Figure 1 plots annual shipments of five different categories of energy-efficient durable goods over the period 2005–2013. These data come from the US Department of Energy and represent all US shipments, regardless of whether the buyer ultimately received a tax credit. We have selected five different categories of durable goods that were eligible for the NEPC. The figure also includes vertical dashed lines indicating the beginning and end of the two years (2009 and 2010) during which the NEPC was particularly generous. If this expansion of the NEPC were leading Americans to invest more in energy-efficiency, we would expect increased sales of energy-efficient products in these years.

Overall, there is no clear evidence of an increase in shipments in 2009 and 2010. Shipments tend to be relatively high in 2009 and 2010 but well within the range observed in other years. It is difficult to make strong statements, however, because of several important confounding factors. Most important, in 2009 and 2010, the United States was still mired in a prolonged economic downturn, and it could well be that, in the absence of the credits, shipments would have been much lower.[7] Without a credible counterfactual, it remains an open question exactly how effective these grants have been at stimulating investments in energy-efficient technologies.

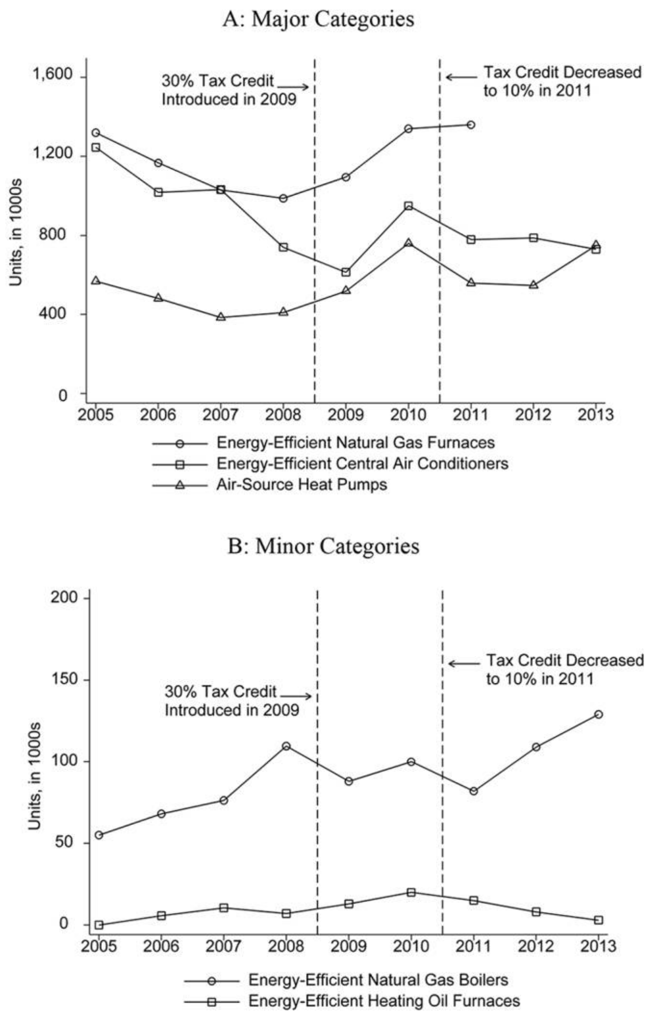


Fig. 1. Residential Energy-Efficiency Investments

B. Residential Energy Efficient Property Credit

The second largest clean energy tax credit is the Residential Energy Efficient Property Credit, or REEPC. This credit is for homeowners who install residential solar panels, solar water heating systems, and fuel cells. Again, neither renters nor landlords are eligible, though there is a parallel program for commercially owned systems, which we discuss in the following. Also established by the Energy Policy Act of 2005, the

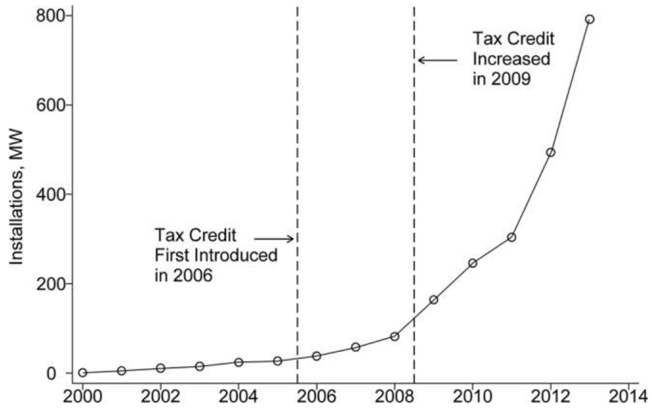


Fig. 2. US Residential Installations of Solar Panels by Year

REEPC was first available in 2006, and between 2006 and 2008 there was a 30% credit for all qualified expenditures up to a maximum limit of $2,000 for most categories. The credit was expanded in 2008 to include small residential wind turbines and geothermal heat pumps. Then, starting in 2009, under the American Recovery and Reinvestment Act, the maximum credit limit was removed for all qualified investments except fuel cells. This change represented a substantial increase in the generosity of the program because these systems typically cost tens of thousands of dollars. The program has continued unchanged since 2009.

Figure 2 plots total annual installations of residential solar photovoltaic systems, measured in megawatts of capacity. These data come from a solar industry association and include all installations in the United States. There has been rapid growth in solar installations throughout this period. This growth has been attributed to several factors, including sharp decreases in solar panel prices, retail electricity tariffs that incentivize distributed generation, state subsidies, and the federal tax credit (Borenstein 2015).

It is difficult to know how much of this growth is due to the federal tax credit. The figure includes vertical lines indicating 2006, when the REEPC was first introduced, and 2009, when the program became much more generous. Solar panel installations are growing quickly throughout this period, but it is impossible to make causal statements based on these before-and-after comparisons. We simply don't know how much of this growth would have occurred absent the federal tax credit. Probably the best evidence to date on the impact of subsidies on residential solar panel adoption comes not from the federal tax credit, but from variation over time in state-level subsidies. In particular, Hughes and Podolefsky (2015) show that households were responsive to rebates offered under the California Solar Initiative, but it is not straightforward to generalize these results to the rest of the United States.

The REEPC and NEPC are both based on similar credits that were available during the late 1970s and early 1980s (Dubin and Henson 1988; Hassett and Metcalf 1995). These credits expired at the end of 1985, and between 1986 and 2005 there were no such federal tax credits. Dubin and Henson (1988) finds that credits claimed in 1979 were higher where winters were more severe and where energy prices were high. In addition, both Dubin and Henson (1988) and Hassett and Metcalf (1995) test whether take-up of the federal credits is higher in states with state-level incentive programs for energy efficiency. Dubin and Henson (1988) find a positive but not statistically significant effect, while Hassett and Metcalf (1995), using panel data, finds a positive and statistically significant effect.

C. *Alternative Motor Vehicle Credit*

Another significant clean energy tax credit is the Alternative Motor Vehicle Credit, or AMVC. This credit is for purchases of qualified hybrids, as well as natural gas, hydrogen, fuel cell, and other alternative fuel vehicles. The credit was first available in 2006, with credit amounts varying from $400 to $4,000, depending on the vehicle model. The AMVC replaced a less generous $2,000 clean fuel vehicle *deduction* that was in place in 2003, 2004, and 2005. The AMVC includes an unusual phase-out rule that limits the total amount of the credit that can go to buyers of vehicles from any particular manufacturer. In particular, the AMVC phases out during the calendar year after which the manufacturer sells 60,000 qualifying vehicles. Toyota and Lexus were phased out first in 2007, followed by Honda in 2008, and Ford and Mercury in 2009. The AMVC was ended for hybrids on December 31, 2010, and the AMVC is currently available only for fuel cell vehicles.

Figure 3 plots US hybrid sales between 1999 and 2013. We break out Toyota from all other manufacturers because it has been so dominant in this market and because the Toyota tax credit was phased out before the tax credit for most other manufacturers. The AMVC was available for Toyota vehicles only in 2006 and for part of 2007. Notably, Toyota

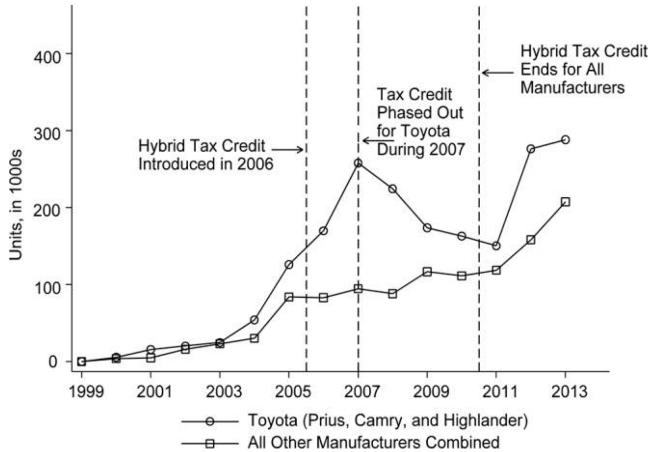


Fig. 3. US Hybrid Vehicle Sales

hybrid sales appear to have been particularly strong in those years. This is consistent with Sallee (2011), who finds a sales spike for the Toyota Prius just before the tax credit was phased out.

There does not appear to be much of a decrease in hybrid sales when the AMVC was ended for all hybrids at the end of 2010. Moreover, since 2010, hybrid sales have increased significantly without the benefit of the AMVC. That said, it is again difficult to make causal statements on the basis of these before-and-after comparisons. Similar to the evidence on solar panel subsidies, probably the most convincing research to date on the effectiveness of hybrid vehicle subsidies comes not from federal tax credits, but from state-level subsidies. In particular, Gallagher and Muehlegger (2011) use panel data to measure the effect of state-level hybrid subsidies on the adoption of hybrids, finding positive and statistically significant impacts.

D. Qualified Plug-In Electric Drive Motor Vehicle Credit

Finally, the Qualified Plug-In Electric Drive Motor Vehicle Credit, or PEDVC, is a credit for electric vehicles and plug-in hybrid vehicles purchased beginning in 2009.[8] This credit was implemented later than the other three tax credits and was the smallest of the four in terms of total expenditures between 2006 and 2012. The size of the PEDVC ranges from $2,500 to $7,500, depending on the battery capacity of the vehicle. For example, the Toyota Prius plug-in hybrid qualifies for a $2,500

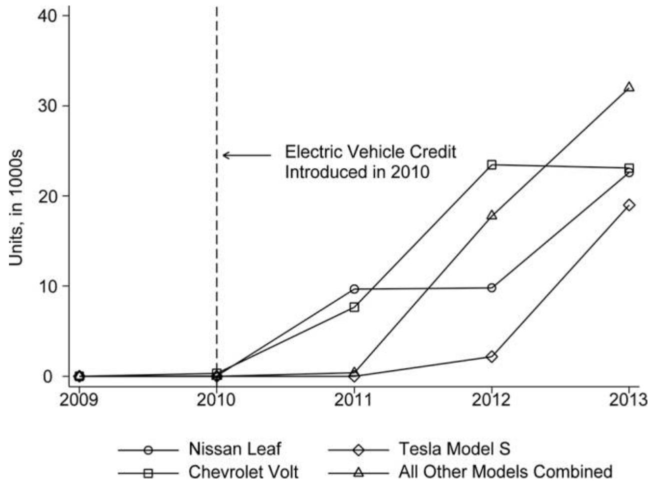


Fig. 4. US Sales of Electric and Plug-In Hybrid Vehicles

credit, whereas the Chevrolet Volt qualifies for a $7,500 credit. Similar to the AMVC, the PEDVC is phased out for a manufacturer's vehicles during the calendar year after which that manufacturer sells 200,000 qualifying vehicles, but no manufacturer has yet reached this threshold. Nissan has sold more qualifying vehicles than any other manufacturer but is still only about halfway there as of December 2014. The PEDVC remains in place and is not scheduled to expire.

Figure 4 plots US electric and plug-in hybrid vehicle sales between 2009 and 2013. We have broken out separately sales for the Nissan Leaf, the Chevrolet Volt, and the Tesla Models S, the three best-selling vehicles in this category. These data come from the US Department of Energy, which has tracked monthly sales of electric and plug-in hybrid vehicles by model since December 2010.[9] The Nissan Leaf and Chevrolet Volt were both introduced in December 2010, the Toyota Prius Plug-In Hybrid was introduced in January 2012, and the Tesla Model S was introduced in June 2012.

Electric and plug-in hybrid vehicle sales have grown rapidly since 2010. Much like with the pattern for residential solar photovoltaic systems, the tax credits have been in place for essentially the entire period of increased electric vehicle sales, so it is tempting to attribute a large causal impact. Again, however, it is simply not possible to make definitive causal statements on the basis of before-and-after comparisons. This period also coincides with a period of sustained oil prices above

Table 1
Annual Expenditures on US Clean Energy Tax Credits, in Millions

Year	Windows and Other Energy-Efficiency Investments (NEPC) ($)	Solar Panels and Other Residential Renewables (REEPC) ($)	Hybrids and Other Alternative Fuel Vehicles (AMVC) ($)	Electric and Plug-In Hybrid Vehicles (PEDVC) ($)
2005	0	0	0	0
2006	957	43	50	0
2007	938	69	185	0
2008	0	217	49	0
2009	5,177	645	137	129
2010	5,420	754	93	1
2011	755	921	14	76
2012	449	818	20	139
Total	13,696	3,467	549	346

Sources: This table was constructed by the authors using US Department of the Treasury, Internal Revenue Service, "Statistics of Income, Individual Tax Returns," 2005–2012 and US Department of the Treasury, Internal Revenue Service, "Individual Income Tax Returns Line Item Estimates," 2005–2012.
Notes: See appendix for details. Tax credits across all four categories totaled $18.1 billion between 2005 and 2012.

$75 per barrel and a recovering economy since 2012, so teasing out the relative impact of the federal credits compared to these other factors is very difficult.

E. *Summary of Total Tax Expenditures*

Table 1 reports annual expenditures for the four major clean energy tax credits. Between 2006 and 2012, total expenditures were $18.1 billion. By far the largest program is the NEPC, with $13.7 billion in total tax expenditures over this period. The REEPC is also substantial, particularly in later years, with $3.5 billion in total tax expenditures. Finally, the two vehicle credits are considerably smaller, adding up together to about $900 million over this time period.

In the appendix, we provide additional information on the different categories of investments within each credit. We constructed these more-detailed statistics using Internal Revenue Service (IRS) data. The data provide an interesting view into which categories are most important and how average credit amounts vary across categories. The NEPC goes mostly to energy-efficient windows (29%), furnaces (18%), air-source heat pumps and air conditioning (17%), and insulation (15%), with average credit amounts across categories ranging from $200 to $700. The REEPC goes to solar panels (54%), geothermal heat pumps (35%), and solar water heating systems (10%), with much larger average credits, averaging above $5,000 for households who install solar panels.

There are large changes across years. Perhaps most strikingly, there is a dramatic surge in expenditures for the NEPC in 2009 and 2010 after the credit was reinstated as a 30% tax credit with a temporarily higher $1,500 credit limit. Tax expenditures exceed $5 billion annually in both 2009 and 2010. The generosity of the REEPC also increased in 2009, and tax expenditures approximately triple in that year. Expenditures on the REEPC then continue at approximately the same level between 2009 and 2012.

This lack of growth in tax expenditures for the REEPC since 2009 is perhaps surprising given the enormous increase in residential solar installations in figure 2. The lack of a corresponding increase in tax expenditures on individual returns reflects, in part, a well-documented move in the solar industry toward third-party ownership (TPO) of residential solar systems. Companies can install a system on a homeowner's roof and then either lease the system to the homeowner or, more commonly, sign a long-term power purchase agreement under which the homeowner buys all the electricity generated by the system at contracted prices. When a system is leased, the homeowner is no longer able to claim the REEPC, but there is an identical 30% credit available for the lessor through the corporate income tax.[10] Leasing was relatively uncommon in the earlier years of our sample but becomes much more significant after 2010.[11]

The size of the AMVC varies substantially across years, decreasing in 2008 after Toyota vehicles became ineligible and then increasing again in 2009 as more eligible hybrids become available. Hybrid vehicles are no longer eligible for the AMVC after 2010, and the program becomes much smaller. Finally, the PEDVC increases significantly between 2010 and 2012.[12] Electric vehicle sales have continued to increase since 2012, so expenditures on the PEDVC have presumably increased as well.

The tax expenditure totals for the AMVC suggest that a relatively small fraction of hybrid buyers received the credit, at least during the first year of the program. Based on sales data from *Automotive News* and assuming an 85% take-up rate, Sallee (2011) estimated that total credits in 2006 would have been $426 million. In the IRS Statistics of Income data, however, total expenditures on the AMVC in 2006 were only $50 million. The discrepancy suggests that only approximately one in eight hybrid buyers actually received the credit. This is a bit of a puzzle because, while undoubtedly some buyers had zero net tax liability in 2006 and, thus, were unable to claim the credit, it seems unlikely that this could explain such a large discrepancy. It is also possible that some buyers didn't know about the credit or forgot to claim it though, again, it seems unlikely that this could explain such a large apparent discrepancy. Another possible explanation is the Alternative Minimum Tax (AMT). Prior to 2009, the AMVC could not be claimed by filers subject to the AMT, but since 2009 all four clean energy tax credits can be applied against the AMT.

Some of the low take-up of the vehicle tax credits is also likely due to leasing of hybrid (and, later, electric) vehicles. Sallee (2011) reports that less than 3.5% of Toyota Priuses were leased from 2002 to 2007. However, leasing has grown more common during the period we study. Between 2006 and 2012, about 20% of new vehicles in the United States were leased.[13] Tal and Nicholas (2013) report that in a survey of 3,800 California households who acquired a new plug-in hybrid or all-electric vehicle in 2012, 29% were under lease, and the remainder were purchased. They also report that, within their survey population, the buy or lease decision was uncorrelated with income.

III. Distributional Analysis

Having provided an overview of US clean energy tax credits, we now turn to our main research question. How does the use of these credits vary across income levels? In this section, we use detailed data from the IRS to calculate the share of the credit going to different income groups. We compare average credit amounts by income category, and we construct concentration curves and concentration indexes. Finally, we contrast the distributional characteristics of these credits with other major US tax credits and with a carbon tax.

A necessary consequence of working with IRS data is that our analysis is based on annual income. We recognize that annual income may be a poor proxy for lifetime income, which would more closely capture the notion of a household's overall "need." Students and retirees, for example, often have low adjusted gross income (AGI) in a given year, even if their lifetime income is much higher. Previous studies have shown that the impact of gasoline and carbon taxes tend to be much more evenly distributed across households when viewed in a lifetime income framework (Poterba 1989; Hassett, Mathur, and Metcalf 2009). In particular, the percentage of income going to a gasoline or carbon tax tends to be more similar across deciles when using lifetime income rather than annual income. We are not able to make such a comparison using our data, but it seems likely this could also be the case for clean energy tax credits.

A. *Average Credit Amount by AGI*

Figure 5 plots the average credit amount per return by AGI category. We constructed these figures using data from the IRS *Statistics of Income* program and the appendix provides a complete description of the data we used and how we made these calculations. Reported on the *y*-axis in these figures is the average credit per return. That is, we take an average over all tax returns, including both filers who did and did not claim these credits. Thus, for example, the far right observation in the first panel means that, among all filers with more than $200,000 in AGI, the average amount claimed in residential energy credits was about $80. For these figures, we pooled data from across all years in which data are available as described in the panel headings.

In this figure and in the analyses that follow, we focus on three categories of credits: (1) Residential Energy Credits (afterward, RECs), (2) Alternative Motor Vehicle Credit (AMVC), and (3) Qualified Plug-In Electric Drive Motor Vehicle Credit (PEDVC). Category (1) is the combination of the NEPC and the REEPC, whereas categories (2) and (3) are exactly the same as in the previous section. The NEPC and REEPC are quite different, as we explained in the previous section, but neither the IRS annual reports nor the IRS public-use microdata report separate statistics for the two tax credits. Consequently, in the analyses that follow, we are forced to focus on the combined category.

For these figures, we divided AGI into six categories. The first five are approximately quintiles, and then the last category ($200,000+) includes about 3% of returns. The figures also include 95% confidence intervals. The IRS reports from which we calculated these average credit amounts are based on large representative samples of tax returns. Fortunately, the IRS also reports standard errors for all estimates, which we have used to construct 95% confidence intervals. See appendix for details. The underlying samples are large, so there tends to be little sampling variation in most income categories, and, in many cases, the confidence intervals are narrow enough that they are obscured by the mean marker.

About 60% of tax filers have less than $40,000 in AGI, and these filers receive very little of any of the three categories of clean energy credits.

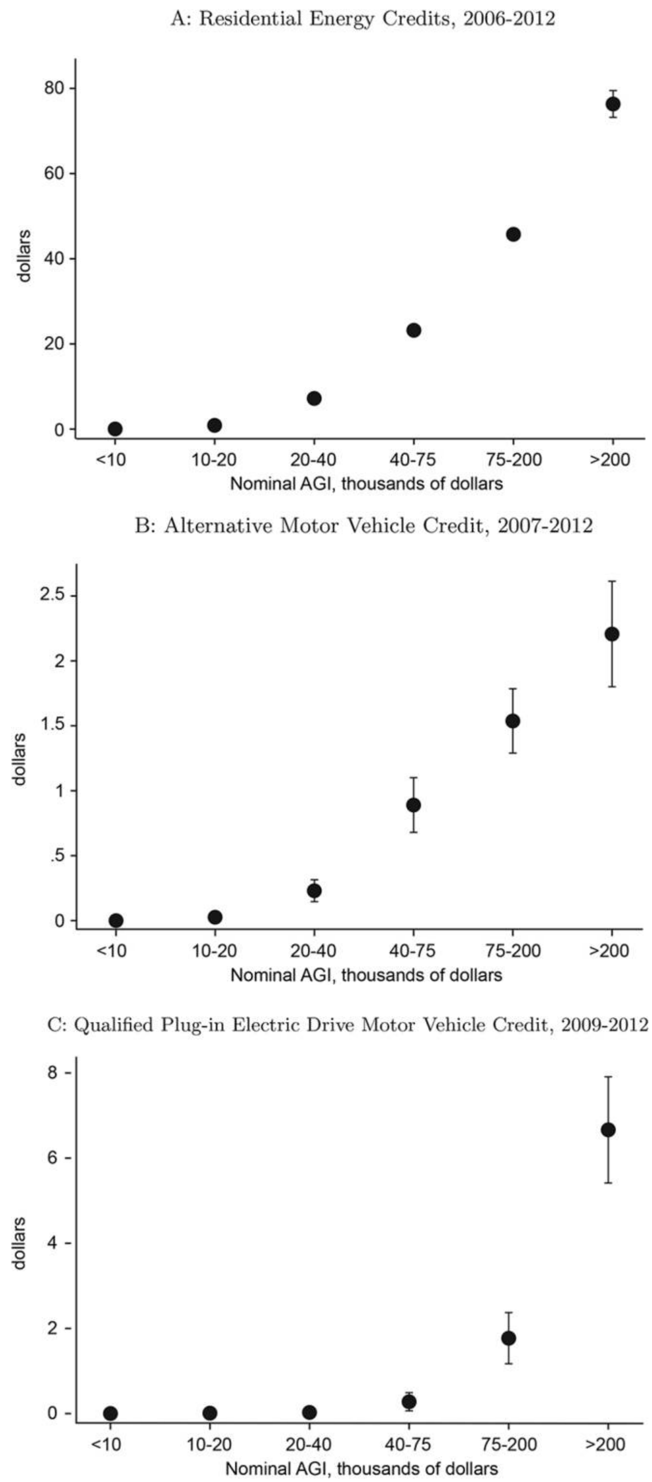


Fig. 5. Average Credit Per Return, by Adjusted Gross Income

In the discussion and analysis that follows, we consider several potential explanations for this near zero take-up among lower-income tax filers. Average credit amounts increase steadily with AGI. With the RECs, the average credit amount in the top income category ($200,000+) is almost twice as high as the average credit amount in any other category. The AMVC is more evenly divided across categories, while still clearly increasing in AGI. Finally, the PEDVC is by far the most concentrated. On average, the top AGI category ($200,000+) receives more than three times the average amount received by filers in any other income category.

For the RECs, one explanation for the correlation with income is that these credits are only available to homeowners.[14] Households who rent their homes are not eligible and, indeed, have much less incentive to make these types of residential investments. Using a different dataset, Borenstein and Davis (2012) show that the proportion of households who own their home increases steadily across income quintiles from about 50% in the first quintile to 90% in the fifth quintile. These are significant enough differences that this could play a substantial role in explaining the correlation between average credit per return and income.

In the appendix, we also examine how the relationship between average credit per return and income has changed over time. Figures A2, A3, and A4 plot year-by-year versions of our figure 5. Overall, the pattern is similar across years. However, there is one important finding in the year-to-year comparisons. The RECs are considerably more concentrated in 2011 and 2012 than in earlier years, with filers with $200,000+ in AGI receiving a considerably higher fraction of total credit dollars. As we showed in table 1, in these two years, annual expenditures on the REEPC grew to eclipse annual expenditures on the NEPC. The fact that credit receipts are more concentrated in those years suggests that the two tax credits have different distributional characteristics, with the REEPC more concentrated among higher-income filers.

B. Extensive versus Intensive Margin

As we document in this section, the correlation between average credit per return and income reflects both an increase in the share of filers claiming the credits and an increase in the average credit amount claimed. Figure 6 describes these "extensive" and "intensive" margins for the RECs. The top panel shows that the share of filers claiming the credit increases steadily from less than 1% for filers with income below $20,000 to about 6% for filers with income above $75,000.

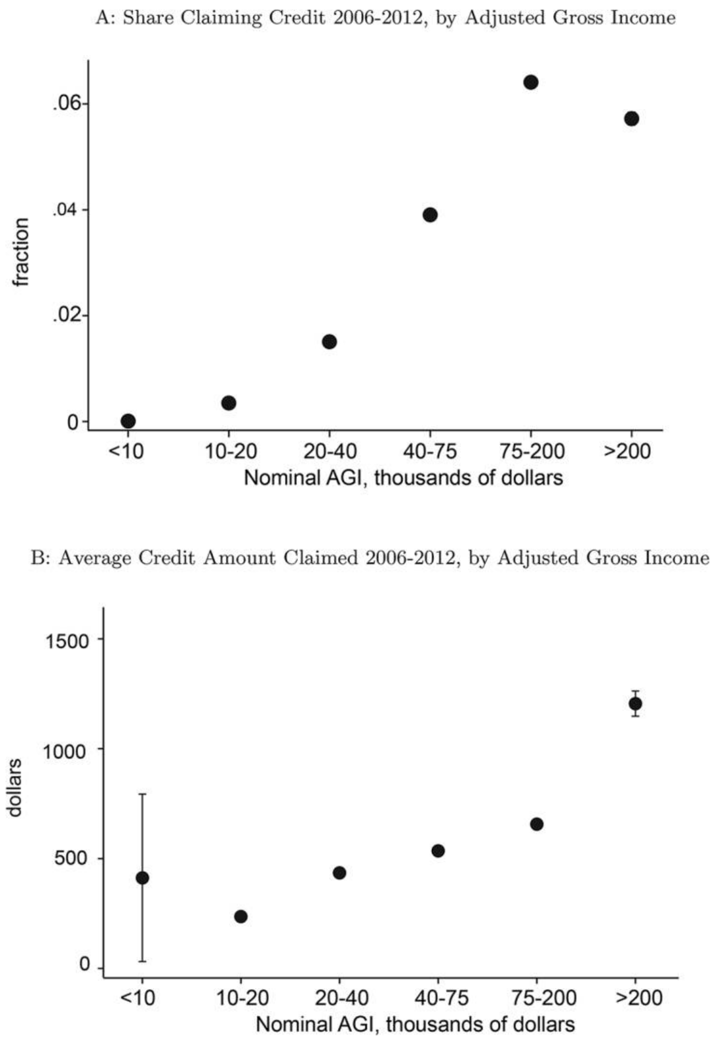


Fig. 6. Residential Energy Credits, Extensive Versus Intensive Margin

The bottom panel in figure 6 plots the average credit amount claimed among filers who claimed the credit. Very few filers with income below $10,000 receive the credit, so the 95% confidence interval is wide. Across the other income categories, there is a clear positive relationship between AGI and the average credit claimed. This is most clear in the highest income category. Filers with $200,000+ in AGI claim, on average, about $1,200, compared to about $600 for filers with income $75,000–$200,000.

Analogous results for the AMVC and PEDVC are presented in appendix figures A5 and A6. The share of filers claiming the credit increases steadily with income for both vehicle credits, with the top income categories several times more likely to claim the credit than other income categories. For these vehicle credits, there appears also to be a positive relationship between income and the average credit amount claimed, but this is less precisely estimated. Thus, the evidence is overall consistent across tax credits, with a positive correlation with income along both extensive and intensive margins.

C. *Measuring the Concentration of Energy Credits*

We now construct concentration curves and concentration indexes for each of the energy tax credits.[15] Income itself is highly concentrated, so these tools allow us to ask how the distribution of tax credits compares to the distribution of income. In particular, is the distribution of tax credits approximately proportional to income or more or less concentrated? We constructed these measures using these same data from the IRS *Statistics of Income* program, except that we now use all 19 income categories rather than just the six categories used earlier.

Figure 7 plots concentration curves for the three different categories of credits. Each plot includes a concentration curve for income. The AGI curve plots the cumulative fraction of total AGI received by that percentile of taxpayers. So, for example, the figures show that the first 50% of taxpayers receive about 15% of all AGI, and the first 80% of taxpayers receive about 40% of all AGI. If income were equally distributed across taxpayers, then the AGI curve would exactly follow the 45-degree line with, for example, the richest 50% of filers receiving 50% of the credits. The farther below the 45-degree line, the more concentrated income is among high-income filers.

The figures also plot concentration curves for the clean energy tax credits; see the darker line labeled "credit" in the first panel. Again, the relevant thought experiment is to line up all filers in order by AGI. But these curves then show the cumulative fraction of total credits received by each percentile of taxpayers. For the different panels in figure 7, the curve for income is the same, but the curve indicating the distribution of credits differs. These curves are very precisely estimated, so we do not plot 95% confidence intervals.

The RECs and AMVC have very similar distributional patterns. In both cases, the credits are *more* concentrated than income for low in-

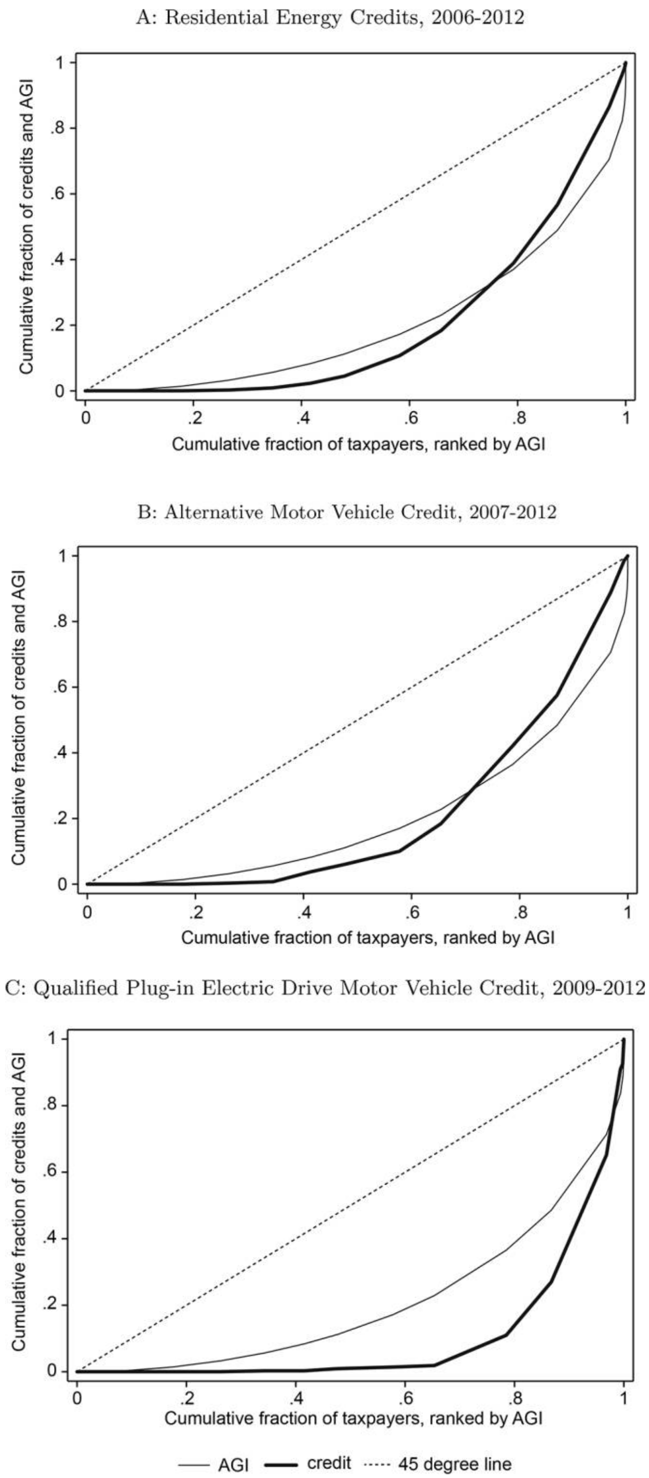


Fig. 7. Concentration Curves

come levels, but then *less* concentrated than income for high income levels. Take the 50th percentile, for example. The bottom 50% of filers represent about 15% of all income but less than 10% all credits. The two curves cross at about the 75th percentile, so the bottom 75% of filers account for about 30% of all credits and about 30% of all income. Then the top 5% of filers receive about 40% of all income but only about 20% of all credits. On the high end, the maximum credit limits begin to become important. The NEPC, for example, has since 2011 had a $500 maximum credit limit. Thus, at very high income levels, the NEPC necessarily becomes a smaller fraction of total income even for filers claiming the maximum credit.

The PEDVC is more concentrated than the other categories of clean energy tax credits. The bottom 80% of filers receive a little more than 10% of all credits, and the bottom 90% of filers receive only about 40% of all credits. It may simply be that electric vehicles, for the moment, are only affordable for relatively rich households. Even after the credit, electric and plug-in electric drive vehicles are expensive compared to equivalently sized gasoline-powered vehicles. Another possible explanation is that in "green" communities (which tend to be high income), driving an electric vehicle could be perceived as a symbol of status. Kahn (2007) makes this argument about hybrids, but, over the last several years, this probably applies better to electric vehicles.[16]

IV. Discussion and Comparisons

We now offer some context for the results of the previous section by comparing the distributional impact to the effect of other tax credit and deduction policies by comparing to a tax on greenhouse gases and by considering the impact of the nondeductability of the clean energy tax credits.

A. Comparisons to Other Tax Expenditures

Many US tax expenditures go disproportionately to higher-income filers. A recent study by the Congressional Budget Office (CBO) reviews the 10 largest tax expenditures in the United States (CBO 2013). None of the clean energy tax credits are in the top 10. About 30% of tax expenditures in these 10 largest categories goes to the bottom three income quintiles, with 50% of tax expenditures going to the top income quintile. Thus, overall, clean energy tax credits are considerably more concentrated in the highest income categories than these top-10 largest US tax expenditures.

This result is a bit surprising because most of the top-10 largest tax expenditures are *exclusions* like employer-sponsored health insurance or *deductions* like the mortgage interest deduction. With exclusions and deductions, a correlation between tax expenditures and income is introduced mechanically through increasing marginal tax rates. Put simply, both exclusions and deductions appear in the 1040 before calculating the amount of tax that must be paid, so they are worth more to filers facing higher marginal tax rates. In contrast, all four of these clean energy tax credits are *credits*, not exclusions or deductions, so there is no mechanical correlation introduced through increasing marginal tax rates. Credits appear in the 1040 after calculating the amount of tax that must be paid and then are applied dollar-for-dollar against whatever tax is due.

Indeed, clean energy tax credits appear to be more concentrated in the highest income categories than most other major tax credits. Table 2 compares the distributional pattern of the clean energy tax credits to the five largest US tax credits in terms of total tax expenditure. For each credit, we report the percentage of credit dollars received by income category as well as the concentration index, calculated as the ratio of the area between the concentration curve and the 45-degree line over the total area under the 45-degree line. A concentration index of zero indicates perfect equality, whereas one indicates perfect inequality with all credit dollars concentrated in the single highest-income filer category. A negative concentration index is possible when the concentration curve lies above the 45-degree line, for example, more than 50% of credits are received by the bottom 50% of filers in terms of AGI.

Comparing concentration indices shows that most other major tax credits are considerably less concentrated among the highest-income filers than the clean energy tax credits. The Earned Income Tax Credit is strongly redistributive by design and reaches a maximum for filers with AGI between about $10,000 and $20,000, depending on filing status and number of children. The Making Work Pay Credit, Child Tax Credit, and First-Time Homebuyer Credit are also considerably less concentrated than the clean energy tax credits, with concentration indexes between .16 and .23. The Foreign Tax Credit, for taxpayers who paid taxes to a foreign country, has a very different pattern, with 88% of all credits going to the filers with $200,000+ in AGI. This credit applies to qualified dividends, capital gains, interest, and other forms of investment earn-

Table 2
Distributional Effects of Selected Tax Credits

	Percent of Credit Received by Income Category (in Thousands)						
	$0–$10	$10–$20	$20–$40	$40–$75	$75–$200	$200+	Concentration Index
			A. Clean Energy Tax Credits				
Residential Energy Credits	0	1	10	28	48	14	0.606
Alternative Motor Vehicle Credit	0	1	9	32	47	11	0.584
Plug-in Electric Drive Vehicle Credit	0	0	1	10	54	35	0.801
			B. Other Major Tax Credits				
Earned Income Tax Credit	18	49	32	1	0	0	–0.415
Making Work Pay Credit	7	14	25	28	26	0	0.163
Child Tax Credit	2	13	31	31	23	0	0.185
First-Time Home Buyer Credit	7	6	23	40	24	1	0.222
Foreign Tax Credit	0	0	1	2	9	88	0.954

Sources: This table was constructed by the authors using US Department of the Treasury, Internal Revenue Service, "Statistics of Income, Individual Tax Returns," 2005–2012. The first five income categories are approximate quintiles (18%, 17%, 24%, 21%, 18%), and 3% of tax returns fall in the last category. Residential energy credits includes both the NEPC and the REEPC. The Earned Income Tax Credit, Making Work Pay Credit, Child Tax Credit, and the First-Time Home Buyer Credit are all refundable, while the Foreign Tax Credit is not.
Note: See appendix for details.

ings and so is mostly relevant to wealthy taxpayers with investments abroad.

In related work, Dubin and Henson (1988) examine the distributional effects of energy efficiency tax credits implemented under the Federal Energy Tax Act of 1978. They find for those earlier tax credits a concentration index of .57, quite similar to the pattern observed 25+ years later with a similar set of credits. Using the same data, they also find that the concentration index for income is .42. We find a considerably higher concentration index for income, .59, reflecting the widely discussed increase in the concentration of income in the United States over the last several decades. See, for example, Piketty and Saez (2014), which documents a steady increase since 1970 in the share of total US income accruing to the top decile.

B. Comparison to a Carbon Tax

Returning to the policy options mentioned in the introduction, we can now compare the distributional aspects of clean energy credits to previous research on a carbon tax. Hassett, Mathur, and Metcalf (2009) find that high-income households would pay much more than low-income households under a carbon tax.[17] The bottom income quintile would increase dollar expenditures only by about one-fourth as much as the highest income quintile.[18] The implied concentration index of expenditures is .13, though, for comparison to the tax credits in table 2, it makes sense to think of this as -.13 as the carbon tax would be *paid* while the tax credits are *received*.[19] This is not unexpected. Under a carbon tax, the prices of most goods and services would increase, and high-income households tend to consume more. Thus, a carbon tax would be disproportionately *paid* by high-income households, while clean energy tax credits are disproportionately *received* by high-income households.

Two other studies of the distributional impact of pricing carbon or taxing gasoline come to similar conclusions. Though the main focus of Williams et al. (2015) is the dynamic general equilibrium impacts of a carbon tax under alternative revenue recycling schemes, they also find that high-income households would tend to bear the largest costs under a carbon tax. For example, they examine one scenario with a simple lump-sum per-capita rebate of carbon tax revenue from a $30/ton tax on CO2, which averages about $1,600 annually per household in all quintiles. Their findings, shown in figure 1B of Williams et al. (2015), imply that, without incorporating external benefits, households in the top income quintile would be made worse off on average by about $6,000 per year while households in the lowest three quintiles would be made better off, on average, by $1,200, $800, and $250, respectively. Similarly, Bento et al. (2009) show that if returned lump sum on a per-capita basis, a gasoline tax could make the bottom four income deciles better off, on average, even without incorporating external benefits. Overall, it seems clear that the *costs* of a carbon tax would be moderately skewed toward high-income households, while the *benefits* of clean energy tax credits are strongly skewed toward high-income households.

C. Does Nonrefundability Matter?

All four clean energy tax credits are nonrefundable. This means that these credits can only be used by taxpayers with positive tax liability. This is a significant distinction because a large fraction of filers do not have positive tax liability. In 2012, for example, the IRS received 144.9 million tax returns, of which 93.1 million had positive tax liability. The other 51.8 million tax returns (35.7%) had nonpositive tax liability. This includes a high proportion of filers with less than $30,000 in AGI though this also includes some higher-income filers with unusually large amounts of itemized deductions. Thus, nonrefundability can potentially help explain the low average credit amount among lower-income quintiles. The Earned Income Tax Credit, Making Work Pay Credit, Child Tax Credit, and First-Time Home Buyer Credit are all refundable, and, perhaps not coincidentally, all have much lower concentration indexes.

We are not aware of any coherent economic argument for making these credits nonrefundable. In related work, Batchelder, Goldberg, and Orszag (2006) propose that all tax incentives should take the form of refundable tax credits. Refundable credits "provide a much more even and widespread motivation for socially valued behavior" and there is nothing inherent about zero income tax liability that would motivate such different tax treatment between taxpayers with $0 and $1 in tax liability.[20]

Making these tax credits refundable would increase take-up and equity, but by how much? How much higher would participation in these programs be if the tax credits were refundable? Although this might initially seem like an easy question, it ends up being surprisingly difficult to construct a credible counterfactual for how much constrained households would have participated had they been eligible. Lower-income filers are more likely to have zero tax liability, but they are also intrinsically less likely to make many of these different types of investments, and it is difficult in practice to determine the causal impact of the constraint.

In this section, we propose a simple empirical test. Using IRS income tax microdata for 2005–2008, we compare the average credit claimed across taxpayers with different levels of net tax liability. The basic idea is to observe how the average credit claimed varies with net tax liability and then to project this down to zero tax liability. If the intercept with zero tax liability is positive, this would suggest that that those with zero tax liability would have claimed these credits had they been eligible.

Figure 8 shows our empirical test with three different bin widths. We focus on the RECs as the microdata do not have information about the AMVC or PEDVC. In all panels, the horizontal axis is net tax liability

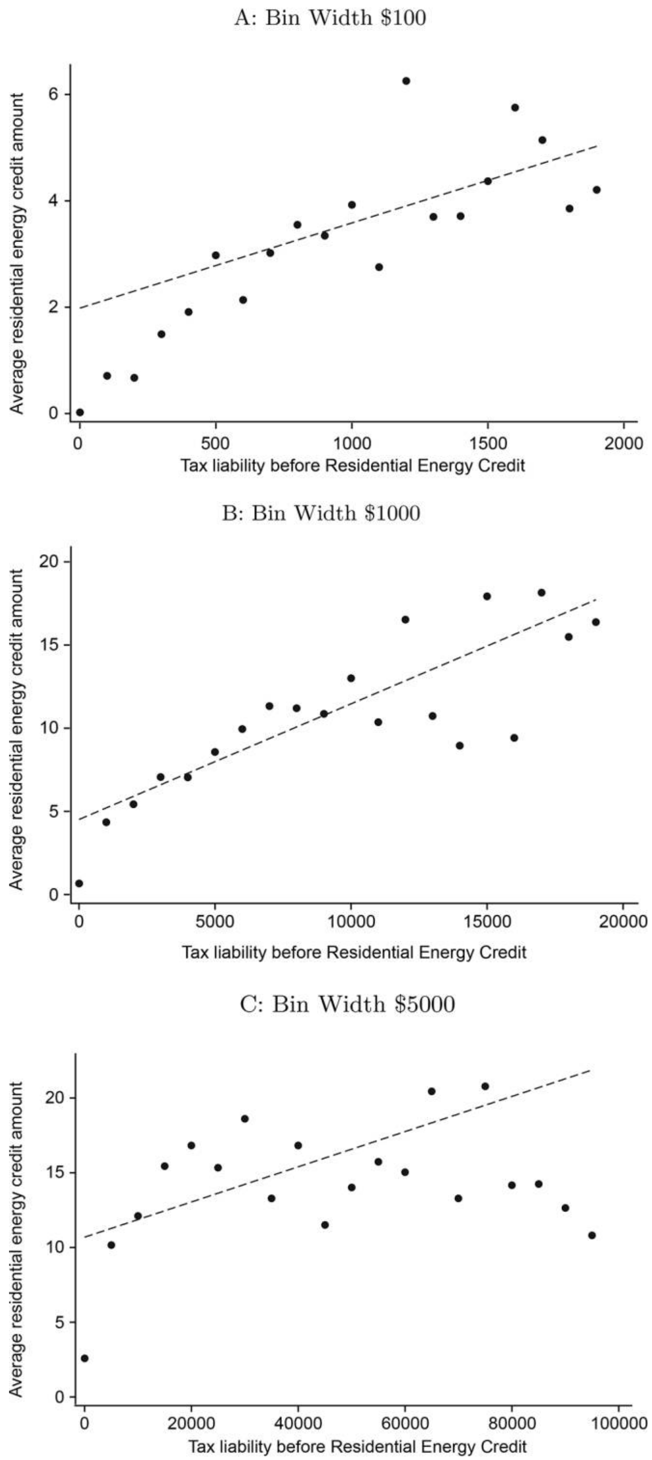


Fig. 8. Does Non-Refundability Matter?

before RECs, and the vertical axis is the average credit amount claimed. We show figures using bin widths ranging from $100 in the first panel to $5,000 in the last panel.

In general, the average credit amount is strongly increasing in net tax liability. However, it is important to point out that this is *mechanically* true as one gets close to zero tax liability. These are nonrefundable credits, so, for example, a taxpayer with only $500 of tax liability cannot claim $1,000 in credits. This explains why, in the first panel, the average credit amount falls toward zero between about $500 and $0 in net tax liability. During these years, the maximum credit amount for the NEPC was $500, so it makes sense that the average credit amount would begin to slope toward zero at this amount.

With the larger bin widths, this mechanical relationship is less visible because only the first bin is affected, and one can see more clearly the underlying relationship between tax liability and credit amount. Each panel also includes a least squares fitted line, weighted by the number of households in each bin and excluding observations below $500. In all three panels, there is a nonzero intercept. That is, it would appear, based on a linear extrapolation, that taxpayers with zero positive tax liability *would* claim the credit were they eligible.

Although this is highly suggestive, quantifying exactly how much refundability matters is difficult. The magnitude of the estimated intercept varies widely across panels from about $2 in the first panel, to $5 in the second, and $10 in the third. This is a difficult extrapolation, moreover, because one needs to somehow disentangle this mechanical relationship (i.e., taxpayers with near zero tax liability *can't* fully claim the credit) from the underlying behavioral relationship (i.e., taxpayers have different underlying demand for the credit, which varies with income). Here we have somewhat arbitrarily thrown out observations below $500, but there may be better ways to do this.

Another point that is easily obscured in this analysis is that there are large numbers of taxpayers with zero tax liability. Because of the way tax liability is constructed using the 1040, it is impossible to have *negative* tax liability. But a large number of households are right at that minimum. For example, in 2012, 51.8 million out of 144.9 million tax returns (36%) had no positive tax liability. And among those with less than $20,000 in AGI, approximately 85% had no positive tax liability. This means that predicting participation in these tax credits for taxpayers that are currently ineligible is not as easy as simply finding the intercept in this regression. The composition of households at $0 is extremely mixed, including those who look very similar to taxpayers with $1 in tax liability, but also much lower income taxpayers who may look quite different.

Thus, overall, it is difficult to draw strong conclusions on the basis of our empirical test. There is some evidence that refundability does matter, but it is difficult to quantify the exact magnitude. Our estimated intercept varies widely across specifications and, in any event, would only provide information about taxpayers that "barely" have zero tax liability and not about the millions of other taxpayers who should be thought of as quite different from taxpayers who are just barely eligible. Perhaps by imposing parametric assumptions it would be possible to make stronger statements, but we defer this for future work.

C. *Impact of Analyzing Tax Filers Rather than Households*

One concern in using individual tax return data for this study is that tax returns don't necessarily correspond to households, the more common unit of analysis in estimating distributional impacts. Our sample deviates from households primarily in two ways. First, it omits some households in which no one files a tax return. Second, it decomposes some households into more than one unit if a married couple files separately or a household includes unmarried adults who file separately. While we cannot correct for either of these factors, we can suggest the size and direction of the biases they might cause.

To evaluate the impact of omitted households, we use IRS publication 1304 from the Statistics of Income for 2012, which reports that a total of 287.7 million people were claimed as filer, spouse, or dependent exemptions on all tax returns filed in 2012. The US census estimates the 2012 US population to be 313.9 million, suggesting that 26.2 million, or about 8.3%, were not covered under any tax return. Some of these were failing to file even though they were required to (known as "ghosts" in IRS parlance), while others had little or no income and were not required to file.[21] Erard et al. (2014) estimate that there were 7.6 million ghosts in 2012, about 29% of the uncovered population, and that their mean income was about half the mean income of filers. The remaining 71% of the uncovered population were almost entirely very low income individuals who were not required to file. Of course, none of these nonfilers received clean energy tax credits. This suggests that including all residents (and overseas US citizens) in the analysis would strengthen our conclusion that the credits are disproportionately claimed by high-income Americans.

On the second issue, the "married filing separately" status was claimed on about 1.9% of returns in 2012, and filers with this status had about the same average AGI as all other filers.[22] It is unclear how one should account for these individuals in a distributional analysis because some of them are in the process of separating finances as part of a divorce, while others are filing separately to take advantage of specific tax rules, for example, deductability of medical or work-related expenses above a certain percentage of AGI. In any case, combining these couples into single households would create more wealthy households in the analysis, but the reduction of total households by about 0.95% would not substantially change our results. We do not have data on unmarried couples living together and filing separately, though it also seems unlikely to substantially change our conclusions.

V. Conclusion

There is growing enthusiasm among policymakers for programs that subsidize clean energy technologies. In addition to the federal tax credits examined here, most US states now have renewable portfolio standards that subsidize electricity generation from renewables, many have state-level subsidies for hybrid and electric cars, and US electric and natural gas utilities spend billions annually on energy-efficiency programs.[23] These subsidies for clean energy technologies could increase further under the US Environmental Protection Agency's Clean Power Plan. A growing body of evidence has shown that these policies are considerably less efficient than first-best policies. Perhaps, however, these policies have desirable distributional impacts. If this were the case, it might be the basis for an economic argument for second-best policymaking.

We focused, in particular, on the distribution impacts of US federal clean energy tax credits. Since 2006, these credits have provided more than $18 billion in subsidies for households who make clean energy investments. Using rich data from tax returns, we show that over the last decade, US clean energy tax credits have gone predominantly to higher-income Americans. Taxpayers with AGI in excess of $75,000 have received about 60% of all credit dollars aimed at energy-efficiency, residential solar, and hybrid vehicles, and about 90% of all credit dollars aimed at electric cars. Thus, while there may well be political reasons to prefer this approach to first-best policies, it would seem to be difficult to argue for these policies on distributional grounds.

We are also struck by the horizontal inequity of these programs. These are nonrefundable tax credits, so millions of mostly lower-income taxpayers are ineligible because they have nonpositive tax liability. We have not been able to come up with any coherent economic argument for making these credits nonrefundable. From an efficiency perspective, there is nothing fundamentally different between filers with positive and negative tax liability, and, from a distributional perspective, restricting the credits to exclude taxpayers without tax liability decreases both horizontal and vertical equity. A related issue is that renters are ineligible for the energy efficiency credit. Principal-agent problems cause landlords to underinvest in energy efficiency when their tenants pay the utility bill (Davis 2012; Gillingham et al. 2012; Myers 2013). As a consequence, there are investments in rental housing that have high private and social rate-of-return. Addressing this market failure is challenging because of imperfect information and split incentives, but excluding this sector altogether misses a large share of the housing stock and makes the credit less equitable.

Nonrefundability and availability only to homeowners no doubt play substantial roles in the finding that residential clean energy tax credits tilt strongly toward upper-income filers, but liquidity constraints and credit costs are probably also a substantial barrier. Tax credits are received many months after the purchase, meaning that filers must have savings or access to credit that allows them to pay for the full investment, a requirement that is surely more onerous for the poor. In addition, the clean energy tax credits are aimed at investments for which the costs are largely up front and the payoffs take place over many years, thus making them less attractive to households facing high costs of credit, which again suggests they are more likely to benefit the wealthy. We have not attempted in this paper to untangle these potential explanations for the skewed benefits across the income strata, but our results suggest that further research on the topic would be valuable.

Appendix

Data Description

For the distributional analysis, we compiled data from three different sources, all based on tax returns filed with the US Department of Treasury, Internal Revenue Service (IRS). Most of our data come, in one form or another, from the IRS's *Statistics of Income* (SOI) program, a federal statistical organization that gathers, analyzes, and publishes information about US income taxes.[24]

Summary Statistics

The first data source is a series of annual reports from the IRS's SOI program which publish summary statistics for most different categories of income tax credits.[25] These data report the total number of returns and total dollar value of the credit by income category. Statistics are reported for 19 or 20 different categories (depending on the year) of AGI ranging from $0 to $10,000,000+. In many of our analyses, we collapse these categories into approximate quintiles to make the evidence easier to interpret.

These summary statistics are calculated by the IRS based on large representative samples drawn from the 140+ million individual income tax returns filed each year. The underlying samples included, for example, 308,000 returns in 2010 and 330,000 returns in 2011.[26] The IRS reports standard errors for all summary statistics, expressed as a percentage of the statistic being estimated. Where appropriate, we use these standard errors to construct 95% confidence intervals. In general, the sampling variation is modest for our main results, (for example, figure 5), but larger and more important to account for when we report results separately by year and credit category in figures A2, A3, and A4.

Line-Item Estimates

The second data source is a different series of annual reports from the IRS's SOI program, which provide frequencies and amounts for individual line items.[27] These reports go line-by-line through the 1040 and accompanying schedules and subforms, providing for each line an estimate of the number of filers that included a nonzero number in the line and the sum of all values recorded by all filers. This line-item information is estimated using the same large representative samples used by SOI to calculate the summary statistics.

These data are a valuable complement to the first data source because they include additional detail that is not available elsewhere. Taxpayers who claim the NEPC or REEPC are required to file Form 5695 "Residential Energy Credits" along with their 1040, but only the total dollar amount from the 5695 is described in the SOI summary statistics. The line-item estimates, however, provide line-by-line information. For example, with the REEPC, these data allow us to determine for table A1 how much of the credit went to photovoltaic systems, geothermal heat pumps, and solar water heating systems. For the NEPC, these data allow us to distinguish between energy-efficient windows, qualified furnaces and boilers, and the other categories of energy-efficiency improvements. Air-source heat pumps are eligible for the NEPC, while geothermal heat pumps are eligible for the REEPC.

Public Use Microdata

The third data source is income tax return microdata from the Public Use Tax Files.[28] These data are a large representative sample of US income tax returns. Public use microdata have been available since 1960, but, in the analyses, we focus on 2005–2008.[29]

Individual identifiers, like name and address, are removed, and some variables like alimony paid or received are rounded or "blurred" to prevent the identification of individual taxpayers. In addition, the state of residence is removed for records with $200,000+ AGI. There are about 140,000 tax returns for each year. These records are a stratified sample of all returns processed during that year. For example, the 139,651 records in the 2008 Public Use data were drawn from the universe of 142+ million returns processed during 2009. The sampling rate varies substantially across strata but, overall, represents about 1 in every 1000 tax returns.[30]

The microdata provide some, but not all of the detailed information from the individual returns. Most relevant for our research, the microdata include the total dollar amount of "Residential Energy Credits" as reported on the main 1040 form, but not separate dollar amounts for the REEPC and the NEPC. The microdata do not include information on the AMVC or the PEDVC. Both vehicle credits are reported on a single line in the 1040 form "other credits," along with several other credits, and only the total amount for this category is included in the microdata.

Despite these limitations, the microdata offer a couple of important advantages relative to the two other data sources. First, the microdata provide the exact AGI for each return, allowing us to more accurately describe the distribution of income across credit recipients. We have constructed concentration curves using the microdata, and they are extremely similar to the figures reported in the paper, providing reassurance that our estimates are not unduly influenced by the coarseness of some of the income categories. Probably more important, the microdata

Table A1
Tax Expenditures by Category, 2005–2012

Category	Total Expenditure, in Millions (1)	Percentage of Total Credit (2)	Number Claiming Credit, in Thousands (3)	Average Credit Claimed ($) (4)
A. Nonbusiness Energy Property Credit (NEPC)				
Energy-efficient windows	4,004	29.3	9,636	415
Qualified furnaces and boilers	2,440	17.8	5,937	411
Heat pumps, ACs, water heaters	2,375	17.4	4,635	512
Ceiling and wall insulation	2,020	14.8	8,433	239
Energy-efficient doors	1,336	9.8	7,868	170
Qualified reflective metal roofs	1,120	8.2	1,578	710
Qualified circulation fans	393	2.9	1,162	339
B. Residential Energy Efficiency Property Credit (REEPC)				
Photovoltaic systems	1,848	53.4	347	5,323
Geothermal heat pumps	1,200	34.7	317	3,784
Solar water heating systems	350	10.1	303	1,155
Wind turbines	52	1.5	48	1,073
Fuel cell systems	12	0.3	31	3,78
C. Alternative Motor Vehicle Credit (AMVC)				
–	549	–	372	1,476
D. Qualified Plug-In Electric Drive Motor Vehicle Credit (PEDVC)				
–	346	–	60	5,755

Sources: This table was constructed by the authors using US Department of the Treasury, Internal Revenue Service, "Statistics of Income Bulletin," 2005–2012 and US Department of the Treasury, Internal Revenue Service, "Individual Income Tax Returns Line Item Estimates," 2005–2012.
Note: See appendix for details.

can allow researchers to examine correlations that cannot be measured in the aggregate statistics. In particular, our empirical test of nonrefundability in Section IV uses the public use microdata to compare credit take-up against tax liability. This type of analysis would not be possible with the aggregate IRS statistics.

Additional Description of Tables and Figures

Figures 1 and A1 were constructed using data from the U.S. Department of Energy, "Energy Star Unit Shipment and Market Penetration Report." Figure 2 was constructed using data from the Solar Energy Industries Association, "Solar Market Insight Report." Figures 3 and 4 were constructed using data from the U.S. Department of Energy, Alternative Fuels Data Center, "U.S. Hybrid Electric Vehicles Sales By Model" and "U.S. Plug-in Electric Vehicles Sales By Model."

Table 1 reports annual expenditures on US clean energy tax credits between 2005 and 2012. For each year, we report total expenditures (in millions) for each of the different clean energy tax credits. The line-item estimates were used to construct expenditure levels for the NEPC and REEPC, which otherwise are not reported separately in the IRS's "Individual Income Tax Returns."

Table 2 describes the distributional effects of selected tax credits. Columns (1) to (6) report the percentage of total credit dollars received by tax filers in each of six categories of AGI. That is, for each income category, we calculate the total amount of credit received by filers in that category between 2005 and 2012 and divide by the total credit received by all filers in all income categories. The last column reports the concentration index for each credit. We calculate the concentration index much like we calculate percentages received by income category, pooling credit receipts and AGI across all years for which each credit was available. The IRS's "Individual Income Tax Returns" report the NEPC and the REEPC together as "Residential Energy Credits," so we cannot examine the distributional effects of these two credits separately.

Table A1 reports tax expenditures and other statistics by category. For the NEPC and REEPC, this includes the different categories of qualified investments, which we characterized as accurately as we could based on the longer descriptions in the tax code. No such categories are available for the AMVC and REEPC, but for completeness we include these credits as well and report the number of filers claiming the credit and average credit claimed.

For each credit, column (1) reports total tax expenditures between 2005 and 2012 by category. Column (2) reports the percentage of total amount of each credit that was claimed for each category. Column (3) reports the total number of tax returns that had eligible expenditures in a given category during the period 2005 to 2012. Taxpayers can claim expenses in multiple categories, so these are not mutually exclusive. Finally, column (4) is the average credit amount claimed in each category, which we calculate by dividing column (1) by column (3). Notably, the average credit claimed for fuel cell systems is smaller than the other categories because there is a per-kilowatt cap that only applies to this category.

The line item data show total reported expenditures by category, without regard to whether claimants were above the maximum credit

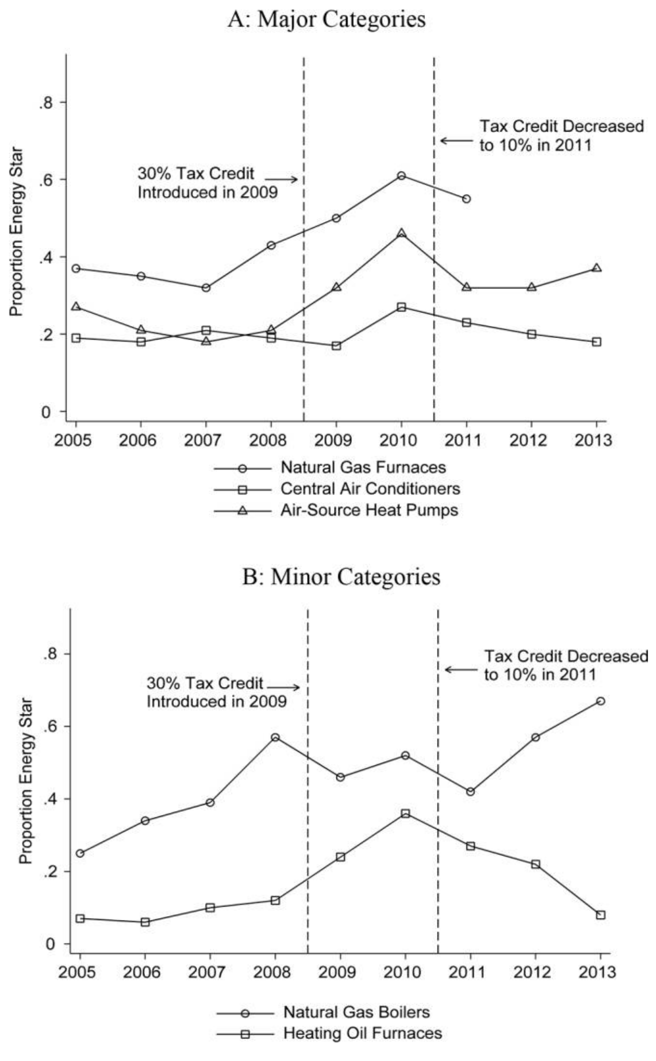


Fig. A1. Residential Energy-Efficiency Investments, Alternative Specification

amount and, thus, ineligible to receive the credit on the entire dollar amount. For example, in 2006, the NEPC was a 10% credit for most types of expenditures, with a maximum total credit of $500, so taxpayers received the credit only for the first $5000 of expenditures. Consequently, total reported expenditures in the line item data exceeds actual tax expenditures for each credit, which are reported in the IRS's "Individual Income Tax Returns" reports. In practice, the former exceeds the latter by less than 20% on average. In calculating the dollar values for table 1, we scaled down each category proportionally. This scaling affects the estimates of total expenditure by category and average credit claimed but not the *percentage* of expenditure by category or the number claiming credit.

Another complication in calculating the exact expenditure amounts by category is that with the REEPC, taxpayers with zero tax liability may carry any unused portion of the tax over to future tax years. With the aggregate data we are not able to track these carryovers so we assume that any credits that are carried over are divided across the expenditure categories in the same proportion as new expenditures in that tax year.

Figures A2, A3, and A4 plot year-by-year versions of figure 5. Plots are not presented for the AMVC for 2006 as summary statistics by AGI category were not made available by the IRS for that year, or for the PEDVC in 2006 to 2008 as the credit was not available in those years.

Figures A5 and A6 plot the share of returns claiming each credit and the average credit amount claimed by AGI bin. We calculate these statistics only over the years for which each credit is available as indicated in the panel headings. Oddly, the IRS's SOI publications for 2006 do not provide the number of returns claiming the AMVC nor the total amount of the AMVC claimed by income category. Thus, for tax year 2006 data, we use the AMVC totals from the IRS SOI complete report table 1.3, "All Returns: Sources of Income, Adjustments, Deductions, Credits, and Tax Items" in table 2. Because AMVC statistics were not published in 2006, we report statistics for the AMVC for 2007 to 2013. The PEDVC started in 2009, so we report statistics for 2009 to 2012. For average credit amount claimed, the 95% confidence intervals tend to be quite wide for the AMVC and PEDVC, particularly for the lowest-income quintiles.

Figures 5, A2, A3, A4, A5, and A6 plot 95% confidence intervals calculated by the authors using the coefficients of variation reported in IRS "Individual Income Tax Returns." In particular, for each estimate, the IRS reports the ratio of the standard error of the estimate to the estimate itself, and we use this to calculate the standard error for categories.

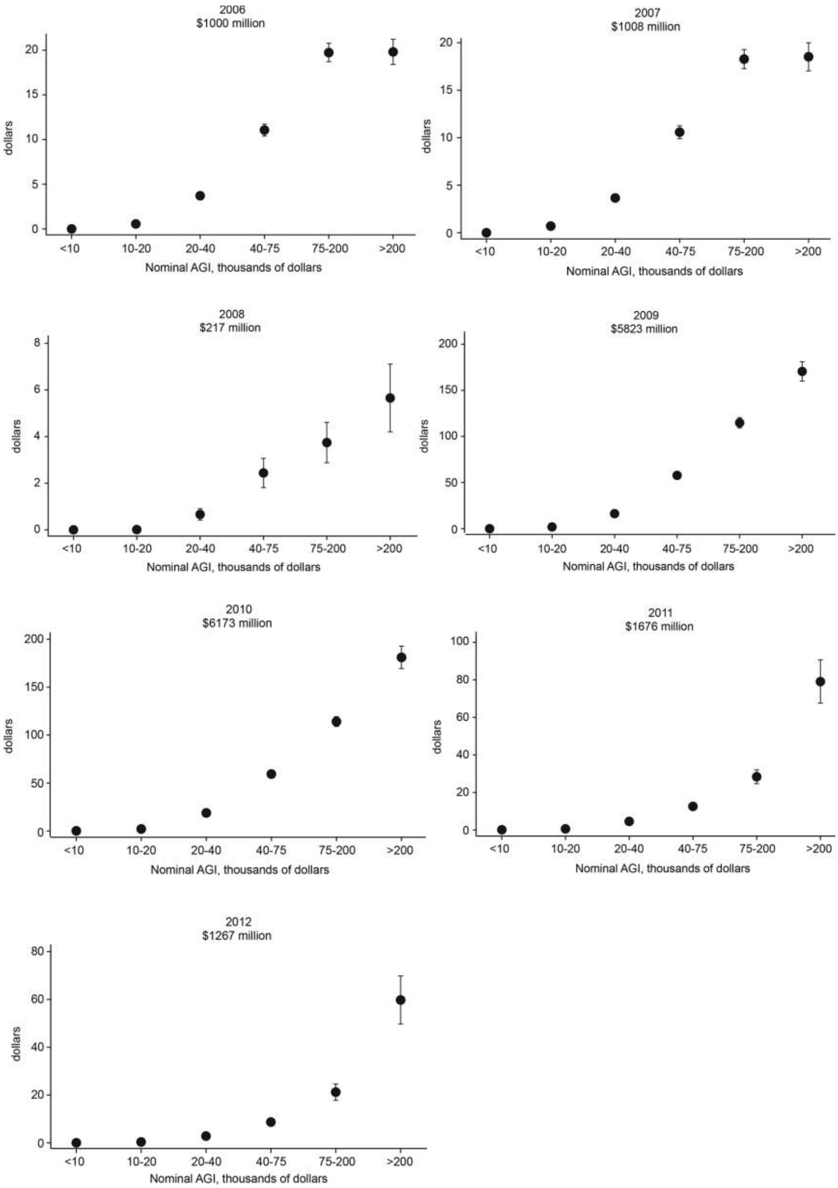


Fig. A2. Average Credit Per Return for Residential Energy Credits

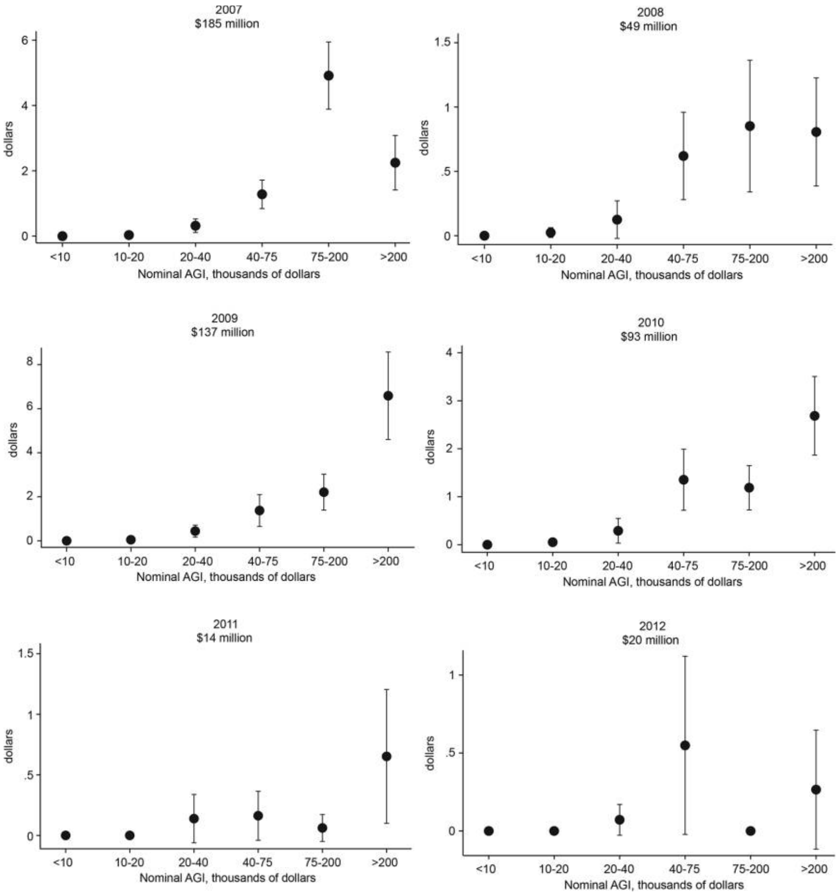


Fig. A3. Average Credit Per Return for Alternative Motor Vehicle Credit

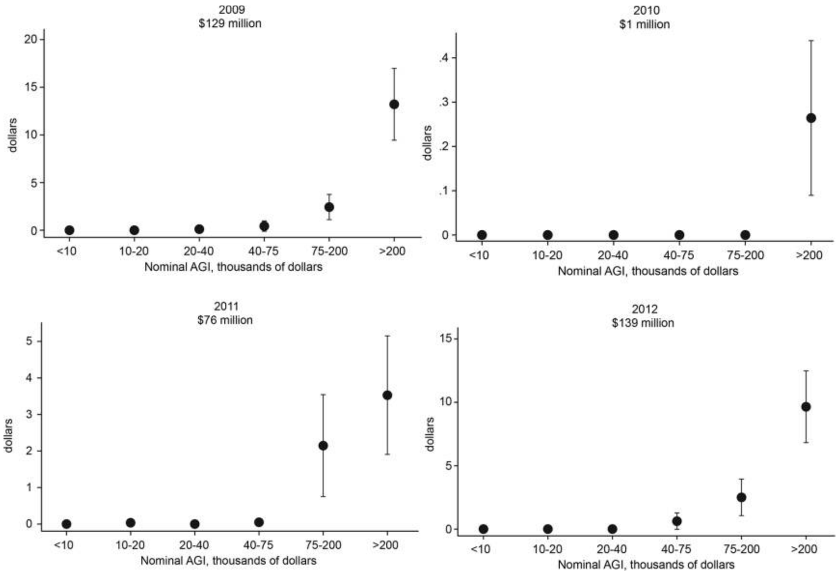


Fig. A4. Average Credit Per Return for Plug-In Electric Drive Vehicle Credit

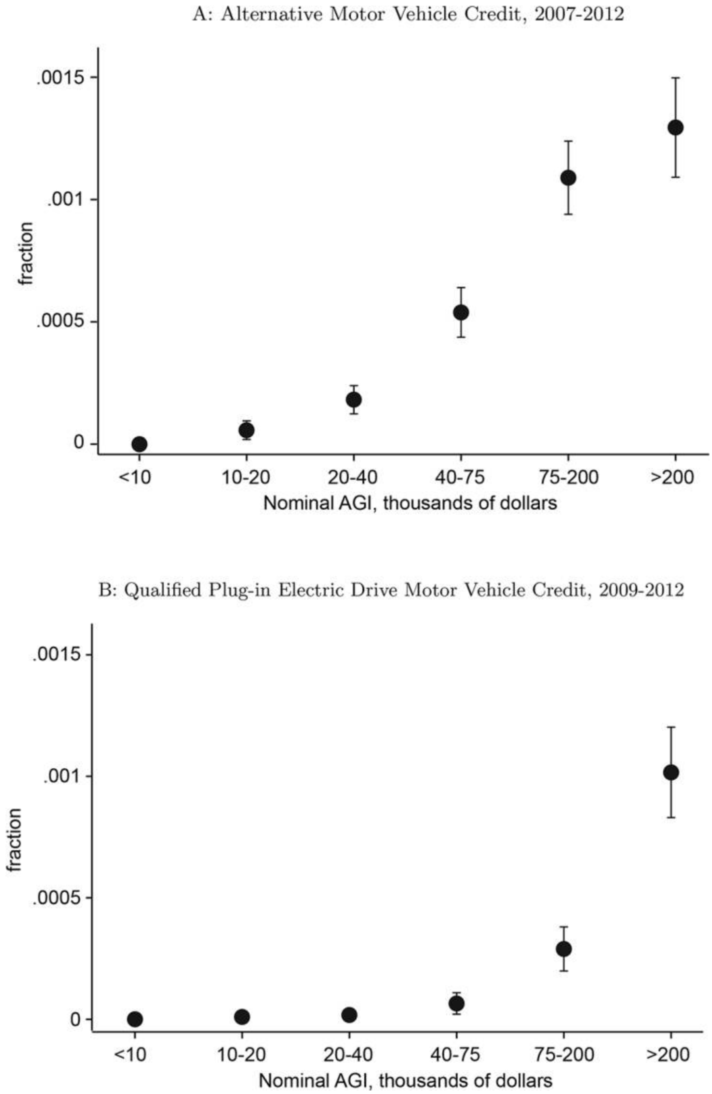
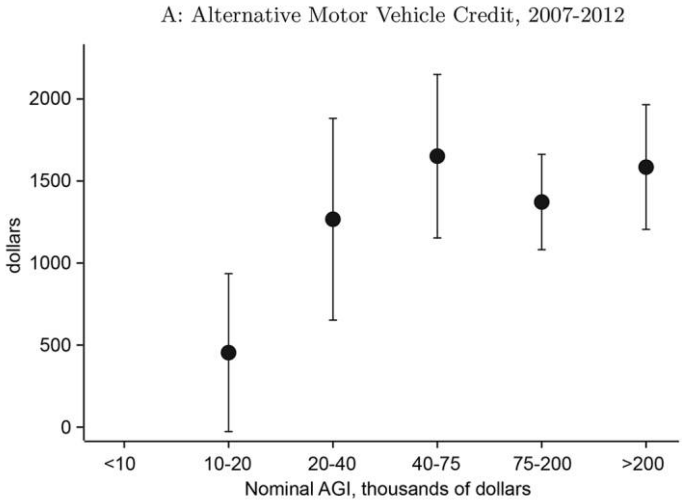


Fig. A5. Share Claiming Credit by Adjusted Gross Income



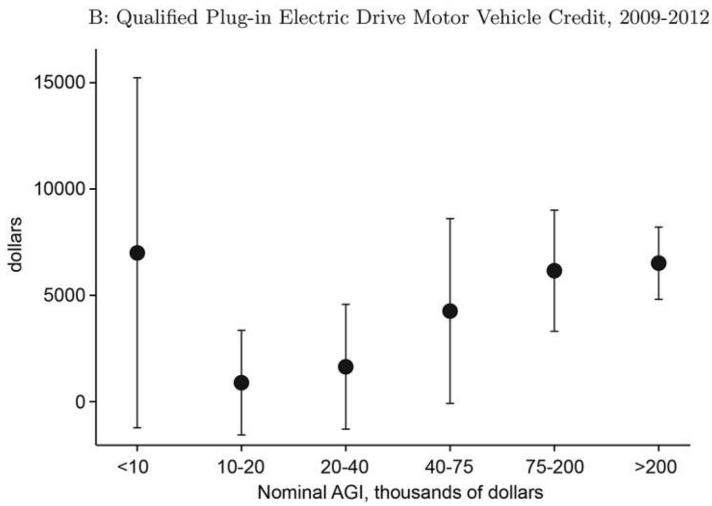


Fig. A6. Average Credit Amount Claimed by Adjusted Gross Income

Endnotes

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1. See Edenhofer et al. (2014, 42–45).

2. For recent surveys on subsidies for renewable and energy efficiency, see Borenstein (2012) and Allcott and Greenstone (2012), respectively.

3. In our analysis and in comparisons to previous estimates in the literature, we restrict attention to the direct impact of the tax credit, and we ignore the source of the funds. In practice, the distributional impact of a subsidy depends on the source of the funds, just as the distributional impact of a tax depends on what is done with the revenue that is generated. With first-best policies, this "revenue recycling" has been shown to be important for distributional impacts (for example, Hassett, Mathur, and Metcalf 2009; Williams et al. 2015). For example, Bento et al. (2009) show that if revenues are returned lump sum, then a gasoline tax can make low-income households better off, on average, even before incorporating externalities. Nonetheless, without knowing the source of the marginal funds needed to support these subsidies, estimating the impact inclusive of funding source would be highly speculative.

4. A separate, and important, issue that we don't address here is the distributional consequences of reducing local pollution and climate change, which are argued to be the goals of these policies. For a recent survey on that topic, see Bento (2013).

5. Unlike the Residential Energy Efficiency Property Credit, discussed next, there appears to be no parallel program for landlords. We could not locate a policy justification for this differential treatment. Still, it is likely that landlord uptake would be very low for the NEPC as the expenditures covered are for insulation and other upgrades that are difficult for a renter to verify and, therefore, unlikely to be capitalized into rents.

6. The American Recovery and Reinvestment Act financed a number of federal clean energy policies in addition to income tax credits. For example, the well-known "Cash for Clunkers" program subsidized hundreds of thousands of new vehicle purchases during the summer of 2009 (Mian and Sufi 2012), and the less-known but also generous "Cash for Appliances" program allocated $300+ million to utility-administered appliance replacement programs between 2009 and 2011 (Houde and Aldy 2014).

7. In an attempt to partially address this concern, we also examined the *proportion* of shipments by year which meet Energy Star guidelines for energy efficiency. See figure A1, which suggests some evidence of an increase in 2009 and 2010, but the increase is modest and only for certain categories.

8. We exclude from the analysis two closely related, but much smaller vehicle-related credits. First, the Qualified Plug-In Electric and Electric Vehicle Credit (PEVC), which from 2009–2012 provided credits similar to the PEDVC for certain low-speed "neighborhood electric vehicles" or, somewhat surprisingly, golf carts. The PEVC ended December 31, 2012. Second, the Alternative Fuel Vehicle Refueling Property Credit (AFVRPC) provides a 30% credit up to $1,000 for equipment used for refueling natural gas, hydrogen, or other alternative fuel vehicles. Charging stations for electric vehicles are also eligible. The AFVRPC has been around in different forms since 1992 and expired at the end of 2014 but may be extended retroactively (Sherlock 2015). Both of these credits are modest compared to the other credits we consider. For example, in 2012, total credits for the PEVC and AFVRPC were $5 million and $8 million, respectively, compared to $139 million for the PEDVC.

9. In constructing the figure, sales during 2009 and the first 11 months of 2010 were assumed to be zero. During these months, the only electric vehicle that was for sale in the United States was the Tesla Roadster, which sold a total of 1,650 total units between March 2008 and April 2011 when production ended. See, for example, CNN Money, "Tesla Roadster Reaches the End of the Line," Peter Valdes-Dapena, June 22, 2011.

10. See, for example, http://www.irs.gov/pub/irs-pdf/i5695.pdf.

11. Borenstein (2015) reports that the share of systems installed under the California Solar Initiative—which covered most California systems and nearly half of all US installations in 2007 to 2011, though a smaller share in later years—was 6%, 12%, 13%, 31%, 48%, 69%, and 70% in 2007 through 2013, respectively. Importantly for our analysis, Borenstein (2015) finds a slight *positive* correlation between income level and use of TPO arrangements in residential solar, suggesting that omitting TPO systems will slightly overstate the share of systems installed by lower-income households.

12. The $129 million in 2009 is puzzling because no mass-market electric or plug-in hybrid vehicles were available for sale in the United States in that year. Treasury has investigated this and concluded that thousands of taxpayers (including several IRS employees) erroneously claimed the PEDVC, as well as the AMVC, in 2009, for example by claiming the PEDVC for hybrids. In later tax years, the IRS made changes to drastically reduce the number of credits claimed erroneously. See US Treasury Inspector General for Tax Administration, "Individuals Received Millions of Dollars in Erroneous Plug-In Electric and Alternative Motor Vehicle Credits," January 2011, 2011-41-011.

13. According to Edmunds data, the percentage of US car sales that were leased fluctuated between 16% and 22% between 2006 and 2012. See Kessler, Aaron M., "Auto Leasing Gains Popularity Among American Consumers," *New York Times*, January 8, 2015.

14. For the vehicle tax credits, homeownership is not an explicit requirement, but renters are much less likely to live in a dwelling with an accessible electric outlet for an electric vehicle and to make the dwelling-specific investment of installing a high-voltage charging station.

15. Concentration curves and indexes are analogous to Lorenz curves and Gini coefficients but with the horizontal axis always ordering observations by income regardless of what is being measured on the vertical axis. See Maguire and Sheriff (2011) for more explanation of the relationship. Unlike a Gini coefficient, a concentration index can be negative, which can occur if the concentration curve lies above the 45-degree line. We calculate concentration curves and indexes for income as well. The concentration curve for income is also a Lorenz curve as the ordering on the horizontal axis corresponds to the attribute for which the density is measures on the vertical axis.

16. Yet another potential explanation comes from Tal and Nicholas (2013), which uses survey data from California to examine the socioeconomic characteristics of households who purchase electric vehicles in California. The vast majority of electric vehicle buyers in California live in the San Francisco Bay area or in Los Angeles, where electric vehicle owners are allowed to drive in high-occupancy vehicle lanes. The value of time is highly correlated with income, so differential willingness-to-pay for reduced travel times could provide a complementary explanation for why so many high-income ratepayers use the PEDVC.

17. Their analysis is based on the Consumer Expenditure Survey (CEX) and incorporates implied changes in expenditures on energy, food, transportation, and other consumer goods and services. We combined their estimates of the share of income by income decile that would go to a carbon tax with average income by decile from the CEX to calculate the implied change in expenditure in dollars by decile. The CEX publishes average income by quintiles, and we interpolated incomes by decile for this calculation.

18. Here and throughout the analysis, we focus on the distributional impact measured as dollars flowing to households in different income brackets rather than as a *proportion* of income. As was clear with our concentration curves in Section III, income itself is highly concentrated, so even modest dollar value impacts on low-income households can represent a high proportion of income. This can be clearly seen in the Hassett, Mathur, and Metcalf (2009) results. Expenditures for a carbon tax would be approximately 3 or 4% of income in the bottom income quintile compared to only about 1% in the top income quintile.

19. The Hassett, Mathur, and Metcalf (2009) estimates are for a $15/ton of CO2e tax, but the results are invariant to the size of the tax given their maintained assumption of no elasticity of consumer demand.

20. On this point, Batchelder, Goldberg, and Orszag (2006) argue that, "It is extremely unlikely that externalities and elasticities change in an abrupt and discontinuous fashion exactly at the point of zero income tax liability or the marginal tax rate thresholds. Yet such discontinuities are inherent in the application of all basic forms for tax incentives other than refundable credits" (28).

21. Slightly under 1% of the population is incarcerated in prisons and jails, the vast majority of whom don't file and are part of the 8.3% total.

22. See IRS Publication 1304, table 1.3, page 36.

23. For energy-efficiency spending, see US Energy Information Administration, Form EIA-861, *Annual Electric Power Industry Report,* table 10.5, "Demand-Side Management Program Direct and Indirect Costs," accessed online February 2015 at http://www.eia.gov/electricity/annual/html/epa_10_05.html. Many utility-sponsored programs are similar to tax credits in that they provide subsidies for consumers who purchase energy-efficient products and technologies.

24. The SOI data are made available online in a variety of different formats. See http://www.irs.gov/uac/Tax-Stats-2 for general information and http://www.irs.gov/uac/SOI-Tax-Stats-Individual-Income-Tax-Return-Form-1040-Statistics for information specifically about the individual income tax.

25. See, for example, US Department of the Treasury, Internal Revenue Service, "Individual Tax Returns 2012," Publication 1304, Washington, DC, accessed online at http://www.irs.gov/pub/irs-soi/12inalcr.pdf. We used, in particular in table 3.3, " All Returns: Tax Liability, Tax Credits, and Tax Payments, by Size of Adjusted Gross Income."

26. See US Department of the Treasury, Internal Revenue Service, "Statistics of Income Bulletin," Fall 2012 (21) and Fall 2013 (21).

27. See, for example, US Department of the Treasury, IRS, "Individual Income Tax Returns Line Item Estimates, 2012", Publication 4801, Washington, DC, accessed online at http://www.irs.gov/uac/SOI-Tax-Stats-Individual-Income-Tax-Returns,-Line-Item-Estimates.

28. See, for example, US Department of the Treasury, IRS, "General Description Booklet for the 2008 Public Use Tax File," Washington, DC, November 2012. We accessed these data at the National Bureau of Economic Research and are thankful to Daniel Feenberg for his helpful guidance with these data.

29. There is a considerable delay before each dataset is released, and 2008 is currently the latest data available through the National Bureau of Economic Research (http://users.nber.org/taxsim/gdb/).

30. The full population of tax returns is not publicly available, but, under some circumstances, researchers have contracted with the IRS to access their entire "Compliance Data Warehouse." These data have their own challenges but are indispensable for studies aimed at, for example, comparisons across cities (Chetty et al. 2014). These data also include "information returns," that is, W-2 forms for individuals who don't file a return so are valuable for studying the EITC and other interventions aimed at taxpayers close to the margin between filing and not filing a return (Chetty, Friedman, and Saez 2013).

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