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THE DISTRIBUTIONAL EFFECTS OF THE FEDERAL ENERGY TAX ACT*

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ABSTRACT

This paper examines the distributional consequences of the tax credits implemented by the Federal Energy Tax Act of 1978. The distributional effects are of interest both for their own sake, and because they have implications for the cost-effectiveness of the credits. If rates of return to conservation are higher for individuals who consume less housing, as earlier evidence suggests, then conservation incentive programs can achieve larger benefits for a given cost if they are distributionally more progressive.

We explain the amount of credit claimed by taxpayers using a tobit model, in which credits claimed are a function of variables that affect the net benefit of weatherization. We estimate the model using data from the 1979 Taxpayer Compliance Measurement Program conducted by the Internal Revenue Service. We find that credits claimed are significantly higher where winters are more severe, where energy prices are high or rising rapidly, and where individuals have higher incomes and spend more on housing.

Progressivity indices based on Lorenz-Gini measures of inequality reveal that the tax credits were somewhat regressive, even holding climate and energy prices constant. This suggests that the credits may have been ineffectively targeted. In addition, we find no evidence that the credits had a measurable incentive effect, suggesting that they have largely provided windfall gains to households who would have insulated anyway.

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1. INTRODUCTION

Spurred initially by rising energy prices during the 1970's, utilities and government agencies at federal, state, and local levels have adopted policies that encourage or mandate energy conservation by households. Policies involving the least amount of market intervention have been informational or educational programs, such as home energy audits and appliance energy-efficiency labeling. At the other end of the spectrum have been regulatory measures, including insulation standards for buildings, fuel efficiency standards for automobiles, and more recently, national energy efficiency standards for appliances. In between have been incentive programs such as tax credits and low-interest loans for capital-intensive conservation measures.

Such policies can be evaluated according to at least three criteria. First, does the policy satisfy principles of economic efficiency, by achieving greater net social benefits than alternative uses of the resources invested? Second, whether or not the objectives satisfy efficiency criteria, is the policy cost-effective in achieving its stated objectives at the least possible social cost? Third, what are the distributional consequences of the program—who enjoys the benefits, and who bears the costs?

In an earlier study (Dubin and Henson, 1988), we found that rates of return to insulation upgrades were higher in smaller, less insulated houses in the Pacific Northwest. There is strong reason to believe that this conclusion is not specific to the Northwest, but reflects generally diminishing marginal productivity of insulation in the production of space-conditioning comfort. This suggests that cost effectiveness and distributional considerations are related: an incentive program that is distributionally more progressive—targeted at lower-income households who consume less housing—may achieve larger net returns. In addition, both the cost effectiveness and distributional consequences of a program depend on the amount of additional conservation that it induces. A policy that is regressive may be ineffectively targeted; if the policy also has little incentive effect, then it may largely represent a "windfall" gain to higher-income individuals who would have insulated anyway.

In this paper we examine what has probably been the most important energy conservation incentive program at the federal level: the tax credits implemented by the Energy Tax Act of 1978. We are interested in the distributional consequences of the Act both for their own sake, and for their implications regarding cost effectiveness. Though these credits expired in 1985, many state tax credits and other federal and state incentive programs remain in effect. Inferences drawn from our study of the 1978 federal credits are likely to have relevance for these programs.

The Energy Tax Act has previously been studied by Hirst, Goeltz, and Manning (1983). Using state-level Statistics of Income (SOI) data from the Internal Revenue Service for the tax years 1978-1980, they found that conservation expenditures increase with household income, fuel expenditure, and winter severity. In this study we focus on the 1979 tax year, using data from the IRS Taxpayer Compliance Measurement Program (TCMP) aggregated by IRS district and audit class. The TCMP data provide greater cross-sectional variation than do the SOI data, permitting us to analyze the effects of a broader set of causal factors.

Our results are consistent with those of Hirst, Goeltz, and Manning. In addition, we find larger energy tax credits taken where energy prices are high or rising rapidly, and where housing expenditures are higher. Using progressivity indices based on Lorenz-Gini measures of inequality, we find that the distribution of observed credits claimed is somewhat regressive. Modified indices, which control for non-income factors, give virtually identical results. Thus the primary beneficiaries of the tax credits appear to have been those households for whom the rates of return to weatherization were lowest.

In the following section we develop a model of residential energy conservation behavior that predicts which households will be more likely to weatherize, and to take the energy tax credit. The model explains why many consumers choose not to weatherize at all. Section 3 describes the Energy Tax Act of 1978 and the data used to estimate the model. We present results in Section 4 and discuss implications in Section 5. Section 6 summarizes and concludes.

2. A THEORETICAL MODEL OF CONSERVATION BEHAVIOR

This section develops a model in which consumers demand for energy is determined jointly with the choice of a level of improvement in the thermal integrity of the dwelling. Using the household production framework, we assume that the household derives utility from consumption of a vector of purchased goods Z and a level of space conditioning comfort t, according to the utility function $U(t, Z)$. We interpret t as "indoor degree-days" of comfort consumed relative to the indoor temperature that would exist in the absence of any space conditioning. Comfort is produced from purchased energy inputs, using a technology that depends on the climate and on the thermal integrity of the house. Higher comfort levels can be achieved through increased use of energy, holding thermal integrity constant, or through improvements in the energy efficiency of the dwelling. Because both energy and conservation measures are costly, the consumer faces a trade-off between comfort and other goods.

Let $Q(t, w; t^0)$ define the energy required to maintain comfort level t when the outdoor temperature is t^0 and the consumer has undertaken a thermal improvement in the amount w. We denote $w = 0$ as the initial level of energy efficiency, which like t^0 is assumed to be exogenous. With positive but diminishing marginal products of both energy and conservation inputs, we have $Q_t > 0$, $Q_{tt} > 0$, $Q_w < 0$, $Q_{ww} > 0$, and $Q_{tw} < 0$, where subscripts denote partial derivatives.

Energy can be purchased at a price of p per BTU, and thermal improvement can be purchased at a cost of $m(w)$, where $m(0) = 0$ and $m'(w) > 0$. Let t_f and t_s be the federal and state marginal tax rates, respectively. The federal government allows a proportion r_f of energy conservation expenses to be credited against the individual's tax bill. The state allows the taxpayer to take a credit at rate r_s, and/or to deduct from income a fraction d_s of the improvement. Assuming that state income taxes are deductible on the federal return, but that federal taxes are not deductible on the state return, the effect of incentives is to make the after-tax cost of conservation equal to

$$c(w) = m(w)[1 - r_f - (1 - t_f)(r_s + t_s d_s)]. \tag{1}$$

With interest rate i, the annualized cost of conservation is $ic(w)$.

Let I be after-tax income in the absence of conservation incentives. The consumer's decision problem is to allocate I optimally among energy inputs, conservation measures, and other goods to achieve maximum utility. That is, to

$$\underset{t,Z,w}{\text{maximize}} \; U(t, Z)$$

$$\text{subject to: } Z + pQ(t,w;t^0) + ic(w) \le I \quad \text{and} \quad (t, Z, w) \ge 0. \tag{2}$$

The associated Lagrangian is

$$L = U(t, Z) + \lambda[I - Z - pQ(t,w;t^0) - ic(w)] \tag{3}$$

where λ is the Lagrange multiplier. The solution to this problem is characterized by the Kuhn-Tucker conditions:

$$L_t = U_t - \lambda pQ_t(t,w;t^0) \le 0 \tag{4a}$$

$$tL_t = t[U_t - \lambda pQ_t(t,w;t^0)] = 0 \tag{4b}$$

$$t \ge 0 \tag{4c}$$

$$L_Z = U_Z - \lambda \le 0 \tag{5a}$$

$$ZL_Z = Z(U_Z - \lambda) = 0 \tag{5b}$$

$$Z \ge 0 \tag{5c}$$

$$L_w = -\lambda[pQ_w(t,w;t^0) + ic'(w)] \le 0 \tag{6a}$$

$$wL_w = -w\lambda[pQ_w(t,w;t^0) + ic'(w)] = 0 \tag{6b}$$

$$w \geq 0 \tag{6c}$$

$$L_\lambda = I - Z - pQ(t,w;t^0) - ic(w) \geq 0 \tag{7a}$$

$$\lambda L_\lambda = \lambda[I - Z - pQ(t,w;t^0) - ic(w)] = 0 \tag{7b}$$

$$\lambda \geq 0. \tag{7c}$$

Solving (4a) - (7c) yields optimal values (t^*, Z^*, w^*) as functions of I, p, and t^0.

If both (4c) and (5c) hold as strict inequalities, then (4a) and (5a) must hold as equalities. In this case we get

$$U_t/U_Z = pQ_t(t^*,w^*;t^0). \tag{8}$$

Thus, if nonzero quantities of energy and goods Z are purchased, then the marginal rate of substitution between them depends on the "marginal price of comfort," $pQ_t(t^*,w^*;t^0)$, which itself is a function of the thermostat setting and the thermal integrity of the structure. From (6a) - (6c) it follows that if $w^* > 0$, then

$$c'(w^*) = -pQ_w(t^*,w^*;t^0)/i. \tag{9}$$

A consumer undertaking an improvement in thermal integrity does so up to the point where the marginal cost of improvement equals the present value of the marginal reduction in energy costs, which again depends on t^* and w^*.

For many consumers (6a) will hold as a strict inequality, so that the optimal level of conservation activity is zero. Many conservation measures tend to be "lumpy," requiring relatively large outlays for materials and labor before any noticeable energy savings are obtained. This is especially true in areas with mild climates or low energy prices, or for insulation retrofits and solar space and water heating systems. Consumers upgrade their residences if and only if the marginal benefit, $-pQ_w/i$, exceeds the threshold value $c'(0)$. That is:

$$w^* > 0 \text{ iff } -pQ_w(t^*,0;t^0)/i > c'(0). \tag{10}$$

The amount of credit is then equal to[1]

$$Y = \begin{cases} r_f m(w^*) & \text{if } w^* > 0 \\ 0 & \text{if } w^* = 0. \end{cases} \tag{11}$$

Changes in I, p, and the components of $c(w)$ have two effects: they change the amount of conservation among those already conserving, and they change the number of individuals conserving.

Income has three separate effects on Y. First, since comfort is a normal good, higher income should be associated with a higher level of t. Therefore, as $Q_{wt} < 0$, a higher level of t will increase the marginal benefit $(-pQ_w/i)$ from improving any initial level of thermal integrity. However, higher-income individuals are likely to have higher initial levels of insulation, which tends to reduce the amount of credit taken. The third effect is an institutional one: the credit can be claimed only by taxpayers who use the 1040 long form—not by 1040A short form filers, who tend to have lower income on average. Overall, credit claims should increase with income, though this is not unambiguous.

Like income, increases in the size of the dwelling have an ambiguous effect on credit claims. In larger houses the price of comfort is higher, increasing the marginal benefit of weatherizing. However, the marginal productivity of a given amount of insulation is smaller, reducing the net benefit of weatherizing. Dubin and Henson (1988) show that the latter effect may be relatively large.

Both higher energy prices and more severe climates increase the marginal price of comfort pQ_t, thus increasing the marginal benefit of weatherizing for any given thermostat setting. However, higher comfort prices also reduce the optimal indoor temperature, reducing marginal benefits. Since the latter effect is probably relatively small, tax credit claims should be higher in areas with colder climates and higher energy prices.[2] In addition, households in areas where energy prices have been *rising* more rapidly are likely to be further from their equilibrium levels of insulation, and hence likely to take larger credits.

Federal claims should also be higher where state tax incentives are larger. Since state taxes are deductible on the federal return, a state credit will reduce marginal retrofit costs $(1 - t_f)$ times as much as a federal credit of equal amount, and therefore should have a proportional effect on conservation activity. A state deduction of the same proportion would reduce retrofit costs t_s times as much as a state credit. If tax credits in general have a significant incentive effect, then federal claims should be higher where state credit rates are higher.

Thus the optimal amount of credit taken is a function of income, the level and rate of change of energy prices, climate, the size and other characteristics of the housing unit, the availability of state incentives, and other factors whose effects we assume to be randomly and independently distributed. In the following section we describe the sources and measurement of these explanatory variables.

3. THE DATA

The purpose of the Energy Tax Act of 1978 was to reduce energy consumption and encourage the development and use of alternate energy sources. The Energy Tax Act allowed a tax credit to be taken based on qualified energy conservation expenditures and renewable energy expenditures. The credit was available from April 20, 1977 until December 31, 1985 but could not be claimed for tax years prior to January 1, 1978. We focus on 1979 tax returns, which report credits taken from January 1, 1979 until December 31, 1979.[3]

The primary data for this study are based on IRS audits of approximately 50,000 taxpayers under the 1979 Taxpayer Compliance Measurement Program. For each of these taxpayers, the

TCMP audits record every item on the standard tax form as self-reported by the taxpayer and as assessed by the TCMP auditor.[4] Since the Internal Revenue Code prohibits the IRS from releasing individual return data in a way that might allow someone to identify taxpayers, or that might allow researchers to identify the criteria by which returns are selected for audit, the data are aggregated in various ways. For example, the 1979 IRS data provide averages across occupations and IRS districts, as well as averages by district and return preparation code (no assistance, IRS assisted, CPA assisted, and so forth).

In our study we use only a small fraction of these data. We focus on a subset of variables that include the location by IRS district, audit class, adjusted gross income, real estate taxes, mortgage payments, and the residential energy credit. The data we use are aggregated across individuals by audit class and IRS district. Table 1 defines the twelve audit classes. With 58 IRS districts, we have a total of $12 \times 58 = 696$ potential observations. Eight of these contain no returns, leaving 688 valid observations. For each observation we are given the number of returns of each type and the dollar amounts for each line item.

[TABLE 1 about here]

Table 2 reports the distribution of expenditures for tax year 1979 by size of adjusted gross income. Of approximately 90 million returns filed, 4.9 million, or 5.4 percent, claimed a credit for residential energy expenditures. Of those 4.9 million returns, 4.8 million, or 98 percent, were for energy conservation and only 2 percent were for renewable energy expenditures. The majority of returns claimed the credit for energy conservation expenditures related to insulation and for storm windows and doors (82 percent of the dollar amount claimed).[5] Our analysis focuses on the columns in Table 2 labeled Total Residential Energy Credit, although it should be clear that these are predominately related to energy conservation expenditures for insulation and storm windows and doors.

[TABLE 2 about here]

We supplement the TCMP data with state-level energy prices from the *State Energy Price and Expenditure Report, 1970-1982* of the Energy Information Administration (1985). Our measure of the price of energy is the average price of all energy used by the residential sector, in dollars per million BTU. The unavailability of substate data forces us to attribute equal energy prices to all districts within each of the six states having more than one IRS district. These states are New York (with four districts), California, Illinois, Ohio, Pennsylvania, and Texas (each with two).

State population–weighted normal heating and cooling degree–days for the period 1951-1980 are taken from the National Oceanic and Atmospheric Administration (1985a, 1985b).[6] For substate IRS districts, normals are calculated using divisional data from NOAA (1981). Because heating and cooling degree-days are highly correlated at the IRS district level, we use only heating degree-days to proxy the effects of the temperature distribution.

Data on state tax incentives are from Appendix A of Rodberg and Schachter (1980). In 1979, twenty-two states provided income tax credits and/or deductions. Of these, fourteen states relied exclusively on credits (seven allowing claims both for renewable-energy equipment and for conservation measures, and seven allowing only renewables); five used only deductions (three for both renewables and conservation, and two for renewables only); and three states used some combination of credits and deductions.[7] Among states allowing credits, all but California allowed a percentage that was invariant to whether the federal credit was claimed. The California law allowed a maximum credit of 55 percent (the largest allowed by any state), which was reduced by the amount of any federal credit taken.

Table 3 lists the definitions of all variables used in the analysis. The dependent variable, AVCR, is the average dollar amount of credit claimed per return filed. The average mortgage interest and real estate tax deductions, AVMORT and AVRLTX, are included as proxies for housing expenditure. The CALIF dummy variable is included due to that state's substitutability of the federal credit for its own, which we expect to reduce the amount of federal claims. Dummy variables for each of the seven IRS regions are included to capture geographical effects not measured by variation in price, income, and climate.[8]

[TABLE 3 about here]

Table 4 presents variable means and standard deviations by region, weighted by the number of returns filed. For example, STATECR is the proportion of taxpayers facing a state tax credit, not the proportion of states in the region that offer a credit. The proportion of returns claiming the credit, PRCREDIT, ranges from over seven percent in the North Atlantic region, followed by the Mid-Atlantic and Midwest, to less than four percent in the West, Southwest, and Southeast. Though not used directly in our analysis, the conditional average credit (the credit claimed by taxpayers taking the credit), is given in Table 5. It is interesting that the West, with the smallest proportion of credits claimed, has the largest average credit claimed among those taking the credit. There appears to be no systematic relationship across IRS districts between the conditional average credit and the proportion of taxpayers claiming the credit.

[TABLES 4 and 5 about here]

The average credit per return filed, AVCR, is by definition the product of the conditional average credit and the proportion of taxpayers filing claims. It is generally higher in regions with colder climates, higher incomes, and high and rapidly rising energy prices—although the Southeast, with the smallest average credit, had the highest average energy prices in 1979. However, intraregional variability in energy prices was also large in that region. From Table 4 it is difficult to identify a relationship between AVCR and housing expenditure. The average credit appears to vary directly with the real estate deduction, though not with the mortgage interest deduction.

4. EMPIRICAL MODEL AND RESULTS

The foregoing discussion suggests that the average credit claimed by taxpayers in the *jth* district/audit class group follows a tobit specification (see Tobin (1958), Maddala (1983)):

$$Y_j = \begin{cases} X_j\beta + u_j & \text{if } Y_j > 0 \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

where X_j is the vector of the exogenous variables discussed above, u_j is an error term assumed to be normally distributed with mean zero and variance σ^2, and β is a vector of parameters to be estimated. Observations for which Y_j takes a value of zero occur for those groups in which $w^* = 0$ for all taxpayers. From Tables 4 and 5 we see that 529 of 688 observations have nonzero credit claims, leaving 159 observations, or 23 percent of the sample, censored at zero.

It is well-known that the expectation of the error term in equation (12) is nonzero and depends on X_j, so that ordinary least squares estimates of β are biased and inconsistent. This is true whether one uses all of the observations, or only the nonzero values of Y. We account for censoring by estimating the model by maximum likelihood, weighting each observation by the number of returns filed in the group to correct for heteroscedasticity caused by variation in group size.[9]

Results are presented in Table 6. For comparison, we also present weighted least squares (WLS) estimates, which fail to account for censoring. The results show that consumers claim significantly larger credits where energy prices are higher—and where, holding the level of prices constant, they have been rising more rapidly. Taxpayers in colder climates take larger credits, and Schedule C filers appear to take smaller ones. The regional dummy variable for the Southeast, which has the smallest average credit in the sample, is omitted. Residents of the Mid-Atlantic, Central, and Southwest regions take larger credits than those in the Southeast for reasons that cannot be explained by regional variation in prices, incomes, and other variables in the model.

[TABLE 6 about here]

Two results are particularly significant, in both a statistical and an economic sense. First, taxpayers who spend more on housing, measured by AVMORT and AVRLTX, take larger credits—though WLS underestimates the effect of AVMORT. Second, even after taking these effects into account, income is still an important variable. To account for a nonlinear relationship between income and conservation expenditures, we include squared and cubed income terms. All income terms are significant at the one percent level. The coefficients suggest that the amount of credit taken increases up to an income level of about $35,400—which is at the 97th percentile of households ranked by adjusted gross income. As income increases above this level, credit claims decline until income reaches the $92,000-$95,000 range, or the 99.7th percentile. We discuss the implications of this relationship further in the next section.

Tax credit claims increase less than proportionally with energy prices, income, heating degree-days, and housing expenditures near the sample means of these variables. Elasticities range from .08 for AVMORT to .80 for AVINC.[10] Following McDonald and Moffitt (1980), the total effect of a change in an explanatory variable can be decomposed into two parts: the effect on the amount of credit taken by those who take the credit, weighted by the the probability the credit is taken; and the effect on the probability of taking the credit, weighted by the expected value of the credit if taken. With 529 of 688 observations (or 77 percent of our sample) having nonzero values for AVCR, changes in the amount of credit taken for those taking the credit account for 55 percent of the total effect.

As noted previously, if energy tax credits in general stimulate additional conservation, then federal credit claims should be higher in states having more generous programs. The statistical insignificance of the coefficient on STATECR indicates that federal claims are unresponsive to the presence of state credits.[11] In addition, federal claims do not appear sensitive to the provision in the California law that reduced the state credit by the amount of federal credit taken. Thus, the data do not reveal a statistically significant incentive effect of energy tax credits.[12]

5. DISTRIBUTIONAL EFFECTS

If the energy tax credits had little incentive effect, then they were largely a windfall, redistributing wealth from taxpayers in general to those filing claims. This raises the question: what were the distributional effects? Our empirical results show a strong income effect on credits claimed. Were the credits distributionally progressive, regressive, or neutral? Furthermore, equity considerations aside, the distributional issue has important efficiency implications. If rates of return to conservation are higher for lower-income households, as our earlier work suggests, then the program's social rate of return should increase with the degree of progressivity.

To examine the progressivity of the energy tax credits, consider Figure 1. The curve labeled "I" is the Lorenz curve, which plots the cumulative percentile of income on the vertical axis, against the percentile of households ranked by income on the horizontal axis. The curve labeled "*C*" plots the cumulative percentile of energy credit taken along the vertical axis, against the same horizontal axis, and is the so-called "concentration curve" of the tax credit (see Kakwani, 1977). The figure indicates, for example, that the poorest 50% of households ranked by income received 20% of all income and claimed 8% of all energy credits taken. If the amount of credit claimed were exactly proportional to income, then the two curves in Figure 1 would coincide. The credit curve lies below the income curve at low income levels, and above the income curve at high incomes, because the shares of tax credit claimed by households at both ends of the income distribution are less than their shares of income. In particular, the poorest third of all households claimed only 1.5% of all credits.

[FIGURE 1 about here]

The degree of inequality in the distribution of income across households can be summarized by the Gini coefficient, which is the ratio of the area between the I curve and the 45-degree line, divided by the total area under the latter. The Gini coefficient ranges from zero, indicating perfect equality, to one, indicating perfect inequality. The Gini coefficient for income (G_I) in Figure 1 is .423. The corresponding Gini measure for the C curve measures the degree of inequality in the distribution of energy credit across households ranked by income; this concentration index (G_C) is .572.

The extent to which the concentration curve of the tax credit lies below the income Lorenz curve indicates the regressivity of the energy credit. We can construct an index of tax credit progressivity as $(AC/AI)-1$, where AC is the area under the C curve and AI is the area under the I curve. The index equals zero for a proportional credit. For a progressive (regressive) credit, the C curve lies above (below) the I curve, giving the index a positive (negative) value. If the two curves do not intersect, the index is equal to $(G_I - G_C)/(1-G_I)$. Following Kiefer (1984) we call this the KP index, due to its relationship to variant 1 of the yield-neutral coefficient of progression (YNCP1) of Khetan and Poddar (1976).[13]

Khetan and Poddar proposed a second variant (YNCP2), which is related to another progressivity index proposed by Suits (1977). This index is calculated from a single concentration curve that relates the cumulative percentile of credit taken on the vertical axis, against the cumulative percentile of income on the horizontal axis, as in Figure 2. The Suits version for a credit, which we call the S index, is defined as $(A/D)-1$, where A is the area under the concentration curve and D is the area under the 45-degree line. For a proportional credit the concentration curve will coincide with the diagonal, giving the index a value of zero. Like the KP index, this measure will be positive or negative depending on whether the credit is progressive or regressive. As pointed out by Suits and by Kiefer, this index has the advantage that the progressivity index for a system of tax (or credit) measures is a weighted average of their individual indices, using average tax (or credit) rates as weights.

[FIGURE 2 about here]

The KP and S indices for the observed credit taken are –.259 and –.122, respectively. These values suggest a somewhat regressive credit. In comparison, Suits estimated S indices for 1970 of +.17 for the individual income tax, –.15 for sales and excise taxes, –.13 for payroll taxes, and –.09 for personal property and motor vehicle taxes. The tax credit appears to be roughly as regressive as payroll or personal property taxes.

Gini-type inequality measures have been criticized for a wide variety of reasons. One limitation of the S index, pointed out by Suits and by Davies (1980), is that because it is an average over the entire income distribution, it cannot be used to unambiguously rank taxes whose concentration curves intersect. The Gini index of income inequality has been critiqued on welfare grounds by Atkinson (1970), Dasgupta, Sen, and Starrett (1973), Rothschild and Stiglitz (1973), Blackorby and Donaldson (1978), and Kiefer (1984). Still, such measures are widely used, and provide some means for informing policy decisions provided their limitations are recognized.

Paglin (1975) has criticized the Gini index on different grounds. By failing to adjust for the age profile of income, the Gini coefficient overstates the degree of lifetime inequality across households. Rather than using equal *annual* incomes as the standard of equality against which the actual income distribution should be measured, he argues that a more reasonable standard of equality would be equal *lifetime* incomes. In a suggestion modified by Formby and Seaks (1980), Paglin recommends calculating the Gini coefficient using as a reference line not the 45-degree line of perfect equality, but the concentration curve of average income by age group.

Our tax credit progressivity indices may suffer from a similar shortcoming. The relationship between energy tax credit claims and income may deviate from proportionality due to variation in energy prices, climate, and other factors. For example, if incomes tend to be higher in areas where the climate is more severe, or where energy prices have been high or rising rapidly (such as the Northeast), then the tax credit might be more regressive due to the added effects of these variables on credits claimed. How regressive is the energy tax credit for a given set of energy prices, temperature, and other variables? Holding constant non-income sources of variation in credits claimed, is the credit more, or less, regressive?

To answer these questions, we ask what the distribution of the tax credit would look like if all taxpayers were identical except for income-related sources of variation. We simulate this distribution by using the tobit model to generate predicted values of AVCR, setting all variables other than income, housing expenditure, and filing status equal to their weighted sample means. The extent to which this simulated distribution deviates from the distribution of income provides a measure of the extent to which the tax credit deviates from proportionality, holding non-income sources of variation constant. This allows us to compute an index based on the *partial* relationship between income and credit claimed. The concentration curves produced by this experiment coincide almost perfectly with those of the observed credit in Figures 1 and 2. The partial KP and S indices based on these curves are -.254 and -.126, respectively—virtually identical to those calculated from the observed distribution.[14]

In summary we see that the energy tax credits were somewhat regressive, even holding constant non-income sources of variation. Lower-income taxpayers, who we expect to have higher rates of return to weatherization, shared less than proportionally in the benefits of the program.[15] In addition to the equity implications, this suggests that the credits could have been more effectively targeted.

6. CONCLUSIONS AND SUMMARY

In this paper we have formulated and estimated a model of energy tax credits claimed by households. We have found that individuals take larger credits where the marginal net benefits of weatherizing are greater—where winters are more severe, and where energy prices are high or have been rising rapidly.

We have also found that tax credit claims increase with housing expenditure, and with income up to about the 97th percentile of the income distribution. We find no evidence that the tax credits had a measurable incentive effect on conservation expenditures, suggesting that the credits were largely a windfall for claimants.

Progressivity indices show that the energy tax credit is about as regressive as payroll or personal property taxes, even holding climate and energy prices constant. It is perhaps not surprising that a tax credit for an activity such as weatherization would tend to be regressive. Still, as much U. S. energy policy in the 1970's appeared to be more concerned with equity than with efficiency considerations, this would seem to have been an unintended result.

Together with our earlier finding that rates of return to conservation are higher in smaller houses, the regressivity of the tax credits takes on added importance. The credits cost the federal government $499 million in forgone tax revenue in 1979 alone. Our results suggest that greater energy savings could have been achieved for the same cost by targeting the credit at taxpayers who consume less housing, perhaps through credit rates that vary inversely with income, or with the mortgage interest or property tax deduction.

NOTES

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1. The Energy Tax Act, in fact, specified a minimum credit of $10, corresponding to a minimum expenditure of $67 (the credit rate was 15 percent). Hence Y is actually positive and equal to $r_f m(w^*)$ only when $m(w^*)$ exceeds $67, not zero. This shift of the threshold merely changes the constant term in the model and is inconsequential for estimation. More seriously, a maximum credit limit of $300 suggests that the sample may be censored from above as well as from below. However, as discussed below, we use aggregate data on the average credit taken per return filed and therefore we do not observe any values of Y at the upper limit.
2. This is the so-called "rebound effect." Dubin, Miedema, and Chandran (1986) estimate that this effect reduces conservation savings by one to thirteen percent of engineering predictions for air-conditioning and space heating in Florida. Dubin and Henson (1988) estimate the rebound effect to be about one-third of the engineering prediction of space heating usage in the Pacific Northwest.
3. Credits taken on qualified conservation expenditures were limited to 15 percent of expenditures (materials and installation charges) up to $2,000 for the principal residence if built prior to April 20, 1977. Qualified expenditures consisted of insulation, storm windows and doors, caulking and weather stripping, and automatic energy-saving setback thermostats.

   Renewable energy credits were available for expenditures on solar, geothermal, and wind source development. Until 1979, the credit was limited to 30 percent of the first $2,000 and 20 percent of the next $8,000 of expenditure. Beginning in 1980, these limits were revised to 40 percent on the first $10,000 of expenditure but were still limited to the taxpayer's principal residence.
4. While not directly the focus of the present paper, we note that the TCMP data allow us to analyze the *actual* credit taken as corrected by TCMP audits. This is preferable to the self-reported data as published in *Statistics of Income*, which may be subject to significant bias.
5. Ninety percent of expenditures for renewable energy sources were for solar.
6. Heating degree-days are calculated as follows: Let t_h be the daily high temperature and t_l be the daily low, and define the daily average as $t_a = (t_h + t_l)/2$. Let t_b be a "base" temperature, typically 65 degrees Fahrenheit. The number of heating degree-days are calculated as $HDD = \max(t_b - t_a, 0)$. Annual heating degree-days are found by summing this quantity over the year. Cooling degree-days are defined as $CDD = \max(t_a - t_b, 0)$.
7. The states allowing only a credit for renewables were Arizona, Delaware, Maine, New Mexico, North Carolina, North Dakota, and Vermont; those using only credits but allowing both renewables and conservation measures were Alaska, California, Hawaii, Michigan, Oklahoma, Oregon, and Wisconsin. Alabama, Arkansas, and Idaho used only deductions but applied them to both renewables and conservation; Colorado and Texas allowed deductions for renewables

only. Kansas and Montana allowed a credit for renewables and a deduction for conservation measures; Massachusetts allowed both a credit and a deduction for renewables only.

8. Due to the unavailability of state-level price indices, we have not adjusted dollar amounts for interstate variation in prices.
9. The aggregate model is related to the micro-level model of individual taxpayers as follows. Let Y_{ij}, X_{ij}, and u_{ij} be the credit taken, the explanatory variables, and the error term for individual i in group j. Let $\delta_{ij} = 1$ if taxpayer i takes the credit, 0 otherwise. Let N_j be the number of taxpayers in group j, and $n_j = \sum_{i=1}^{N_j} \delta_{ij}$ be the number claiming the credit. Then the micro-level model is:

$$Y_{ij} = \begin{cases} X_{ij}\alpha + u_{ij} & \text{if } -p^i Q_w^i(t_i^*, 0;\, t_i^0)/i > c'(0) \\ 0 & \text{otherwise} \end{cases}$$

which can be written $Y_{ij} = \delta_{ij}(X_{ij}\alpha + u_{ij})$. The macro model is:

$$Y_j = \frac{1}{N_j}\sum_{i=1}^{N_j} Y_{ij} = \frac{1}{N_j}\sum_{i=1}^{N_j} \delta_{ij} X_{ij}\alpha + \frac{1}{N_j}\sum_{i=1}^{N_j} \delta_{ij} u_{ij.}$$

Estimation of this latter equation requires information about the distribution of X_{ij}. For example, if it were known that all taxpayers in group j faced identical exogenous variables so that $X_{ij} \equiv X_j$, then it can be shown that $E(Y_j) = \Phi(X_j\alpha/\sigma)X_j\alpha + \sigma\phi(X_j\alpha/\sigma)$, where $\Phi(\cdot)$ and $\phi(\cdot)$ are the standard normal cumulative distribution and density functions, respectively. One could then proceed by weighted nonlinear least squares estimation of the equation $Y_j = E(Y_j) + W_j$. Lacking distributional information on X_{ij}, we cannot estimate the micro parameters, α, and focus instead on the parameters of the aggregate model, β.

10. Elasticities are calculated using the derivatives $\partial E(Y_j) / \partial X_j = \Phi(X_j\beta / \sigma)\beta$, where $\Phi(\cdot)$ is the cumulative normal distribution (see McDonald and Moffitt, 1980). The amount of energy credit claimed is also relatively inelastic with respect to PEN79(.65), GRPEN(.74), HDD(.36), and AVRLTX(.36). All elasticities are significantly different from zero at the 10 percent level or better.
11. From equation (1), $\partial c / \partial r_f = (\partial c / \partial r_s)/(1 - t_f)$. Because both r_f and r_s affect w^* through changes in the budget constraint, a change in r_f should affect w^* by $1/(1 - t_f)$ as much as a change in r_s. If federal credit claims respond to interstate variations in r_s, then there is support for the proposition that tax credits in fact stimulate additional conservation expenditures. Specifications that use the state tax credit rate as an explanatory variable, rather than the dummy variable STATECR, produce insignificant results.
12. The uncertainty surrounding this question in the literature is reflected in the title of a 1982 federal report, *Studies on Effectiveness of Energy Tax Incentives are Inconclusive* (U.S. General Accounting Office, 1982).

13. Khetan and Poddar define YNCP1 to be positive for a progressive *tax*. Throughout this discussion, we redefine these indices for *credits* to maintain the sign convention that a negative value for an index indicates regressivity, and a positive value indicates progressivity.
14. We allow AVMORT, AVRLTX, SCHEDC, and SCHDEF to vary with income because income is likely to strongly affect these variables. Modifying this experiment reveals that the regressivity of the tax credit is due largely to the association between income and housing expenditure; filing status has no significant effect on regressivity. For example, holding filing status constant leaves the partial progressivity indices virtually unchanged. Holding housing deductions constant as well, and allowing only income to vary, produces slightly progressive KP and S values of +.10 and +.12, respectively. (However, in this latter case the concentration curves for income and credit claimed intersect at about the 45th percentile of the income distribution, below which the credit remains regressive.)
15. Why do individuals having higher rates of return to conservation undertake less of it? There is some evidence that lower-income households have higher discount rates, therefore requiring a higher rate of return on conservation investments. This may be partly due to the greater uncertainty of their income streams. For example, see Hausman (1979).

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TABLE 1. Audit Class Definitions

1. Non-business return; 1040A short form; standard deduction; total positive income (TPI) under $10,000.
2. Non-business return with TPI under $10,000; other than Audit Class 1.
3. Non-business return with TPI of $10,000 - $25,000; standard deduction; no Schedule C, Schedule F, or Distributive Income.
4. Non-business return with TPI of $10,000 - $25,000, other than Audit Class 3.
5. Non-business return with TPI of $25,000 - $50,000.
6. Non-business return with TPI greater than $50,000.
7. Schedule C return with total gross receipts (TGR) under $25,000.
8. Schedule C return with TGR of $25,000 - $100,000.
9. Schedule C return with TGR greater than $100,000.
10. Schedule F return with TGR under $25,000.
11. Schedule F return with TGR of $25,000 - $100,000.
12. Schedule F return with TGR greater than $100,000.

TABLE 2. Residential Energy Expenditure 1979
by Adjusted Gross Income*

Size of adjusted gross Income	Total Residential Energy Credit		Total Energy Conservation Expenditure		Total Insulation Expenditure		Total Storm Windows Expenditure		Total Renewable Expenditure	
	Number of Returns	Amount	Number of Returns	Amount	Number of Returns	Amount	Number of Returns	Amount	Number of Returns	Amount
TOTAL	4,911,119	498,967	4,781,772	3,302,364	2,896,338	1,331,718	2,543,590	1,403,014	76,555	190,283
Under $5,000	62,778	7,076	54,933	39,897	34,917	19,869	24,963	16,643	878	1,742
$5,000 under $10,000	313,926	33,575	293,750	206,906	172,943	105,698	156,170	77,114	4,823	6,591
$10,000 under $15,000	542,141	50,360	524,677	347,375	318,322	131,186	270,020	151,212	8,711	6,610
$15,000 under $20,000	761,780	73,591	749,281	497,881	463,361	208,714	401,702	208,817	8,177	13,912
$20,000 under $25,000	857,505	78,163	835,237	509,719	531,636	201,674	456,459	218,839	10,066	17,668
$25,000 under $30,000	790,869	77,549	776,305	517,945	464,371	202,807	427,839	230,829	9,179	43,901
$30,000 under $40,000	931,451	97,145	911,984	649,735	552,990	262,524	480,687	270,397	16,512	43,196
$40,000 under $50,000	315,940	34,958	311,960	234,465	186,038	87,285	166,221	102,144	5,675	15,612
$50,000 under $75,000	220,502	28,569	214,179	176,594	116,615	63,760	108,655	76,773	7,906	23,550
$75,000 under $100,000	58,242	8,301	55,715	54,528	28,704	21,716	27,396	22,785	2,286	6,900
$100,000 under $200,000	46,625	7,878	44,739	53,013	23,968	21,440	19,772	21,147	1,962	8,681
$200,000 or more	9,359	1,801	9,014	14,306	4,473	5,046	3,706	6,314	380	1,901

* Amounts in thousands of dollars.

Source: Thompson and Hillelson (1982).

TABLE 3. Variable Definitions

Variable	Definition
AVCR	Average credit taken per return filed
AVINC	Average income per return, thousands of dollars
AVMORT	Average mortgage deduction taken per return, hundreds of dollars
AVRLTX	Average real estate tax deduction per return, hundreds of dollars
CALIF	1 if California, 0 otherwise
GRPEN	Average annual percentage rate of energy price increase
HDD	Population-weighted average heating degree-days, 1951-80, thous.
PEN79	Price of energy to residential sector, 1979, $/million btu
PRCREDIT	Proportion of returns claiming energy credit
SCHEDC	Schedule C return: (Audit classes 7, 8 and 9).
SCHEDF	Schedule F return: (Audit classes 10, 11, and 12).
STATECR	1 if state allows energy tax credit, 0 otherwise

TABLE 4. Variable Means and Standard Deviations by IRS Regions
(Standard Deviations in Parentheses)

Variable	Region							
		1	3	4	5	6	8	9
	Entire Sample	Southeast	Midwest	Central	Southwest	North Atlantic	Mid-Atlantic	Western
AVCR	5.23 (7.71)	2.97 (4.09)	5.45 (7.12)	5.65 (5.95)	3.50 (5.98)	7.53 (9.65)	7.91 (9.78)	4.13 (8.17)
AVINC	15.92 (14.54)	14.09 (12.88)	16.06 (14.02)	16.35 (13.91)	15.57 (14.61)	16.80 (17.36)	16.33 (14.60)	16.28 (14.15)
AVMORT	5.28 (7.79)	4.39 (6.84)	5.01 (7.02)	4.39 (5.98)	5.20 (7.74)	3.96 (5.87)	4.84 (7.07)	8.28 (10.81)
AVRLTX	2.07 (3.56)	1.02 (1.97)	2.10 (3.25)	1.84 (3.19)	1.23 (2.19)	3.95 (5.71)	2.60 (4.09)	1.86 (2.60)
CDD	1.17 (0.83)	2.15 (0.79)	0.85 (0.30)	0.78 (0.20)	2.15 (0.81)	0.57 (0.20)	0.84 (0.18)	0.88 (0.79)
GRPEN	11.41 (1.49)	12.04 (0.88)	10.80 (0.38)	11.98 (0.89)	9.94 (2.31)	12.68 (0.50)	12.38 (0.66)	10.32 (1.00)
HDD	4.71 (2.02)	2.47 (1.17)	6.78 (1.19)	6.02 (0.70)	3.11 (1.78)	6.21 (0.88)	5.30 (0.61)	3.34 (1.78)
PEN79	6.28 (1.76)	8.69 (2.18)	5.28 (0.30)	5.17 (0.24)	5.79 (0.84)	6.87 (0.19)	6.61 (0.74)	5.60 (2.23)
PRCREDIT	0.052 (0.067)	0.035 (0.046)	0.068 (0.076)	0.060 (0.062)	0.035 (0.049)	0.074 (0.088)	0.068 (0.077)	0.031 (0.044)
STATECR	0.298 (0.457)	0.172 (0.378)	0.177 (0.382)	0.302 (0.459)	0.215 (0.411)	0.248 (0.432)	0.019(a) (0.136)	0.806 (0.396)
Number of valid obs(b)	688	84	108	72	108	115(b)	72	129(b)
Thousands of returns filed	90,371	13,201	12,687	12,252	11,917	12,102	12,21	15,995

Notes:

(a) In region 8, Delaware allowed a $200 credit for domestic solar hot water systems (Rodberg and Schachter, 1980, p. 41). Lacking data on average expenditures and the average credit taken, we set STATECR=1 for these observations.

(b) Number of audit class/district categories in which at least one return was filed. Region 6 contains five empty cells: two districts (Providence and Manhattan) had no returns filed in audit classes 10 and 12, and one district (Brooklyn) had no returns in class 10. Three cells are empty in Region 9: classes 10 and 11 in the Anchorage district and class 12 in Honolulu.

TABLE 5. Conditional Average Credit Taken by Claimants
(Standard Deviations in Parentheses)

Variable	Region							
		1	3	4	5	6	8	9
	Entire Sample	Southeast	Midwest	Central	Southwest	North Atlantic	Mid-Atlantic	Western
Conditional average credit	100.95 (60.87)	85.88 (37.31)	80.27 (43.38)	93.32 (36.10)	101.54 (59.14)	101.91 (32.36)	116.11 (35.45)	134.86 (138.84)
Number of valid obs(a)	529	69	94	62	87	80	55	82
Thousands of returns claiming credit	4,686	455	861	741	411	894	832	490

Notes:

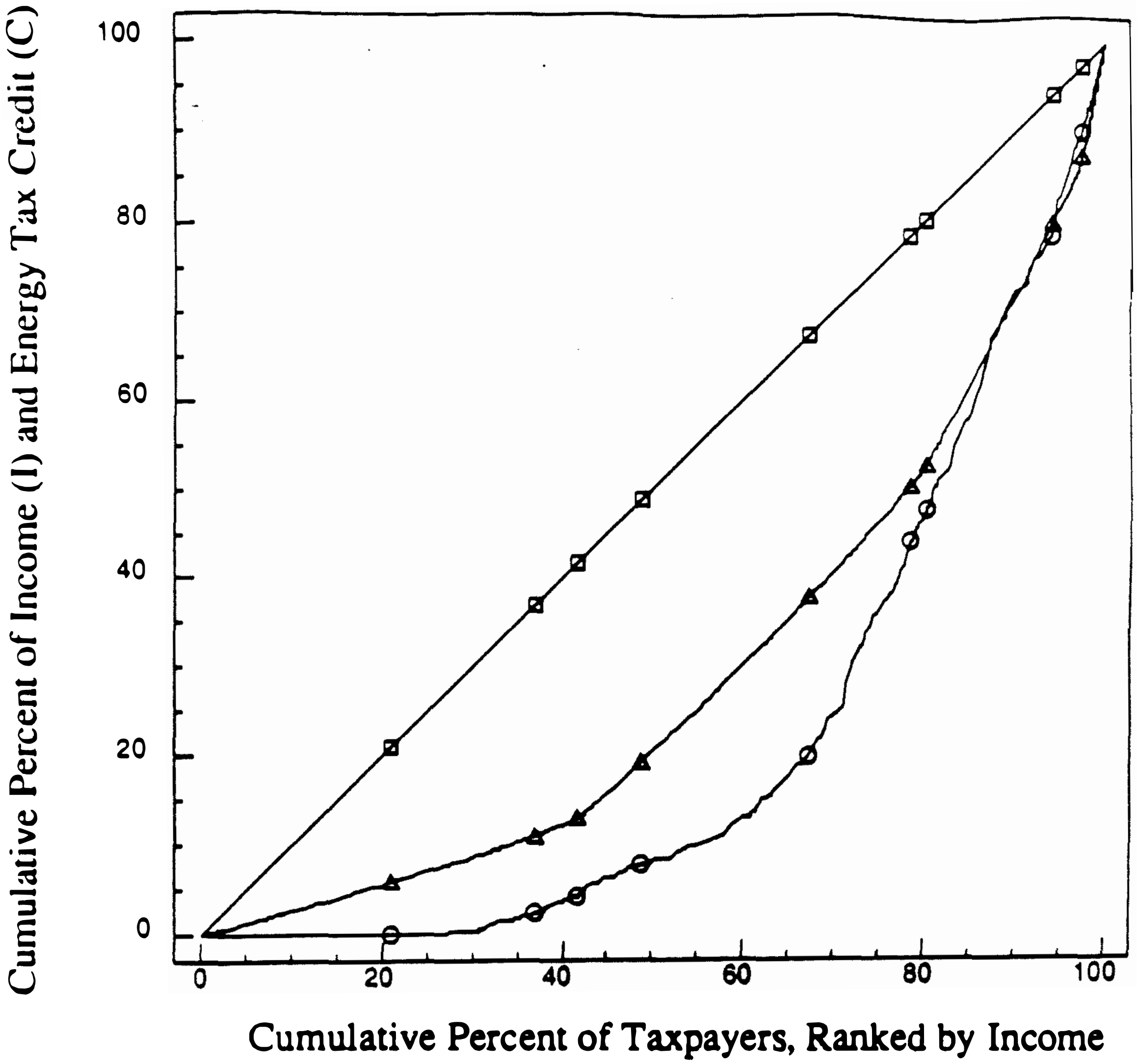
(a) Number of audit class/district categories in which at least one taxpayer claimed the energy tax credit.

TABLE 6. Results
(t-statistics in parentheses)

VARIABLE	WLS	TOBIT
CONSTANT	-13.179***	-19.111***
	(-4.590)	(-5.082)
PEN79	0.646***	0.703***
	(3.410)	(2.926)
GRPEN	0.328**	0.439**
	(2.003)	(2.027)
AVINC	0.428***	0.743***
	(7.124)	(9.467)
$(AVINC)^2$	-0.0078***	-0.014***
	(-4.390)	(-6.663)
$(AVINC)^3$	0.000035**	0.000074***
	(2.506)	(4.532)
HDD	0.541**	0.519**
	(2.571)	(1.974)
AVMORT	0.068	0.108*
	(1.426)	(1.877)
AVRLTX	1.260***	1.175***
	(11.996)	(9.384)
SCHEDC	-2.151**	-1.893*
	(-2.512)	(-1.929)
SCHEDF	0.709	-0.578
	(0.437)	(-0.309)
STATECR	0.173	0.221
	(0.335)	(0.338)
CALIF	-0.936	-1.286
	(-0.751)	(-0.788)
MIDWEST	1.047	1.753
	(1.077)	(1.409)
CENTRAL	1.618*	2.313**
	(1.814)	(2.022)
SOUTHWEST	2.306**	2.262*
	(2.573)	(1.930)
NO. ATLANTIC	-0.359	-0.047
	(-0.374)	(-0.038)
MID-ATLANTIC	2.363***	3.216***
	(2.814)	(3.014)
WESTERN	2.026**	1.539
	(2.110)	(1.254)
Std. Error	8.2935	8.4839

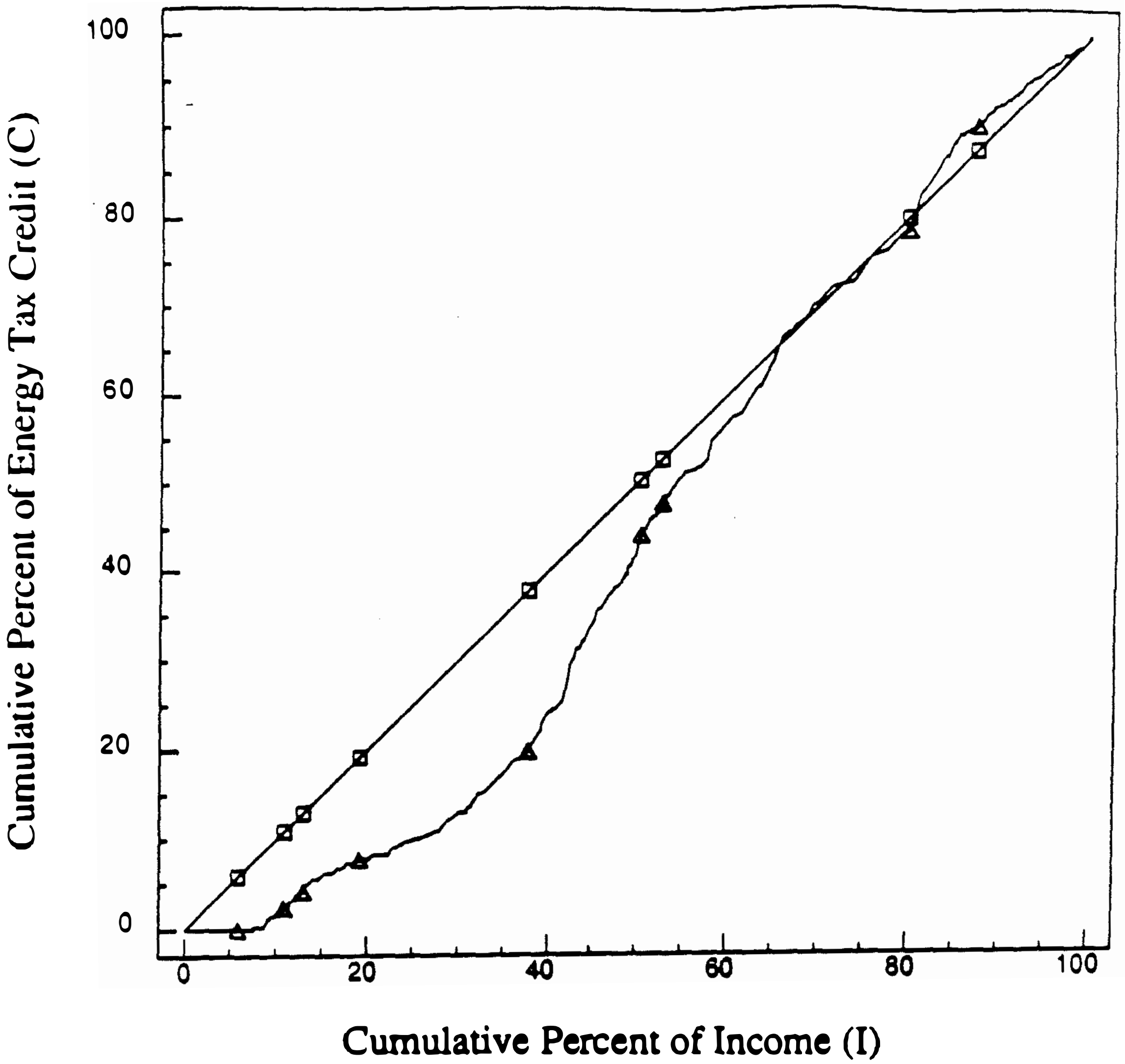
Note: Asterisks indicate statistical significance at critical levels of 10% (*), 5% (**), and 1% (***).

FIGURE 1



Income (I) = Δ
Credit (C) = O

FIGURE 2



Income (I) = □
Credit (C) = Δ